Korean J. Soil Sci. Fert. **43**(1), 113-118 (2010) **Note**

A Brief Review of Soil Systematics in Germany

Rog-Young Kim, Jwa-Kyung Sung, Seok-Cheol Kim, Byoung-Choon Jang, and Yeon-Kyu Sonn*

Division Soil & Fertilizer Management, National Academy of Agricultural Science, RDA, Suwon, Republic of Korea

Due to diverse soil-forming environments and different purposes of the soil classification, numerous soil classification systems have been developed worldwide. The World Reference Base for Soil Resources (WRB) and the Soil Taxonomy of the United States are well-known in Korea. However, the German Soil Systematics based on somewhat different principles from the two former systems is little-known. The objective of this paper is therefore to give a short overview of the principles of the German Soil Systematics. The German Soil Systematics consists of a six-level hierarchical structure which comprises soil divisions, soil classes, soil types, soil subtypes, soil varieties, and soil subvarieties. Soils in Germany are firstly classified into one of four soil divisions according to the soil moist regime: *terrestrial soils*, *semi-terrestrial soils*, *semi-subhydric/subhydric soils*, and *peats*. *Terrestrial soils* are subdivided into 13 soil classes based on the stage of soil formation and the horizon differentiation. *Semi-terrestrial soils* are differentiated into four classes regarding the source of soil moist: groundwater, freshwater, saltwater, and seaside. *Semi-subhydric/subhydric soils* are subdivided into two classes: semi-subhydric and subhydric soils. Peats are classified into two classes of natural and anthropogenic origins. Classes can be compared to orders of the U.S. Taxonomy. Classes are subdivided into 29 soil types with regard to soil forming-processes for *terrestrial soils*, into 17 types with regard to the soil formation for *semi-terrestrial soils*, into five types with regard to the content of organic matter for *semi-subhydric/subhydric soils*, and also into five types with regard to peat-forming processes for *peats*. The soil mapping units in Germany are types, which can be additionally subdivided into ca. 220 subtypes, several thousands of varieties and subvarieties using detailed nuances of morphologic features of soil profile. Soil types can be compared to great groups of the U.S. Taxonomy.

Key words: Pedogenesis, geogenesis, morphologic features, soil forming factor, soil mapping

Introduction

Classification is fundamentally important to any science. In the discipline of soil science, however, many different soil classification systems have been developed worldwide. The World Reference Base of Soil Resources (WRB) accepted as the international standard soil classification system is first published in 1998 jointly by the International Soil Reference and Information Centre (ISRIC), the International Union of Soil Science (IUSS) and the FAO (IUSS Working Group WRB, 2007). The general principles on which the WRB classification system is based are soil properties defined in terms of diagnostic horizons, properties and materials, which should be measurable and observable in the field as far as possible (Fig. 1). The WRB system comprises a two-level structure (Fig. 2). At the first level, it has 32 reference soil groups (RSGs) that represent the major soil regions of the world (IUSS Working Group WRB, 2007; Krogh, 2006). At the second level, the RSGs are additionally combined with 179 prefix and suffix qualifiers, allowing very precise characterization and classification of individual soil profiles.

In the Unites States the soil classification described in Soil Taxonomy classifies soils at six levels based on soil properties, like the WRB system, and soil climatic conditions (Fig. 1; Soil Survey Staff, 2010). The six-level structure is composed of 12 orders, 68 suborders, 444 great groups, ca. 2500 subgroups, ca. 8000 families, and ca. 23000 series (Fig. 2; Brady and Weil, 2008).

These two classification systems of the WRB and the U.S. Soil Taxonomy are well-known in Korea, whereas the German Soil Systematics considered as a

Received : January 8. 2010 Accepted : January 30. 2010
*Corresponding author : Phone: +82312900338
E-mail: sonnyk@korea.kr

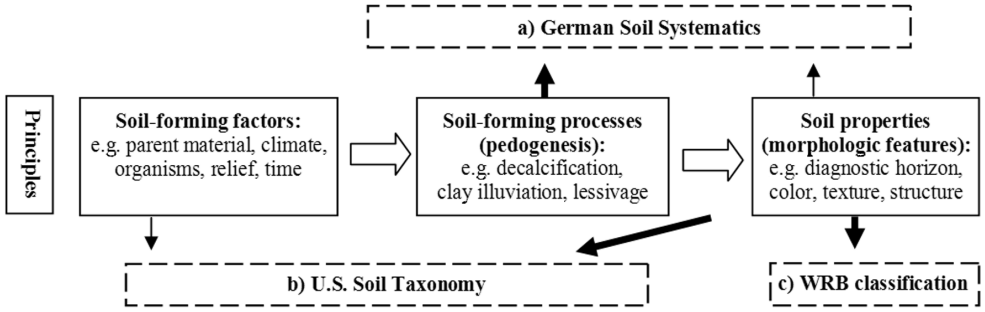

Fig. 1. Comparison of the German Soil Systematics to the U.S. Taxonomy and the WRB classification with regard to their main principles (bold arrow: major criteria; thin arrow: minor criteria; AG Boden Working Group, 2005; IUSS Working Group WRB, 2007; Soil Survey Staff, 2010).

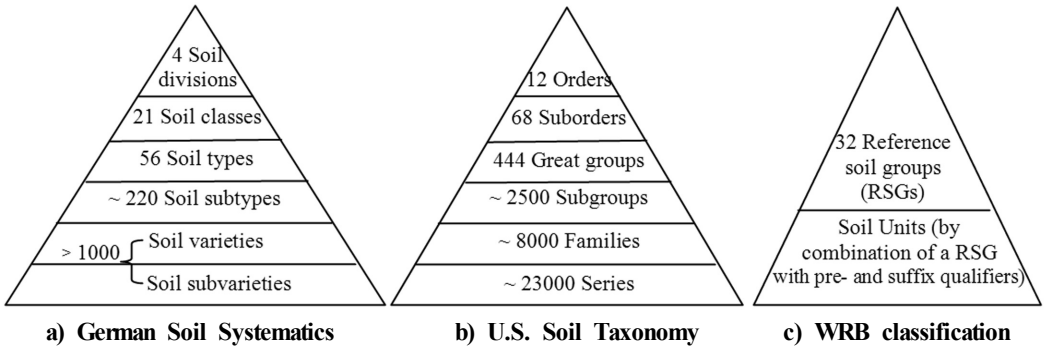

Fig. 2. Comparison of the German Soil Systematics to the U.S. Taxonomy and the WRB classification with regard to their hierarchical structures (AG Boden Working Group, 2005; Brady and Weil, 2008; IUSS Working Group WRB, 2007).

classification system based on pedogenesis is little-known. Therefore, this paper will give a short overview of principles of the German Soil Systematics.

Principles of the German Soil Systematics

The German Systematics consists of a six-level hierarchical structure which comprises 4 soil divisions, 21 soil classes, 56 soil types, ca. 220 soil subtypes, several thousands of soil varieties and soil subvarieties (Fig. 2; AG Boden Working Group, 2005). Four soil divisions with their 21 classes and 56 soil types are tabulated in Table 1a and b together with their symbols and horizon sequences, compared to the nomenclature of the WRB classification. The German Systematics is based on pedogenesis (soil-forming processes) for upper levels of the hierarchical structure and on morphologic features (e.g. diagnostic horizons, color) for lower levels of the hierarchical structure (Fig. 1 and 2; Blume and Stahr, 2002). The geogenic features like parent materials and soil texture are also considered (see below).

Soils in Germany are firstly classified into one of four **soil divisions** according to the soil moist regime: *terrestrial soils, semi-terrestrial soils, semi-subhydric/subhydric soils*, and *peats* (Table 1a and b). This system allows us to classify not only terrestrial soils, but also subhydric soils (underwater soils) which are not defined in the classifications of the WRB system and the U.S. Soil Taxonomy.

As shown in Table 1a, *terrestrial soils* are subdivided into 13 **soil classes** based on the stage of soil formation, the horizon differentiation, and the anthropogenic influence: e.g. *O/C-soils* only with O- and C-horizon, *Braunerde* with well developed Bv horizon (WRB: Cambisols or Cambic Umbrisol; U.S. Taxonomy: Ochrepts or Umbrepts), *Podsole* with Ae horizon (WRB: Podzols; U.S. Taxonomy: Spodosols), and *terrestrial anthropogenic soils* as anthropogenic affected soils (WRB: Terric or Regic Anthrosol). *Semi-terrestrial soils* are differentiated into four soil classes regarding the source of soil moist (Table 1b). They are soils influenced by groundwater, freshwater, and saltwater, or soils in seaside. *Semi-subhydric/subhydric soils* are subdivided into two soil classes of semi-subhydric and subhydric soils regarding the period of the inundation (Table 1b). *Peats* are

Table 1a. Overview of German soil systematic units with their names, symbols and horizon sequences compared to the nomenclature of the WRB classification (AG Boden Working Group, 2005; Blume and Stahr, 2002).

1. Soil division: TERRESTRIAL SOILS					
Soil classes (13)		Soil types (29)			WRB classification
Name	Symbol	Name	Symbol	Horizon sequence	
O/C soils	F	Fselshumusboden	FF	O/mC	Folic Histosol
		Skeletthumusboden	FS	O/xlC	
Terrestrial raw soils	O	Syrosem	OO	Ai/mC	Lithic Leptosol
		Lockersyrosem	OL	Ai/lC	Protic Arenosol Calcaric Regosol
Ah/C soils without Schwarzerden	R	Ranker	RN	Ah/imC	Umbric Leptosol
		Regosol	RQ	Ah/ilC	Haplic Arenosol
		Rendzina	RR	Ah/cC	Rendzic Leptosol
		Pararendzina	RZ	Ah/eC	Phaeozem
Schwarzerden	T	Tschernosem	TT	Axh/Axh+lC/C	Haplic Phaeozem
		Kalktschernosem	TC	Acxh/Acxh+elCc/eCc	Chernozems
Pelosole	D	Pelosol	DD	Ah/P/tC	Vertic Cambisol
Braunerden	B	Braunerde	BB	Ah/Bv/C	Umbrisols Cambisols
Lessives	L	Parabraunerde	LL	Ah/Al/Bt/C	Luvic Arenosol Haplic Luvisol Eutri-vetic Cambisol
		Fahlerde	LF	Ah/Ael/Bt/C	Podzoluvisols
Podsole	P	Podsol	PP	Aeh/Ae/Bh/Bs/C	Podzols
		Staupodsol	PS	Ahe/Sw-Ae/Sd-Bms/C	
Terrae calcis	C	Terra fusca	CF	Ah/T/cC	Chromic Cambisol
		Terra rossa	CR	Ah/Tu/cC	Rhodic Cambisol
Paleosole	V	Fersiallit	VV	···/IIBj/Cj/Cv	-
		Ferrallit	VW	···IIBu/Cj/Cv	-
Slack water soils	S	Pseudogley	SS	Ah/Sw/Sd	Stagnic Luvisol
		Haftpseudogley	SH	Ah/Sg/C	
		Stagnogley	SG	Sew-Ah/Srw/IISrd	Stagnic Albeluvisol
Reduktosole	X	Reduktsol	XX	Ah/Yo/Yr	Reducti-anthropic Regosol
Terrestrial anthropogenic soils	Y	Kolluvisol	YK	Ah/M/II···	Terric or Regic Anthrosol
		Plaggenesch	YE	Ah/E/II···	
		Hortisol	YO	Ap/Ex/(Ex-)C	
		Rigosol	YY	R/C	
		Tiefumbruchboden (Treposol)	YU	R-Ap/R+···	

classified into two soil classes of natural and cultivated peats (Table 1b). Soil classes can be compared to soil orders of the U.S. Taxonomy.

The soil classes of terrestrial soils are further subdivided into 29 **soil types** with regard to parent materials for poorly developed soils and soil forming-processes by means of diagnostic horizons for strongly developed soils: e.g. *Ranker* with carbonate < 2 % (WRB: Umbric Leptosol), *Rendzina* with carbonate > 75 % (WRB: Rendzic Leptosol), *Lessives* as a result of the soil forming process lessivage with Al/Bt-horizon (WRB: Haplic Luvisol), *Pseudogley* as a result of pseudo-gleization with Sw/Sd-horizon (WRB: Stagnic Luvisol), and *Podsole* as a result of podzolization with Ae/Bh-

Table 1b. Continued.

2. Soil division: SEMI-TERRESTRIAL SOILS					
Soil classes (4)		Soil types (17)			WRB classification
Name	Symbol	Name	Symbol	Horizon sequence	
Alluvial soils (freshwater)	A	Rambla	AO	aAi/alC/aG	Fluvisols
		Paternia	AQ	aAh/ailC/aG	Paternia
		Kalkpaternia	AZ	aAh/aelC/aG	Gleyic Regosol Gleyic Fluvisol
		Tschernitza	AT	aAxh/aC/aG	Fluvisols
		Vega	AB	aAh/aM/(IIalC/)(II)aG	Fluvisols Cambisols
Gleye (groundwater)	G	Gley	GG	Ah/Go/Gr	Gleysols
		Nassgley	GN	Go-Ah/Gr	
		Anmoorgley	GM	Go-Aa/Gr	
		Moorgley	GH	H/Gr	
Marschen (saltwater)	M	Rohmarsch	MR	(z)(e)Go-Ah/ ((z)(e)Go/)(z)(e)Gr	Salic or Thionic Fluvisol
		Kalkmarsch	MC	(e)Ah/eGo/(z)eGr	Calcaric Fluvisol; Calcaric Gleysol
		Kleinmarsch	MN	Ah/Go/(z)(e)Gr	Gleysols
		Haftnaessemarsch	MH	mit Ah/(e)Sg-Go/(z)(e)Gr	
		Dwogmarsch	MD	Ah/Sw/IIfAh-°Sd/ fGo-°Sd/Go/Gr	
		Knickmarsch	MK	Ah/Sw/Sq/Gr	Planosols
		Organomarsch	MO	oAh/oGo/oGr	Histosols Gleysols
Strand Soils (seaside)	U	Strand	UA	(z)(e)Ai/((z)(e)lC)/zeG	Arenosols Fluvisols Solonchaks
3. Soil division: SEMI-SUBHYDRIC AND SUBHYDRIC SOILS					
Soil classes (2)		Soil types (5)			
Semi-hydric soils	I	Watt	IW	(z)(e)Fo/(z)(e)Fr	Sali-Thionic Fluvisol; Salic or Eutric Fluvisol
Sub-hydric soils	J	Protopedon	JP	Fi/...	-
		Gyttja	JG	Fo/...	-
		Sapropel	JS	Fr/...	-
		Dy	JD	Fh/...	-
4. Soil division: PEATS					
Soil classes (2)		Soil types (5)			
Natural peats	H	Niedermoor	HN	nHw/(nHr/)(IIfF/)...	Histosols
		Hochmoor	HH	hHw/(hHr/)(uHr/)(nHr/)(IIfF/)...	
Cultivated peats	K	Erdniedermoor	KV	nHv/(nHt/)nHw/(nHr/)(IIfF/)...	Histosols
		Mulmniedermoor	KM	nHm/nHa/nHt/nHw/(nHr/)(IIfF/)	
		Erdhochmoor	KH	hHv/hHw/(hHr/)(IIuHr/)(II,IIInHr/) (…fF/)...	

horizon (WRB: Podzols; Table 1a). The soil classes of *semi-terrestrial soils* are subdivided into 17 soil types according to the degree of soil formation: e.g. *Gley, Nassgley, Anmoorgley, Moorgley* (WRB: Gleysoils; see horizon sequences in Table 1b). The soil classes of *semi-subhydric/subhydric soils* are subdivided into 5 soil types according to the content and quality of organic matter: e.g. *Gyttja* from grey-black, organism-rich, and nutrient-rich

mud and *Dy* from loose, brown to black, nutrient-poor, and acidic mud. The soil classes of *Peats* are subdivided into 5 soil types based on the peat forming processes: e.g. *Hochmoore* from precipitation and *Niedermoore* from groundwater (WRB: both Histosols). Soil types can be compared to great soil groups of the U.S. Taxonomy.

Soil types can be additionally subdivided into **soil subtypes** consisting of typical-subtype (typifies the soil type), intergrade-subtype (typifies the soil type but shows some additional characteristics) and transition-subtype (deviates from soil type). Specific horizon sequences and detailed nuances of morphologic features like the humus content and the iron accumulation are considered to determine the soil subtype.

Soil subtypes can be additionally subdivided into **soil varieties** with regard to ca. 40 qualitative features like humus forms and coloration. Soil varieties can be also subdivided into **soil subvarieties** by quantitative features like the degree of podzolization, base saturation and lessivage. The number of soil varieties and soil subvarieties is open and amounts to several thousand possibilities. The soil mapping units in Germany are soil types or soil subtypes with additional designation of parent materials, which compose '**Soil forms**'. Examples of Soil forms are Podzol from drifting sand over glacial loam or Podzol from alluvial sand over alluvial loam. Soil forms allow soils from different landscapes systematically to be compared.

Conclusion

The definitions of soil systematics and soil classification are different in the strict sense. Using the German Soil Systematics, soils are grouped on the basis of geogenic and pedogenic processes and assigned to soil types. Soil types combined with parent materials compose 'Soil forms', which are used in Germany as soil mapping units. The key point of the German Soil Systematics is to understand the geogenic and pedogenic processes. In contrast, the classification of the U.S. Taxonomy and the WRB focuses on soil properties without considering genetic processes. Therefore, a direct comparison of the nomenclature of two different systems is often complicated.

Acknowledgment

This study was supported by 2009 Post Doctoral Course Program of National Academy of Agricultural Science, Rural Development Administration, Republic of Korea.

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독일 토양분류체계 소개

김록영 · 성좌경 · 김석철 · 장병춘 · 손연규*

농촌진흥청 국립농업과학원 토양비료관리과

각 나라마다 토양이 생성되는 환경이 다르고, 토양분류가 활용되는 목적이 다르기 때문에 세계적으로 다양한 토양분류체계가 발전되어 왔다. 1998년부터 국제적으로 통용되기 시작한 WRB 분류체계와 미국의 분류체계인 Soil Taxonomy는 그동안 국내에 잘 알려져 왔지만, 위의 두 체계와 분류기준을 달리하는 독일 분류체계인 Soil Systematics는 아직 잘 알려져 있지 않다. 본 논문에서 독일 분류체계의 구성과 분류기준을 소개하고자 한다. German Systematics는 6 단계 구조로 이루어져 있고, 상부에서 하위 순서로, soil divisions, soil classes, soil types, soil subtypes, soil varieties, soil subvarieties로 세분화된다. 독일 토양은 먼저 토양수분상태에 따라 4개의 soil divisions 중 하나로 분류되며, 이들은 육지토양, 반육지토양, 반습지/습지토양, 토탄토양이다. 육지토양은 다시 토양발달상태, 층위분화에 따라 13개의 soil classes로 분류되며, 예로 토양발달이 미약한 O/C-토양, 토양발달이 많이 진전되고 Ae-층을 갖는 Podsole (WRB 명명법: Podzols; U.S. Taxonomy: Spodosols)를 들 수 있다. 반육지토양은 지하수토양, 담수토양, 해수토양, 해변토양의 4개의 soil classes로, 반습지/습지토양은 반습지토양, 습지토양의 2개의 soil classes로, 토탄토양도 자연적, 인위적 토탄토양의 2개의 soil classes로 세분화된다. Soil classes는 U.S. Taxonomy의 orders와 비교될 수 있다. 육지토양의 soil classes는 다시 29개의 soil types로, 토양발달이 미약한 토양은 모재에 따라, 토양발달이 진전된 토양은 토양생성과정에 따라 분류된다. 반육지토양의 soil classes는 토양발달 정도에 따라 17개의 soil types로, 반습지/습지토양의 soil classes는 유기물함량에 따라 5개의 soil types로, 토탄토는 생성과정에 따라 5개의 soil types로 세분화된다. Soil types은 독일 토양조사의 기본 단위이며, U.S. Taxonomy의 great groups과 비교될 수 있다. 토양단면의 미세한 형태학적 차이를 고려하여 다시 약 220개의 soil subtypes, 수천 개의 soil varieties과 soil subvarieties로 세분화될 수 있다.

요약어 : 토양생성과정, 지질형성과정, 형태학적 특징, 토양생성인자, 토양조사