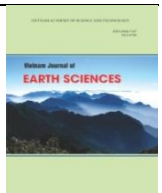
Vietnam Journal of Earth Sciences, 44(4), 502-520, https://doi.org/ 10.15625/2615-9783/17245

Vietnam Academy of Science and Technology
Vietnam Journal of Earth Sciences
http://www.vjs.ac.vn/index.php/jse



Upgrading the Vietnam semi-quantitative soil classification system

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Received 18 October 2021; Received in revised form 11 March 2022; Accepted 18 June 2022

ABSTRACT

A quantitative soil classification system (SCS) has been the aim of generations of Vietnam soil scientists. The SCS is a system of harmonizing the traditional Vietnam SCSs and creating a capability for international exchange. Up to now, there are three partially developed Vietnam official SCSs and three Vietnam semi-quantitative ones. This article aims to upgrade the Vietnam semi-quantitative SCS based on Vietnam's traditional pedogenetic (qualitative) and the World Reference Base for Soil Resources in 2014 (quantitative). For this purpose, a study was conducted to compare and analyze the correlation between the published Vietnam semi-quantitative SCSs and the official ones. Six SCSs were compared and analyzed. The results show that the Vietnam semi-quantitative SCS-2006 was selected to continue adapting and updating. Apart from the necessary adjustments, the study added 12 diagnostic horizons, 4 diagnostic properties, 2 diagnostic materials, 2 soil groups, 11 soil types, and 37 soil sub-types in the Vietnam semi-quantitative SCS-2006. Finally, the Vietnam semi-quantitative SCS includes 25 soil groups, 86 soil types, 492 soil sub-types with 30 diagnostic horizons, 7 diagnostic properties, 6 diagnostic materials, 58 qualifiers, and 9 criteria for defining soil varieties. The system keeps the traditional aspects of Vietnam's official SCSs and allows the exchange of international soil information.

Keywords: international exchangeable, semi-quantitative, soil classification system, diagnostic horizons, diagnostic properties, diagnostic materials, Vietnam.

1. Introduction

Soils are vital, especially in agricultural production at local and global scales. A soil classification system (SCS) plays a crucial role in soil surveys, proposes scientific bases for mapping soil types, and provides information on soil resources and reality requirements related to soil management, usage, and teaching. Each country in the world often has its soil classification system, for example, Russia (Soviet Union) (Shishov et al., 2005), the United States (USDA, 1999), Germany (Otto, 1997), Japan (Hiroshi et al., 2015), Chinese SCS (Gerasimova, 2010). The systems change progressively in tandem with soil science development, moving from

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qualitative to semi-quantitative to quantitative classification, enabling the exchange of soil information internationally. They are open systems; thus, they are usually updated and improved based on developments in soil science. For example, the Russian SCS was developed from the traditional factor-genetic opinion to the quantitative new SCS in 1997 (Shishov et al., 2005). The Germany SCS was also based on the factor-genetic approach, developed in 1953 in both West Germany and East Germany. The modern German SCS created in 1994 relied on a morpho-genetical principle in which the genesis horizons were focused (Otto, 1997). The Chinese SCS was still based on the factor-genetic approach; however, in 1994, the Chinese Soil Taxonomy was published 2001 (Gerasimova, 2010). Although each country has its soil classification system, the need for international soil information exchange is increasing daily, especially after the world reference base for soil resources was approved in 1998. It is based on the legend of the soil map of the world published by FAO-UNESCO, abbreviated the FAO SCS. It is a system developed based on a quantitative approach. The soil classification is applied to soil properties defined in terms of diagnostic horizons, diagnostic properties, and materials, which should be measurable and observable in the field to the greatest extent possible. The system is the world soil reference base for exchanging international soil information. Its structure has two levels: (1) level one with 32 main soil groups; (2) level two including main soil groups with qualifiers, which are soil units or soil sub-units. This is the international SCS; thus, it is applicable for classifying soils in any country but does not substitute its soil classification system (FAO, 2014). Since the FAO system was published, many pieces of research have been conducted to establish the correlation between national soil classification systems and the FAO one. These results have been scientific bases for rationally adjusting the national systems into international ones. However, the primary structural characteristics and nomenclatures are kept, for instance, in the Russian soil classification system (Shishov et al., 2005) and the Chinese one (Gerasimova, 2010; Huang et al., 2017).

Vietnam is located in the tropical zone of the monsoon type of climate. In the context of global climate change, Vietnam has quite substantial changes in rainfall and extreme weather (Thanh Hoa Pham Thi et al., 2021; Huy Hoang Cong et al., 2022, Phuong Nguyen Ngoc Bich et al., 2022). Its topography is strongly fragmented, hilly, and mountainous, and two main delta river plains. Therefore soils are diverse. Vietnam's soil classification is closely related to rational natural resource utilization and environmental protection. For example, soil types are associated with different ecological risks, including heavy metal pollution (Nguyen Van Hoang et al., 2020). Consequently, soil classification was done a long time ago in Vietnam. In keeping with the trend of international integration, the Vietnam soil classification research aimed at exchanging global soil information has progressed since 1991, especially since 2000. However, for various reasons, the goal of developing a Vietnam quantitative or at least semi-quantitative soil classification system to meet the need has not yet been fully achieved and has continued adapting and updating.

Research on soil classification in Vietnam could be divided into three stages:

(1) Before 1975, Vietnam separated into North Vietnam (following the Soviet Union SCS) and South Vietnam (following the US Soil Taxonomy).

(2) 1975-1990, the Vietnam SCS was unified.

(3) 1990-present (the official Vietnam SCSs were issued, which were in line with the international SCSs).

Fridland et al. (1959) conducted the most prominent research in the first stage. They conducted the most notable research in the first stage. They developed the SCS of Northern Vietnam based on the pedogenetic approach, which consists of two groups: (1) soils in hilly, mountainous regions (including 10 sub-groups), (2) soils in the river delta and coastal regions (including 8 sub-groups). While in the South of Vietnam, Moorman proposed a soil classification system with 25 soil types in the Republic of Vietnam in 1961 (Moormann, 1961). In the second, soil surveying, classifying, and mapping were implemented at the national scale for master planning and exploiting new lands. The Vietnam official soil map was published on a small scale with 13 soil groups and 31 soil types. After that, many pieces of research on soil classification were carried out at different scales in Vietnam. Several soil nomenclatures were translated into Vietnamese from Chinese such as pink soils into red soils. Some new soil groups and types were defined as tropical black and degraded gray soils (Ho Quang Duc, 2002). Research correlating Vietnam's official SCS with the international one was implemented at the end of the 1980s, such as Seghal (1989). Several soil maps at regional and local scales were revised and improved in the third stage. At the same time, the Vietnam official SCSs at large and medium scales were legalized (MOST, 2012). These official systems were developed based on the pedogenetic approach, and soils were classified using qualitative methods. However, the systems have not unified many soil groups and types. This problem has affected the entire Vietnam SCS. Vietnamese soil scientists also applied the FAO SCS and Soil Taxonomy of the United States to compile toil maps in several areas in Vietnam, mainly at scales above 1:50.000 (Ton That Chieu, 1992; Vo Tong Xuan et al., 1994; Truong Xuan Cuong et al., 2007; Le Thai Bat and Luyen Huu Cu, 2007; Duong Thanh Nam et al., 2009; Nguyen Van Toan, 2015; and Nguyen Van Toan et al., 2015).

Recently, there have been some studies on developing the Vietnam SCS based on the semi-quantitative approaches and harmonization of Vietnam's traditional pedogenetic SCS with the international one, especially WRB such as Vietnam Soil Science Society (ASSS, 2000), National Institute of Agricultural Planning and Projection (NIAPP, 2005), Soils and Fertilizers Research Institute (SFRI, 2006). The research findings have significantly improved the Vietnam SCS based on the quantitative approach. However, there still have been some limitations in the research. Still, they have not improved considerably, especially after the FAO SCS was updated in 2014 and new-recorded soils in Vietnam since 2007. The FAO SCS had upgraded twice in 2006 and 2014, but the Vietnam semi-quantitative SCS had not been adapted and updated. The paper aimed to adapt and update the Vietnam semi-quantitative soil classification system based on the published ones, the traditional Vietnam pedogenetic (qualitative), and the World Reference Base for Soil Resources (quantitative).

2. Principles and methodology

2.1. Principles

The following rational principles would be used to adapt and update the Vietnam semi-quantitative SCS: (1) Harmonization with the Vietnam official SCSs, which ensures that the selected system still keeps the fundamental aspects of Vietnam's traditional systems, especially several typical soils and nomenclatures; (2) Inheriting the advantages coming from the Vietnam semi-quantitative SCSs, new knowledge of soil classification by Vietnam soil scientists; (3) Achieving progress of the FAO SCS, which ensures exchangeability of international information on soil resources.

2.2. Methodology

The Vietnam semi-quantitative SCS was adapted and updated using the following methodology (Fig. 1). The relationship and differences between soil groups in the Vietnam SCSs in nomenclatures were considered. It is the first step, which provides a scientific basis to select a semi-quantitative SCS meeting the requirements of the above principles. After that, the relationship between soil types in the different Vietnam SCSs in terms of nomenclatures was analyzed further. Furthermore, several adapted and supplemented new soil groups, types, and sub-types into the selected SCS were carried out based on the traditional Vietnam ones, new-recorded soils in Vietnam. Finally, the diagnostic horizons, materials, properties, and criteria for defining soil groups were adapted and updated to upgrade the Vietnam semi-quantitative SCS based on the FAO-2014.

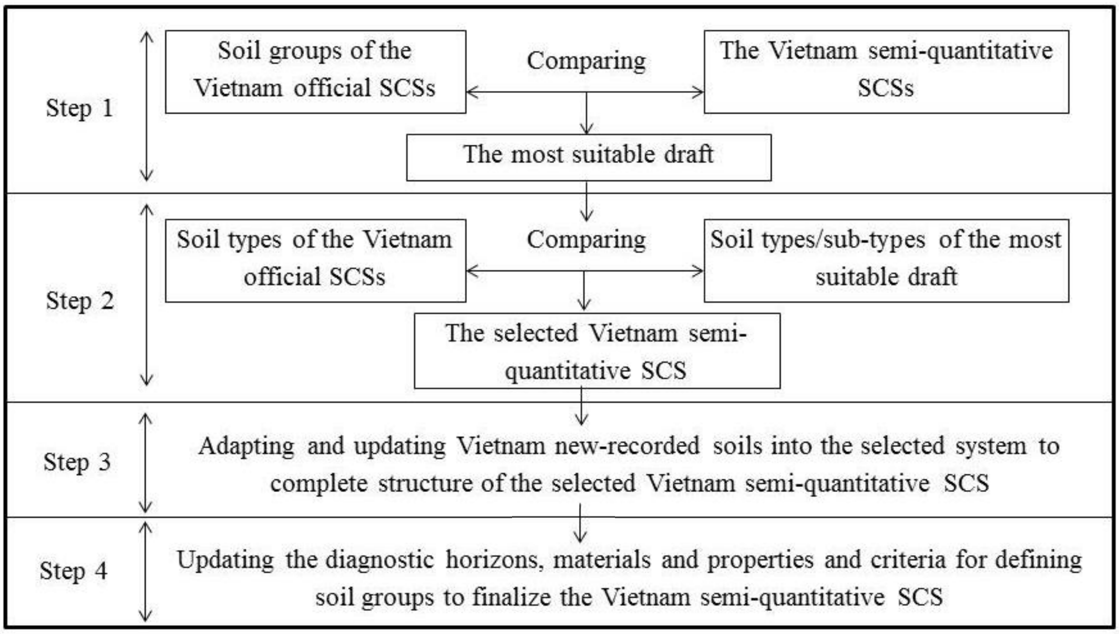

Figure 1. The methodology for upgrading the Vietnam semi-quantitative SCS

3. Results

3.1. The most suitable Vietnam semi-quantitative soil classification system

3.1.1. Soil groups

As mentioned above, there are three official Vietnam SCSs: (1) first, the legend of soil map at scale 1:1.000.000, including 13 soil groups and 31 soil types, (2) second, the legend of soil map at scale 1:50.000 - 1:100.000 with 14 soil groups and 75 soil types, (3) third, the legend of soil map at scale 1:5.000 - 1:25.000 with 16 soil groups and 101 soil types. There are three typical Vietnam semi-quantitative SCSs. They are (1) first, the legend of soil map at scale 1:1.000.000 with 21 soil groups and 61 soil types (ASSS, 2000), and (2) second, the legend of soil map at scale 1:50.000- 1:100.000 with three levels: 20 soil groups, 55 soil types and 177 soil sub-types (NIAPP, 2005),

(3) third, the legend of soil map at large and medium scale with four levels: 22 main soil groups, 76 soil types, and 457 soil sub-types, and soil varieties (SFRI, 2006). The published Vietnam semi-quantitative SCSs were developed based on the FAO-1998. The first version was only a translation of nomenclatures, while in the second and third, the soil groups were all defined based on FAO-1998.

There are 16 soil groups synthesized from the official legends of the soil map (Table 1).

Table 1. Correlation between the soil groups in the official and published semi-quantitative SCSs

No	SCS-1976	SCS-2000	SCS-2005	SCS-2006
1	Coastal sandy soil	Sandy soil	Sandy soil	Sandy soil
2	Saline soil	(1) Saline soil (2) Alkali saline soil	Saline soil	Saline soil
3	Acid sulfate soil	Acid sulfate soil	Acid sulfate soil	Acid sulfate soil
4	Swampy and peat soil	(1) Swampy soil (2) Peat soil	(1) Swampy soil (2) Peat soil	(1) Swampy soil (2) Peat soil
5	Alluvial soil	Alluvial soil	Alluvial soil	Alluvial soil
	-	Soil with plinthite, petroplinthite or pisoliths	Soil with plinthite, petroplinthite or pisoliths	Soil with plinthite, petroplinthite or pisoliths
6	Degraded gray soil	Gray soil	Gray soil	Degraded gray soil
7	Semi-arid brown-gray soil	Brown soil	Semi-arid brown-gray and red soil	Semi-arid soil
8	Black soil	Black soil	Black soil	Black soil
9	Yellow-red soil	Red soil	(1) Red-brown soil (2) Red-yellow soil	(1) Red-brown soil (2) Red-yellow soil
14	Carbonate soil	Soil with an accumulation of secondary carbonates	Soil with an accumulation of secondary carbonates	Soil with the accumulation of secondary carbonates
10	Mountain red-yellow humic soil	-	(1) Mountain red-brown humic soil (2) Mountain red-yellow humic soil	-
11	High mountain humic soil	High mountain humic soil	High mountain humic soil	High mountain humic soil
12	Podzolic soil	Podzolic soil	-	Podzolic soil
13	Eroded skeletic soil	Eroded skeletic soil	Soil with thin soil depth	Soil with thin soil depth
	-	Soil with an incipient subsurface soil formation	-	-
	-	Glass-rich volcanic ejecta soil	-	Soil on volcanic materials
	-	Cracking soil	-	Cracking soil
	-	Purple-brown soil	Purple-brown soil	Purple-brown soil
15	Bed piled soil	Anthropogenesis soil	Anthropogenesis soil	Anthropogenesis soil
16	Valley soil	-	-	Soil in colluvial materials
	-	-	-	Compact clay layer soil

Coastal sandy soil - Haplic Arenosols; Sandy soil - Arenosols; Saline soil - Solonchaks; Alkali saline soil - Solonetz; Acid sulfate soil - Thionic Gleysols; Peat soil - Histosols; Alluvial soil - Fluvisols; Soil with plinthite, petroplinthite or pisoliths - Plinthosols; Degraded gray soil - Dystric Acrisols; Semi-arid brown-gray soil - Lixisols; Black soil - Luvisols; Yellow-red soil - Acrisols; Red soil - Ferralsols; Carbonate soil - Calcisols; Mountain red-yellow humic soil - Humic Acrisols; High mountain humic soil - Alisols; Podzolic soil - Podzols; Eroded skeletic soil - Leptosols; Soil with an incipient subsurface soil formation - Cambisols; Glass-rich volcanic ejecta soil - Andosols; Cracking soil - Vertisols; Purple-brown soil - Nitisols; Bed piled soil - Cumulic Anthrosols; Anthropogenesis soil - Anthrosols; Valley soil - Regosols; -: missing

Table 1 and Fig. 2 show the correlation between the soil groups in the Vietnam official SCSs and the semi-quantitative ones. They indicate that the Vietnam semi-quantitative SCS-2006 retained most of the soil groups in the Vietnam official SCSs; secondly, the Vietnam semi-quantitative SCS-2000; and lastly, the Vietnam semi-quantitative SCS-2005. The Vietnam semi-quantitative SCS-2006 comprises more soil groups found in the Vietnam official CSCs than the other Vietnam semi-quantitative SCSs. Moreover, it was developed based on a selective acquisition of FAO's achievements in 1998 and soil classification research in Vietnam up to 2007. Hence, the Vietnam semi-quantitative SCS-2006 is selected to supplement the following analyses.

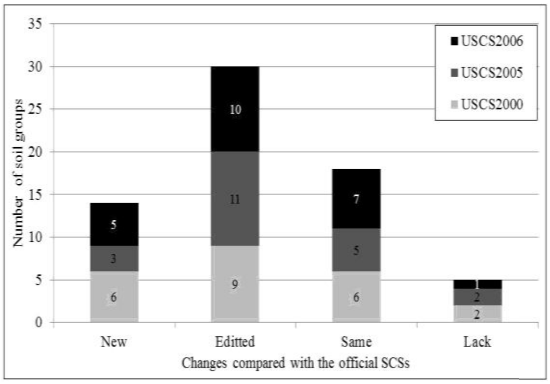

Figure 2. Changes in soil groups in the published semi-quantitative SCSs compared to the official SCSs

3.1.2. Soil types and soil sub-types

The comparison below proves that the soil types/sub-types in the Vietnam semi-quantitative SCS-2006 correlate with the soil types in the Vietnam official SCSs-2012. Some soil types are recorded in the Vietnam official SCSs-2012 but are missing in the semi-quantitative Vietnam SCS-2006. These soils are the hydrolysis acid sulfate soil (a soil category belonging to Thionic Gleysols), the young alluvial soil overlying gleyic alluvial soil (belonging to Fluvisols), and the podzolic gray soil (belonging to Dystric Acrisols). However, checking 63 provincial soil maps in Vietnam have not been recorded. The results show that the soil types and sub-types in the Vietnam semi-quantitative SCS-2006 have a relative correlation with the soil types in the official Vietnam SCSs-2012 (Table 2). The table is only an example of a comparison between 41 out of 101 soil types belonging to three soil groups in the official Vietnam SCSs-2012 with the correlative soil types/sub-types in the Vietnam semi-quantitative SCS-2006.

In summary, the Vietnam semi-quantitative SCS-2006 embraces all the soil groups and lower soil taxa in the official Vietnam SCSs. Therefore, it was selected to adapt and update the Vietnam semi-quantitative SCS because it keeps the fundamental aspects of Vietnam's traditional systems and inherits the advantages from the Vietnam semi-quantitative SCSs and new knowledge of soil classification from Vietnam soil scientists up to 2007.

3.2. The upgraded Vietnam semi-quantitative soil classification system

3.2.1. Diagnostic horizons, properties, materials, and qualifiers

The upgraded Vietnam semi-quantitative SCS has 30 diagnostic horizons, 7 diagnostic properties, 6 diagnostic materials, and 58 qualifiers. Fig. 3 and Fig. 4 illustrate some common diagnostic horizons, properties, and materials appearing in Vietnam.

Table 2. An example of the correlation between the soil types and soil sub-types in the Vietnam semi-quantitative SCS-2006 with soil types in the Vietnam official SCS-2012 (41 out of 101 soil types) ([*]: Soil types)

The official SCS-2012	The semi-quantitative SCS-2006[a]
Acid sulfate soil (Thionic Gleysols)	
III1. Potential acid sulfate soil 19. Shallow potential acid sulfate soil 15. Shallow potential acid sulfate soil in mangroves; 16. Shallow potential acid sulfate soil with high salinity; 17. Shallow potential acid sulfate soil with moderate salinity; 18. Shallow potential acid sulfate soil with low salinity; 24. Deep potential acid sulfate soil 20. Deep potential acid sulfate soil in mangroves; 21. Deep potential acid sulfate soil with high salinity; 22. Deep potential acid sulfate soil with moderate salinity; 23. Deep potential acid sulfate soil with low salinity;	Potential acid sulfate soil[*] Saline potential acid sulfate soil; Potential acid sulfate soil with high humus; Potential acid sulfate soil overlying coastal sandy sediments; Cracking potential acid sulfate soil; Typical potential acid sulfate soil;
III2. Active acid sulfate soil 28. Shallow active acid sulfate soil; 25. Shallow active acid sulfate soil with high salinity; 26. Shallow active acid sulfate soil with moderate salinity; 27. Shallow active acid sulfate soil with low salinity; 32. Deep active acid sulfate soil; 29. Deep active acid sulfate soil with high salinity; 30. Deep active acid sulfate soil with moderate salinity; 31. Deep active acid sulfate soil with low salinity;	Active acid sulfate soil[*] Saline active acid sulfate soil; Active acid sulfate soil with high humus; Active acid sulfate soil overlying coastal sandy sediments; Cracking active acid sulfate soil; Typical active acid sulfate soil
III3. Hydrolysis acid sulfate soil 33. Hydrolysis acid sulfate soil	-
Degraded gray soil group (Dystric Acrisols)	
55. Gray soil on old alluvium	Dark gray soil with plinthite, petroplinthite or pisoliths[*]; Soil with plinthite, petroplinthite or pisoliths, low base saturation[*]; Soil with plinthite, petroplinthite or pisoliths, very low base saturation[*]
56. Gray soil on acid magma stones	Gray soil with plinthite, petroplinthite or pisoliths[*]; Gray soil with nodules[*]; Gray soil with very low base saturation[*]
57. Gray soil on sandy rocks	
58. Degraded gray soil on old alluvium	Soil with plinthite, petroplinthite or pisoliths and leached albic layer[*]
59. Degraded gray soil on acid magma rocks	Degraded gray soil[*]
60. Degraded gray soil on sandy stones	
61. Gleyic degraded gray soil	Gleyic degraded gray soil
62. Gleyic gray soil	Gleyic gray soil[*]
63. Podzolic gray soil	-
Yellow red soil group (Acrisols/Ferralsols)	
73. Purple brown soil on basic magmatic rocks	Purple brown soil with high weathering[*]; Purple-brown soil with low base saturation[*]; Purple-brown soil with high base saturation[*]
74. Purple-brown soil on purple shales	
75. Yellow-red soil on neutral and basic magmatic rocks	Dark red-brown soil[*]; Light red-brown soil[*]; Typical red-brown soil[*]
77. Yellow-brown soil on neutral and basic magmatic rocks	
84. Yellow-brown soil on old alluvium	
78. Brown-red soil on limestones	Hardened soil with accumulation of secondary carbonates[*]; Soil with accumulation of secondary carbonates and clays[*]; Typical soil with accumulation of secondary carbonates[*]
79. Yellow-brown soil on limestones	
76. Yellow-red soil on neutral and basic magmatic rocks	Dark red-yellow soil[*]; Light red-yellow soil[*]; Typical red-yellow soil[*]
80. Yellow-red soil on metamorphic rocks	
81. Yellow-red soil on shales	
82. Yellow-red soil on acid magmatic rocks	
83. Light yellow soil on sandy stones	
85. Yellow-red soil altered by paddy rice cultivation	

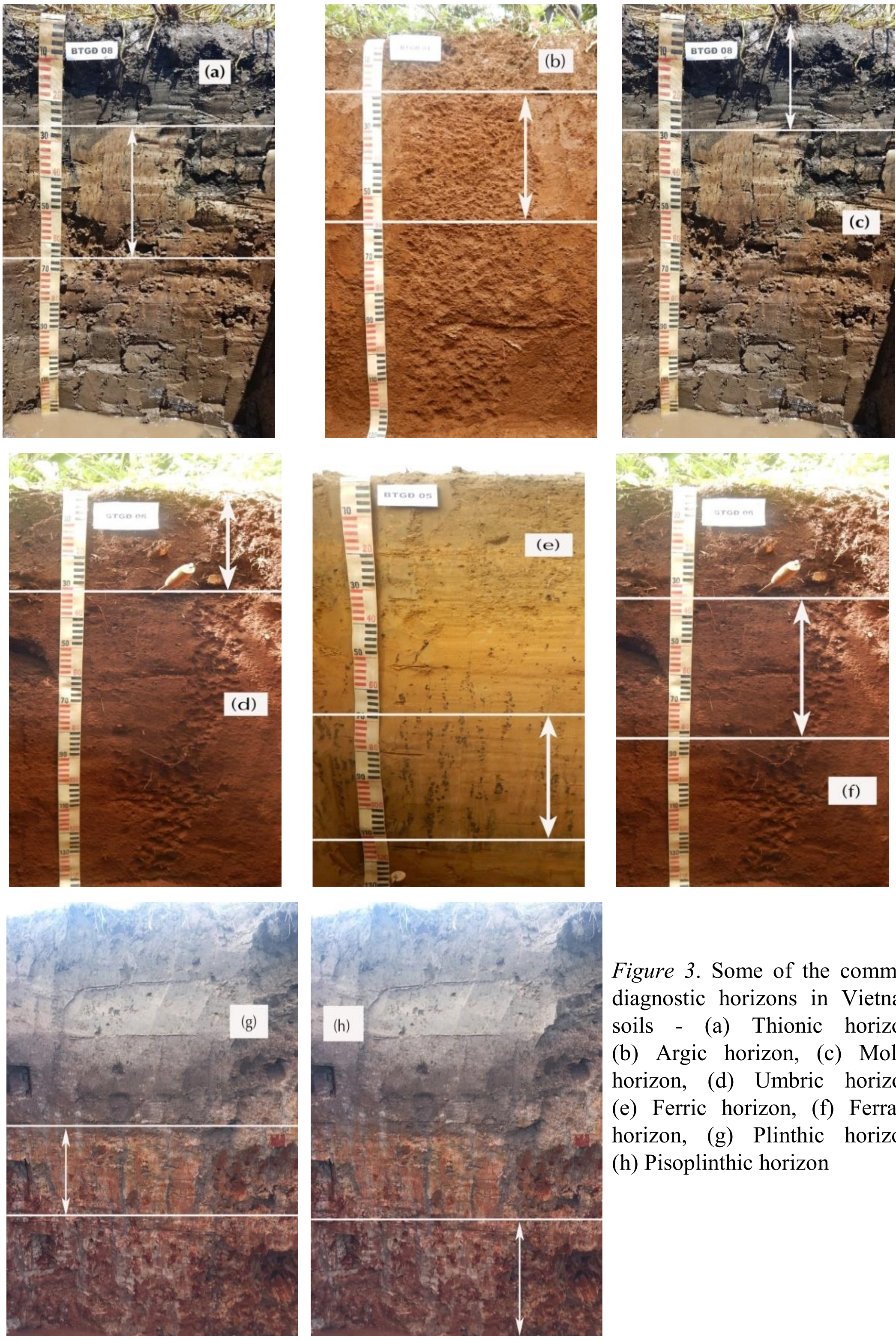

Figure 3. Some of the common diagnostic horizons in Vietnam soils - (a) Thionic horizon, (b) Argic horizon, (c) Mollic horizon, (d) Umbric horizon, (e) Ferric horizon, (f) Ferralic horizon, (g) Plinthic horizon, (h) Pisoplinthic horizon

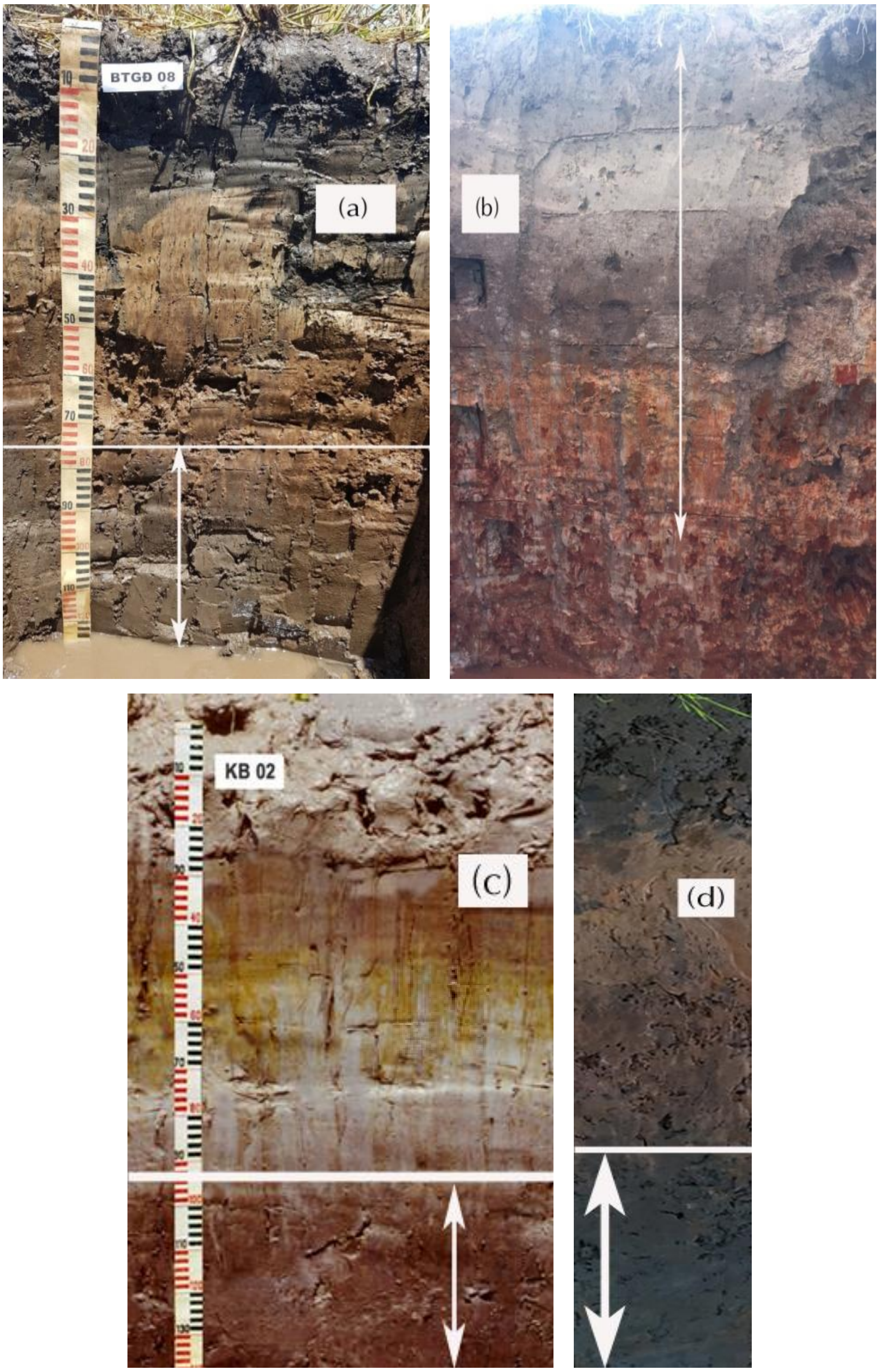

Figure 4. Some of the common diagnostic properties and materials in Vietnam soils - (a) Gleyic property, (b) Stagnic property, (c) Fluvic material, (d) Sulfidic material

There are 58 qualifiers for defining soils at low levels (soil types, sub-types) in the Vietnam semi-quantitative SCS.

(1) Effects of carbonate: Rich in calcic, > 2% $CaCO_3$ in the layer within 20-50 cm.

(2) Albic: have albic materials within 0-100 cm. Before, it was "have albic horizons."

(3) Aluminum saturation: Aluminum saturation ≥ 50% in at least one layer within 50-100 cm.

(4) Pedogenetic new alteration: has a cambic horizon within 0-100 cm.

(5) Fertilizing (used for soils affected by cultivation): soils forming in fertilizing conditions; soil depth ≥ 50 cm; average SOC ≥ 1.0% (weight); BS ≥ 50%; P_2O_5 (available) > 10 mg/100 g soil.

(6) Compaction: has a layer with soil bulk density ≥ 1.5 g/cm^3, thickness ≥ 15 cm within 0-100 cm.

(7) No differentiation (used for riverside sandy soils): There is no clear stratification.

(8) Hydragric: has a hydraulic horizon.

(9) A coral layer (for coastal sandy soils): has ≥ 10% (volume) of coral materials and its thickness > 15 cm within 0-100 cm (in Latin Anthozogenic proposed by the authors).

(10) Homogeneous texture: Difference between the clay amount in a horizon with the highest and the horizon with the lowest one < 20% within 0-125 cm.

(11) Light texture: has a layer of ≥ 30 cm thick within ≤ 100 cm of the mineral soil surface. Before, it "has soil texture of loamy sand or coarser within 0-50 cm".

(12) Different texture: has a sandy layer intermixing, or a clay horizon changes abruptly compared with the overlying layer, and its clay amount increases by ≥ 20% (absolute) if the clay amount of the overlying layer > 20%.

(13) Abrupt textural difference: has a property of abrupt textural contrast within 0-100 cm.

(14) Hard rocks: has a hard rock layer within 25-100 cm.

(15) Dark black: has the chernic horizon with a thickness of ≥ 30 cm within 0-100 cm.

(16) Stagnic: has the stagnic property in a layer of ≥ 25 cm thick within ≤ 75 cm of the mineral soil surface. Before, it was "has the stagnic property within 0-50 cm".

(17) High base saturation: has BS (base saturation) ≥ 50% in half or more of part 20-100 cm from the mineral soil surface. Before, it was "has BS ≥ 50% within 20-100 cm".

(18) Low base saturation: has BS < 50% in half or more of the part 20-100 cm from the mineral soil surface. Before it was "has BS < 50% within 20-100 cm".

(19) Very low base saturation: BS < 50% within 0-100 cm, BS < 20% in at least few subhorizons.

(20) Rich in humus: has high SOC: average SOC (weight) ≥ 1% within 0-25 cm for the thin layer soil group - Leptosols; and ≥ 1% within 0-50 cm for the remaining soil groups.

(21) Gleyic: has the gleyic property in a layer of ≥ 25 cm thick within ≤ 75 cm of the mineral soil surface. Before, it "has the gleyic property within 0-100 cm".

(22) Active acid sulfate: has the thionic horizon with Jarosite Hue ≥ 2, Chroma ≥ 6, pH_H_2O ≤ 3.5.

(23) Potential acid sulfate: has sulfidic materials (> 0.75% S and pH_H_2O > 3.5) within 0-100 cm.

(24) Overlying sulfidic materials (for the fluvial soil group): has sulfidic materials within > 100 cm. Before, it "had sulfidic horizons."

(25) Overlying a substrate formed on parent rock (for the fluvial soil group): has a layer formed on parent rock within 50-100 cm.

(26) Overlying coastal sandy substrate: has a coastal sandy layer within 50-100 cm.

(27) Duric: has the duric horizon within 0-100 cm.

(28) Ferric: has a layer of iron accumulation in the form of mottles or nodules > 15% (volume) and its thickness ≥ 15 cm within 0-100 cm.

(29) Petrocalcic: has the petrocalcic horizon within 0-100 cm.

(30) No surface layer: has a surface layer disturbed, has no horizons: A, H, O, B within 0-125 cm.

(31) Mixing shells/mussels/scallops: has a layer ≥ 10% (volume) of shells/mussels/scallops and its thickness > 15 cm within 0-100 cm (in Latin Bivalvigenic proposed by the authors).

(32) Mixing coarse fragments: > 40% (weight) of coarse fragments (d > 0.2 cm) within 0-100 cm.

(33) Piling up bed: has a surface layer disturbed by piling up bed for cultivating (drainage).

(34) Mottle: have mottles within 0-100 cm.

(35) Red color (for sand dunes): Hue 10R or redder, Value (moist) ≥ 5, and Chroma (moist) ≥ 6.

(36) Red-brown: Hue 5 YR or redder; Value (moist) < 3.5 and difference between Value (dry) and Value (moist) ≤ 1.

(37) Yellow red: has color with Hue 5 YR or redder; Value (moist) ≥ 4 and Chroma (moist) ≥ 5.

(38) Dark brown: has to color with Hue 7.5 YR or redder; Value (moist) ≥ 4; Chroma (moist) ≥ 3.

(39) Yellow-brown: has color with Hue 7.5 YR or redder; Value (moist) ≥ 4 and Chroma (moist ≥ 5.

(40) Yellow white (for sand dunes): has color with Hue 10YR or more yellow; Value (moist) > 6.

(41) Light yellow: with Hue 7.5 YR or more yellow; Value (moist) ≥ 5; Chroma (moist) ≥ 4.

(42) High salty: has content of Cl^- > 0.25%.

(43) Low and moderate salty: has Cl-: 0.05-0.25% content.

(44) Low base: has exchangeable base cations plus exchangeable acidity < 6 meq/100 g clay in some sub horizons within 25-100 cm.

(45) Toxic: has ions that cause toxicity for plants within 0-50 cm.

(46) Salinization: has EC > 4 dS/m at 25°C within 0-50 cm.

(47) High coarse fragments: 40-90% (weight) of coarse fragments (d > 2.0 cm) within 0-100 cm.

(48) Cracking: has the vertic horizon within 0-100 cm. Before, it is "has the vertic properties".

(49) Light color: has color with Hue 7.5YR or redder, Chroma (moist) > 4.

(50) Umbric: has the umbric horizon within 0-50 cm.

(51) Cement horizon (for the podzolic soil group): a cement layer due to Al + OM, thickness > 1 cm.

(52) Tight and hard surface horizon: has a surface soil layer of 20 cm with a massive hard structure.

(53) Friable surface horizon: a surface horizon with friable and reasonable structure, thickness ≥ 30 cm.

(54) Accumulation of secondary carbonates: has the calcic horizon or secondary carbonate (a layer of ≥ 15 cm with $CaCO_3$ ≥ 15% within 50-100 cm).

(55) Clayic accumulation: has an increase of clay (absolute) ≥ 4% within 50-100 cm.

(56) Mollic: has the mollic horizon within 0-50 cm.

(57) Irrigated by alluvial water: has a light color layer (Value and Chroma (moist) > 3) formed by irrigating alluvial water over a long time. A surface soil layer has higher clay content than a subsurface, excellent clay. The weighted average of ≥ 0.5% SOC, decreases with depth but remains t ≥ 0.3% at the lower limit of the layer. Before, it "has an orchic horizon."

(58) Ochric: the mineral soil surface with a thickness of 10 cm has SOC ≥ 0.2%, not a Mollic or Umbric horizon, Rich in humus qualifier.

3.2.2. Soil groups, soil types, soil sub-types, and soil varieties

For the soil groups, there are 25 soil groups in the Vietnam semi-quantitative SCS (Table 3). They are defined by typical soil features produced by the primary pedogenetic process, except where unique soil parent materials are of overriding importance or a particular forming location. The features are mainly shown by above mentioned diagnostic horizons, properties, and materials.

The soil types and sub-types are differentiated in each soil group according to soil features quantified, such as color, properties, and a particular forming location. The features are the qualifiers mentioned above. They have significantly affected the primary characteristics. There are 86 soil types and 492 sub-types in the Vietnam semi-quantitative SCS (Table 3). An example of nomenclature of soil sub-types belonging to the soil type "The actual acid sulfate soil" is "The actual acid sulfate soil rich in humus".

Table 3. Soil types and numbers of soil sub-types in the updated Vietnam semi-quantitative SCS

Soil types (Vietnamese)	Soil types (FAO)	N*
I. Sandy SG (Arenosols): *Soil texture with loamy sand or coarser (average) within 0 - 100 cm*		
I.1. Sand dune soil	Aeolic Arenosols	3
I.2. Coastal sandy soil	Haplic Arenosols	8
I.3. Riverside-streamside sandy soil	Fluvic Arenosols	6
I.4. Loose sandy soil	Cambi Arenosols	5
II. Saline SG (Solonchaks): *Salic horizon*		
II.1. Mangrove saline soil	Gleyic Solonchaks	3
II.2. Strong saline soil	Chloridic Solonchaks	5
II.3. Low and moderate saline soil	Sulfatic Solonchaks	6
III. Alkali saline SG (Solonetz): *Natric horizon*		
III.1. Semi-arid alkali saline soil	Protoaridic Solonetz	6
IV. Acid sulfate SG (Thionic Gleysols): *Gleyic property + thionic horizon/sulfidic material*		
IV.1. Potential acid sulfate soil	Protothionic Gleysols	9
IV.2. Actual acid sulfate soil	Orthithionic Gleysols	5
V. Alluvial SG (Fluvisols): *Fluvic material*		
V.1. Gleyic alluvial soil	Gleyic Fluvisols	4
V.2. Alluvial soil with a layer with an incipient subsurface soil formation	Cambic Fluvisols	6
V.3. Alluvial soil affected by carbontate	Calcaric Fluvisols	6
V.4. Acidic alluvial soil	Dystric Fluvisols	11
V.5. Less acidic and neutral alluvial soil	Eutric Fluvisols	10
VI. Gleyic SG (Gleysols): *Gleyic property + no thionic horizon/sulfidic material*		
VI.1. Gleyic soil rich in humus	Mollic/Umbric/Histic Gleysols	5
VI.2. Gleyic soil with low base saturation	Dystric Gleysols	8
VI.3. Gleyic soil with high base saturation	Eutric Gleysols	8
VII. Peat SG (Histosols): *Organic material ≥ 10 cm*		
VII.1. Acid sulfate peat soil	Thionic Histosols	7
VII.2. Saline peat soil	Protosalic Histosols	4
VII.3. Waterlogged peat soil	Stagnic Histosols	4
VII.4. Fibric peat soil	Fibric Histosols	5
VIII. Plinthic clay SG (Plinthosols): *Plinthic/petroplinthic/pisoplinthic horizon*		
VIII.1. Soil with plinthic clay and albic layer	Albic Plinthosols	6
VIII.2. Dark gray soil with plinthite, petroplinthite or pisoliths	Umbric Plinthosols	6
VIII.3. Soil with plinthite, petroplinthite or pisoliths, low base saturation	Orthodystric Plinthosols	5
VIII.4. Soil with plinthite, petroplinthite or pisoliths, very low base saturation	Hyperdystric Plinthosols	5

Soil types (Vietnamese)	Soil types (FAO)	N*
IX. Degraded gray SG (Dystric Acrisols): *Argic horizon with CEC_{clay} < 24, BS < 50%, Value ≥ 4 and Chroma ≤ 3 (moist)*		
IX.1. Degraded gray soil	Albic Dystric Acrisols	6
IX.2. Degraded gray soil with plinthite, petroplinthite or pisoliths	Plinthic Dystric Acrisols	4
IX.3. Gleyic degraded gray soil	Gleyic Dystric Acrisols	4
IX.4. Degraded gray soil with nodules	Ferric Dystric Acrisols	4
IX.5. Degraded gray soil with very low base saturation	Hyperdystric Acrisols	4
X. Semi-arid brown gray SG (Lixisols): *Argic horizon with CEC_{clay} < 24, BS ≥ 50%*		
X.1. Semi-arid yellow-gray soil	Chromic Lixisols	7
X.2. Semi-arid red soil	Rhohic Lixisols	7
XI. SG with accumulation of secondary carbonates (Calcisols): *Calcic/petrocalcic horizon*		
XI.1. Hardened soil with accumulation of secondary carbonates	Protocalcic Calcisols	3
XI.2. Soil with accumulation of secondary carbonates and clays	Differentic Calcisols	6
XI.3. Typical soil with accumulation of secondary carbonates	Haplic Calcisols	5
XII. Black SG (Luvisols): *Argic horizon with CEC_{clay} ≥ 24, BS ≥ 50%*		
XII.1. Gleyic black soil	Gleyic Luvisols	6
XII.2. Black soil with nodules	Ferric Luvisols	5
XII.3. Light brown-black soil	Xanthic Luvisols	6
XII.4. Typical black soil	Haplic Luvisols	7
XIII. Glass-rich volcanic ejecta SG (Andosols): *Layer with andic/vitric properties*		
XIII.1. Glass-rich volcanic ejecta soil with thin soil depth	Leptic Andosols	5
XIII.2. Glass-rich volcanic ejecta soi on volcanic vitric materials	Vitric Andosols	8
XIII.3. Typical glass-rich volcanic ejecta soil	Haplic Andosols	7
XIV. Cracking SG (Vertisols): *Vertic horizon*		
XIV.1. Cracking soil rich in calcic	Calcic Vertisols	5
XIV.2. Cracking soil with low base saturation	Dystric Vertisols	6
XIV.3. Cracking soil with high base saturation	Orthoeutric Vertisols	6
XV. Purple brown SG (Nitisols): *Nitic horizon*		
XV.1. Purple-brown soil with high weathering	Ferralic Nitisols	7
XV.2. Purple-brown soil with low base saturation	Dystric Nitisols	6
XV.3. Purple-brown soil with high base saturation	Orthoeutric Nitisols	5
XVI. Red SG (Ferralsols): *Ferralic horizon*		
XVI.1. Red-brown soil rich in humus	Mollic/Umbric Ferralsols	5
XVI.2. Dark red-brown soil	Rhohic Ferralsols	6
XVI.3. Light red-brown soil	Xanthic Ferralsols	6
XVI.4. Typical red-brown soil	Haplic Ferralsols	5
XVII. Yellow red SG (Acrisols): *Argic horizon with CEC_{clay} < 24, BS < 50%, Value < 4 and Chroma > 3 (moist)*		
XVII.1. Yellow-red humic soil	Mollic/Umbric Acrisols	8
XVII.2. Dark yellow-red soil	Rhohic Acrisols	10
XVII.3. Light yellow-red soil	Xanthic Acrisols	12
XVII.4. Typical yellow-red soil	Haplic Acrisols	11
XVIII. Compact clay layer SG (Planosols): *Abrupt textural difference*		
XVIII.1. Compact clay layer soil with a soft, loose surface layer	Mollic/Histic Planosols	8
XVIII.2. Compact clay layer soil with dark colour	Umbric/Histic Planosols	6
XVIII.3. Compact clay layer soil with low base saturation	Orthodystric Planosols	8
XVIII.4. Compact clay layer soil with high base saturation	Orthoeutric Planosols	6
XIX. High mountain humic SG (Alisols): *Argic horizon with CEC_{clay} ≥ 24, BS < 50%*		
XIX.1. High mountain fibric humic soil	Histic Alisols	4
XIX.2. High mountain alic humic soil	Xanthic Alisols	6
XX. Podzolic SG (Podzols): *Spodic horizon*		
XX.1. Podzolic soil rich in humus	Histic Podzols	4
XX.2. Tropical podzolic soil	Haplic Podzols	3
XI. SG with a thin soil depth (Leptosols): *Soil depth < 25 cm*		
XXI.1. Soil with thin soil depth and rich in pebbles and gravels	Hyperskeletic Leptosols	7

Soil types (Vietnamese)	Soil types (FAO)	N*
XXI.2. Soil with thin soil depth and a hard rock layer	Lithic Leptosols	7
XXII. SG in colluvial materials (Regosols): *Colluvial materials, no diagnostic horizon*		
XXII.1. Gleyic colluvial soil	Gleyic Regosols	8
XXII.2. Waterlogged colluvial soil	Stagnic Regosols	7
XXII.3. Skeletic colluvial soil	Skeletic Regosols	7
XXII.4. Acidic colluvial soil	Dystric Regosols	5
XXII.5. Neutral colluvial soil	Eutric Regosols	6
XXIII. Anthropogenesis SG (Anthrosols): *Anthropogenic diagnostic horizons*		
XXIII.1. Soil on terraced fields in hilly and mountainous regions	Escalic Anthrosols	6
XXIII.2. Soil affected by cultivating	Haplic Anthrosols	5
XXIII.3. Soil in mining exploration areas	Technic Anthrosols	4
XXIV. Dark brown SG (Phaeozems): *Mollic horizon*		
XXIV.1. Dark brown soil leached	Luvic Phaeozems	8
XXIV.2. Gleyic dark brown soil	Gleyic Phaeozems	5
XXIV.3. Waterlogged dark brown soil	Stagnic Phaeozems	5
XXIV.4. Dark brown soil affected by carbonate	Calcaric Phaeozems	5
XXIV.5. Dark brown soil mixed with coarse fragments	Skeletic Phaeozems	2
XXIV.6. Dark brown soil with nodules	Ferric Phaeozems	2
XXV. SG with an incipient subsurface soil formation (Cambisols): *Cambic horizon*		
XXV.1. Acid soil with an incipient subsurface soil formation	Dystric Cambisols	2
XXV.2. Less acidic and neutralsoil with an incipient subsurface soil formation	Eutric Cambisols	2
XXV.3. Gleyicsoil with an incipient subsurface soil formation	Gleyic Cambisols	2
XXV.4. Waterlogged soil with an incipient subsurface soil formation	Stagnic Cambisols	2
XXV.5. Ferralic soil with an incipient subsurface soil formation	Ferritic Cambisols	2
Total	**86**	**492**

*: Numbers of soil sub-types; "II. Saline SG (Solonchaks): *Salic horizon"* means II. Vietnamese name (FAO name): *key criterion to define this soil group*

According to soil features affecting soil capacity, soil varieties are defined from the soil sub-types. The criteria (properties) for defining the soil varieties are arranged in order of preference (the first to the ninth criterion). They do not conflict with the criteria used to define the soil groups, soil types, and soil sub-types. The properties are (1) soil texture, (2) soil compaction, (3) pH-KCl, (4) organic matter, (5) CEC, (6) soil depth, (7) mixing coarse fragments, (8) base saturation, (9) soil minerals. They are measured for the surface horizon of each soil. Soil varieties are named by the soil sub-types plus a class name of one of the properties concerning nomenclature. A comma separates the soil sub-types and the class name of one of the properties. An example of a soil variety nomenclature belonging to the soil sub-type "The actual acid sulfate soil rich in humus" is "The actual acid sulfate soil rich in humus, high clay."

3.3. Physical and chemical criteria of soil samples for the Vietnam semi-quantitative SCS

27 physical and chemical criteria of soil samples are required for analysis when the Vietnam semi-quantitative SCS is applied. 18 out of 27 criteria are frequently used to classify soils. They are soil texture, soil bulk density, pH, SOC, $CaCO_3$, $CaSO_4$, CEC, exchangeable base cations, exchangeable Al and acidity, EC, free Fe and Al, active Fe and Al, P_2O_5 (available), exchangeable Fe^{2+} and Mn^{2+}. There are 7 typical criteria: water-dispersible clay, free Mn, Fe, and Al in the form of organic matter bond, Cl^-, SO_4^{2-}, inorganic S (S^{2-} in the form of sulfate). Two rarely used criteria are (1) Fe_2O_3, and (2) clay minerals. The Vietnam standards analvze 14 out of 27 in the above criteria. In contrast, 11 out of 27 criteria are interpreted by the procedure published by SFRI (1998). The

remaining ones, including inorganic S and clay minerals, are done by Sullivan et al. (2000), Mehba and Jackson's (1960) procedures, respectively. The procedures for analyzing these criteria are the same as those mentioned in FAO-2014.

4. Discussions

4.1. Advantages and disadvantages of the semi-quantitative Vietnam SCS-2006

Concerning advantages, the system was developed according to geographical pedogenetic-based soil classification combined with the quantitative category of FAO. The soil groups, types, and subtypes were defined by specific criteria harmonized with the FAO SCS-1998.

The following disadvantages were identified: (1) it was developed based on FAO-1998 which was out of date; (2) Several new soil groups were recorded in Vietnam from 2007 to 2020 as the dark brown soil (Phaeozems), soil with an incipient subsurface soil formation (Cambisols) are missing; (3) position of the alkali saline soil group (Solonetz) and the gleyic alkali saline soil (Gleyic Solonetz) has not been suitable; (4) nomenclatures of soil groups and types/sub-types need to be adjusted based on the nomenclatures of the soil groups that used to be utilized before as traditional soil names.

4.2. Comparing with the semi-quantitative Vietnam SCS-2006

4.2.1. Diagnostic horizons, properties, materials, and qualifiers

12 horizons were added for the diagnostic horizons, while two horizons were changed into one diagnostic material and property. Besides, one horizon was removed, and 17 were adjusted. For the diagnostic properties, four properties were supplemented. One property was transformed into the diagnostic horizon, one was removed, and two were edited. For the diagnostic materials, two materials were added. Two materials were edited (Table 4). The main reasons for addition, transformation, removal, and adjustment are out of date of the Vietnam semi-quantitative SCS-2006 compared with FAO-2014 and new soil groups recorded in Vietnam from 2007 to 2020. The above changes are based on the FAO-2014 and new-recorded soils. Nine qualifiers were adjusted (qualifier 2, 11, 16, 17, 18, 21, 24, 48, 57) compared with the SCS-2006.

Table 4. Changes and supplements of diagnostic horizons, properties, and materials compared with the Vietnam semi-quantitative SCS-2006

Horizons	Properties	Materials	Note
Anthraquic, hortic, irragric, terric, pretic, petroplinthic, pisoplinthic, gypsic, petrogypsic, fragic, natric	Vitric, geric, abrupt textural difference, lithic discontinuity	Organic, technic hard	Supplement
Albic ➔		Albic	Transform
Andic ➔	Andic		Transform
Hydragric 🡐	Hydragric		Transform
Orchic	Alic		Remove
Cambic, duric, ferric, vertic, ferralic, spodic, nitic, plinthic, thionic, calcic, petrocalcic, argic, mollic, umbric, chernic, salic, histic	Stagnic, Gleyic	Fluvic, sulfidic	Adjustment

(➔ Direction of transformation)

4.2.2. Soil groups, soil types, soil sub-types, and soil varieties

There are 4 soil groups adjusted nomenclatures for the soil groups compared to the Vietnam semi-quantitative SCS-2006 (Table 5). They are the semi-arid brown-gray soil group (Lixisols), the glass-rich volcanic ejecta one (Andosols), the red one

(Ferralsols), and the yellow-red one (Acrisols). The nomenclature of the first group has been used officially since 1976. The nomenclatures of the second and third ones have been proposed and utilized informally since 2000 (ASSS, 2000). The nomenclature of the last one has been proposed because Vietnam is a tropical country. Ferralitic soils usually have iron content which is higher than aluminum ones. It means that the red color is more dominant than the yellow one. Thus the nomenclature of the yellow-red soil group reflects more truthfully the essence of tropical soils.

Table 5. Changes in the upgraded Vietnam semi-quantitative SCS

<table>
<tr><th>No</th><th>The SCS-2006</th><th>The upgraded SCS</th><th>Note</th></tr>
<tr><td>1</td><td>The semi-arid SG</td><td>The semi-arid brown-gray SG</td><td rowspan="4">Renamed</td></tr>
<tr><td>2</td><td>The SG on volcanic materials</td><td>The glass-rich volcanic ejecta SG</td></tr>
<tr><td>3</td><td>The red-brown SG</td><td>The red SG</td></tr>
<tr><td>4</td><td>The red-yellow SG</td><td>The yellow-red SG</td></tr>
<tr><td>5</td><td>The semi-arid SG</td><td>The alkali saline SG</td><td>Separated</td></tr>
<tr><td>6</td><td>-</td><td>The dark brown SG</td><td>New</td></tr>
<tr><td>7</td><td>-</td><td>The SG with an incipient subsurface soil formation</td><td>New</td></tr>
</table>

SG: Soil group; The semi-arid brown-gray SG-Lixisols; The glass-rich volcanic ejecta SG-Andosols; The red SG-Ferralsols; The yellow-red SG-Acrisols; The alkali saline SG-Solonetz; The dark brown SG-Phaeozems; The SG with an incipient subsurface soil formation-Cambisols

In addition, the alkali saline soil group (Solonetz) was separated from the semi-arid brown-gray one (Lixisols). Two main soil groups that were supplemented were the dark brown one (Phaeozems) and the soil group with an incipient subsurface soil formation (Cambisols). The dark brown soil group (Phaeozems) was recorded in Cao Bang province (Le Thai Bat and Luyen Huu Cu, 2007), in the hilly regions of North East Vietnam (Nguyen Van Toan, 2015) (Fig. 5). At the same time, the soil group with an incipient subsurface soil formation (Cambisols) was recorded in Ha Nam province (Truong Xuan Cuong et al., 2007) (Fig. 6). Nomenclatures of the 18 remaining soil groups in the finalized Vietnam semi-quantitative SCS are the same as those in the Vietnam semi-quantitative SCS-2006.

The definition of the soil group in colluvial materials has remained the same as the one proposed in the Vietnam semi-quantitative SCS-2006. It is defined by two criteria: (1) formed in valleys of the hilly and mountainous regions and by colluvial materials; (2) no diagnostic horizon. Besides, the criterion "Has the thionic horizon or sulfidic materials or both of them within 0 - 100 cm" used to define the acid sulfate soil group (Thionic Gleysols) was also retained in the Vietnam semi-quantitative SCS like the Vietnam semi-quantitative SCS-2006. The other criteria for determining this soil group proposed in the Vietnam semi-quantitative SCS-2006 were adjusted following the FAO SCS-2014. For the degraded gray soil group (Dystric Acrisols), the criterion "The diagnostic horizon with gray, Value (moist) ≥ 4 and Chroma (moist) ≤ 3" was retained in the Vietnam semi-quantitative SCS like the Vietnam semi-quantitative SCS-2006, too. Concerning the semi-arid brown-gray soil group (Lixisols), the criterion "Base saturation ≥ 50%" was also retained. The other criteria to define the degraded gray soil group (Dystric Acrisols) and the semi-arid brown-gray one (Lixisols) were proposed in the Vietnam semi-quantitative SCS-2006. They were adjusted following the FAO SCS-2014, too. The definition of the remaining 18 soil groups in the SCS-2006 was edited based on the FAO SCS-2014 to update the Vietnam semi-quantitative SCS. The critical criteria to define the soil groups are presented in Table 3.

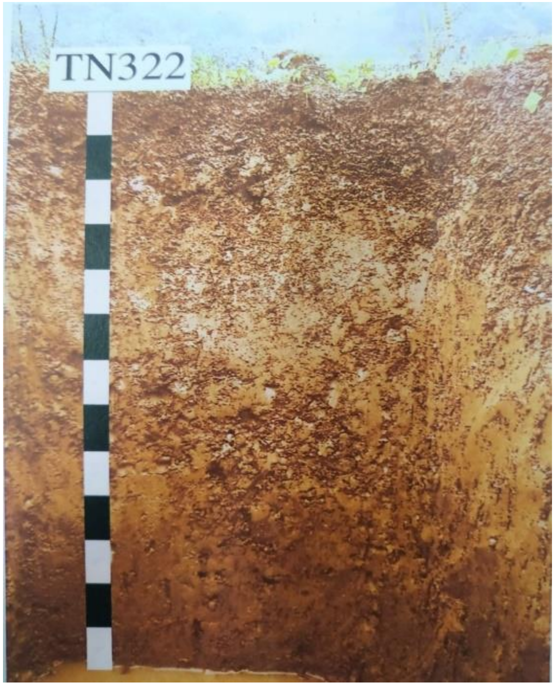

Figure 5. An image of the soil profile for the dark brown soil group (Phaeozems) (Tan village, Thanh Long commune, Thong Nong district, Cao Bang province)

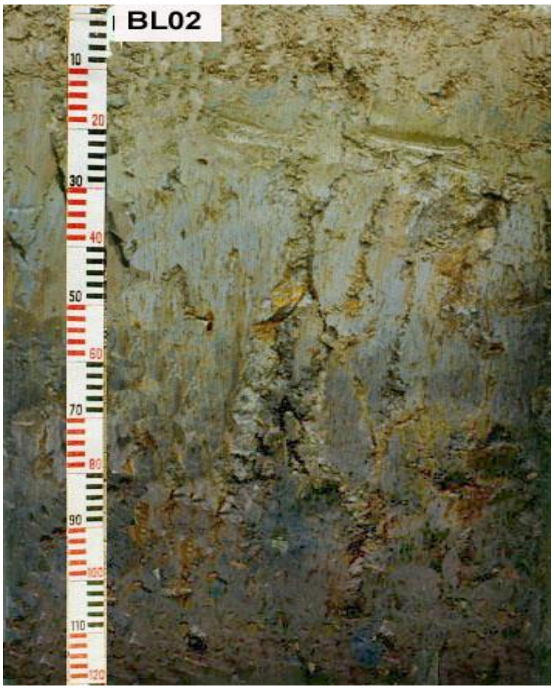

Figure 6. An image of the soil profile for the soil group with an incipient subsurface soil formation (Cambisols) (Tram Bun field, An Lao village, An Lao commune, Binh Luc district, Ha Nam province)

For soil types and sub-types, Table 6 shows that the criteria used to define soil types were adjusted in the updated Vietnam semi-quantitative SCS compared with the Vietnam semi-quantitative SCS-2006. The nomenclature of typical glass-rich volcanic ejecta soil types (belonging to Andosols) was derived from volcanic materials. The alkali saline soil type (Haplic Solonetz) was separated from the semi-arid soil group (Lixisols) in the Vietnam semi-quantitative SCS-2006 and moved to the alkali saline soil group (Solonetz) to assure the structure of the SCS. The gleyic alkali saline soil sub-type (Gleyic Haplic Solonetz) was added into the alkali saline soil type (Haplic Solonetz). In addition, 6 soil types and 27 soil sub-types belonging to the dark brown soil group (Phaeozems), and 5 soil types and 10 soil sub-types belonging to the soil group with an incipient subsurface soil formation (Cambisols) were supplemented (Table 3).

Table 6. Definition of soil types the Vietnam semi-quantitative SCS adjusted

Soil types	Criteria	
	The SCS-2006	The finalized SCS
Gleyic alluvial soils	Alluvial soils have the gleyic horizon > 30 cm, within 0-100 cm	Alluvial soils have the gleyic property > 30 cm, within 0-100 cm
Soils with plinthite, petroplinthite or pisoliths, albic horizon	Soils with a plinthic clay layer have the albic horizon within 0-100 cm	Soils with plinthite, petroplinthite or pisoliths have albic materials within 0-100 cm
Albic gray soils	Gray soils have the albic horizon within 0-50 cm	Gray soils have the albic materials within 0-50 cm

For soil varieties, criteria of base saturation for defining were added, and ones of CEC were adjusted to the updated Vietnam semi-quantitative SCS compared with the Vietnam semi-quantitative SCS-2006.

5. Conclusions

This study added 12 diagnostic horizons, 4 diagnostic properties, and 2 diagnostic materials to adapt and update the Vietnam semi-quantitative SCS. Furthermore, 17 diagnostic horizons, 2 diagnostic properties, and 2 diagnostic materials were adjusted. Two diagnostic horizons and two diagnostic properties were transformed. One diagnostic horizon and one diagnostic property were removed. Nine qualifiers were edited. For the soil groups, two groups were supplemented: (1) the dark brown one (Phaeozems) and (2) the soil group with an incipient subsurface soil formation (Cambisols). The nomenclatures of four soil groups were adjusted. The alkali saline soil group (Solonetz) was split. Eighteen soil groups were edited. For the soi types and sub-types, the definition of three soil types was edited. Six soil types and 27 soil sub-types belonging to the dark brown soil group (Phaeozems) and 5 soil types and 10 soil sub-types belonging to the soil group with an incipient subsurface soil formation (Cambisols) were supplemented. Finally, the Vietnam semi-quantitative SCS includes 25 soil groups, 86 soil types, and 492 soil sub-types with 30 diagnostic horizons, 7 diagnostic properties, 6 diagnostic materials, 58 qualifiers, and 9 criteria for defining soil varieties. It keeps the traditional characters of the official Vietnam SCSs and allows the exchange of international soil information. The results of upgrading the Vietnam semi-quantitative SCS are significant progress for getting feedback and approaching an authorized office's approvable through a workshop.

Acknowledgments

This article was supported by VAST Project, code BSTMV.7/19-21, and the MOST project "Quantifying soil organic carbon pools in the Red River delta region for monitoring soil quality and greenhouse gas emission from soils, code ĐTĐL.CN-49/21.

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