19th World Congress of Soil Science

Symposium 1.4.2
Soil classification-benefits and constraints to pedology

Soil Solutions for a Changing World,

Brisbane, Australia

1 – 6 August 2010

Table of Contents

Concentrations of trace elements in soils: The three keys

Denis Baize

INRA, UR2072 Science du Sol, Centre de recherche d'Orléans, France, Email denis.baize@orleans.inra.fr

Abstract
Taxonomic categories of the highest level (e.g. the RSG of the World Reference Base for soil resources) are not adequate when dealing with trace element concentrations in soils. This does not however mean that pedology, its basic concepts and knowledge accumulated over more than a century, are of no use in this domain. Examples of the role of soil forming processes on trace element contents in soils will be provided.

Key Words
Trace elements, soil classification, geochemical background, pedogeochemical concentration, pedology

There is no question here of denying the importance of soil classifications or reference bases as languages of communication between scientists, as well as tools for soil cartographers wishing to class and compare soils. However, the highest categories of national or international systems are often used in an inappropriate way, for example as stratification units in the study of trace element contents in soils. Trace elements (TE) are the 80 stable elements, each with a mean concentration of less than 0.1 % of the upper continental crust. Together, they represent only 0.6 %, while the 12 major elements constitute 99.4 %.

Inadequacy of taxonomies
Categories at the highest taxonomic level, such as the reference soil groups (RSG) of the WRB (IUSS, 2006) are not relevant to the study of TE concentrations in soils. There are two main reasons: 1°) the attribution of a particular solum to a high level taxon is a hazardous and subjective practice. Sometimes the analytical determinations needed for an irrefutable diagnosis are unavailable. The result of all this is that, even using the same system of classification or reference base, different specialists do not give the same name to a given solum. 2°) Names such as Leptosols, Fluvisols, Cambisols, Anthrosols, Regosols, Gleysols, etc. give no information either as to the particle-size distribution or about the mineralogical composition, hence on the geochemical inheritance! Any stratification of a given data-set of soil chemical analyses according to this criterion is doomed to failure!

RSGs are few and far between which, because they are closely linked to a specific particle-size distribution or parent rock, can give us any useful indication in this domain. Podzols like Arenosols, are developed in sandy materials which are very poor in weatherable minerals and hence display very low TE contents. In contrast, by their very definition, Vertisols always show heavy clay textures, although the information given does not go beyond a mere granulometric description. In the same way, it is well known that most Andosols are developed in volcanic rocks, but these can present widely variable chemical compositions.

The initial inheritance: the geochemical background
Under any climate, the **number one key** which from the outset determines the concentrations in TE found in soils today is the chemical composition **inherited** from the parent material, usually called "geochemical background". This corresponds to the mineralogical composition of the rock whether originally-formed (in the case of extrusive and igneous rocks) or initially deposited (in the case of marine sediments, moraines, loess and alluvium), which have sometimes been modified by subsequent mineralization (Figure 1).

A first example is given by still weakly differentiated soils, which are abnormally rich in nickel and chromium, because they developed from rocks containing large amounts of olivine, pyroxenes, chromite, spinels, etc., which are all minerals bearing Ni and Cr. This is the case, for example, of the basalts and basanites of the French Massif Central (Soubrand *et al.,* 2007) or of the Réunion Island (Doelsch *et al.,* 2006) and the serpentinites in the Swiss Alps (Gasser *et al*., 1995).

Another example is that of certain soils developed in alluvium showing abnormally high contents of some TEs. As a general rule, alluvium display extremely variable particle-size (from heavy clays to large boulders), but above all, their composition is totally dependent on the lithology of materials abraded upstream. So, some alluvial soils of little streams flowing down the Vosges or the Cévennes (France), exhibit high concentrations of

© 2010 19th World Congress of Soil Science, Soil Solutions for a Changing World
1 – 6 August 2010, Brisbane, Australia. Published on DVD.

Pb, Zn, and Cu, simply because these alluvium are located downstream of strongly mineralized rocks.

The case of moraines is different, being deposited by Alpine glaciers (Switzerland – the canton of Geneva and France – the Savoy region). The glacial tills deposited by the ancient Rhone glacier contain numerous little fragments of "green stones". That is the reason why the still weakly differentiated soils developed in them are heavily loaded in nickel (40 to 220 mg/kg) and chromium (78 to 226 mg/kg), whereas they are poor in iron and of medium texture. Nothing similar is observed in the case of the Jura glaciers.

The second key: soil processes leading to natural pedogeochemical concentration (NPGC)
In regions with temperate climates and in those with cold climates, the **soil forming processes which can markedly change this inheritance** in upper soil horizons are few. These are:

- Partial or total dissolution of carbonates results in the relative accumulation of non-lixiviated TE; the total dissolution of limestone causes huge changes since the calcite constitutes between 90 and 99 % of the rock dissolved (Prudente *et al.,* 2002). Thus, those constituents which have not been evacuated in the deep karst network (clay minerals, iron oxides, cadmium, and zinc) reach very high concentrations in residual soils.
- Dilution by very abundant organic matter(in the case of Umbrisols with humose topsoils);
- Translocation of clay particles (vertical or lateral illuviation – e.g. case of Luvisols and Planosols) leading, over the long-term, to the formation of upper soil horizons which have markedly lower TE content than deeper soil horizons;
- Direct and total weathering of clay minerals by acidolysis, ferrolysis, etc. giving rise to upper soil horizons which are very poor in trace and major elements;
- Podzolisation, where iron, aluminium and most trace metals form organo-metallic complexes, which are able to move down from the upper A and E layers and accumulate at depth in spodic B horizons;
- Absolute accumulation of iron, manganese and a suite of associated trace metals, in particular soil horizons with a dominantly blackish hue.

A good instance of this is provided by soils formed in the clayey residue resulting from the total carbonate dissolution of Jurassic limestone with a unusually high cadmium content (i.e. with 0.40 to 8 mg/kg rock - France, Swiss Jura). A large part of the freed cadmium remaining *in situ*, adsorbed onto iron and manganese oxy-hydroxides, gives rise to soil horizons whose natural concentrations exceed 2 mg/kg, and can even reach 22 mg/kg (Baize and Sterckeman, 2001; Prudente *et al.,* 2002; Rambeau, 2006).

Another illustrative case is that of soils of the Sinemurian "back slope" in Auxois (Burgundy). The marine limestone of Sinemurian age was locally mineralized by a suite of trace elements (As, Cd, Cu, Co, Ni, Pb, Zn, Tl). These TE come from hydrothermal venting along a network of faults delimiting an old Hercynian horst. The soils which can be observed today developed in the residual clay resulting from the limestone dissolution, which provoked a further TE concentration process in soils, which consequently have much higher TE contents than the underlying rock (Baize and Chrétien, 1994).

In the case of very old strongly and deeply weathered soils of the inter-tropical areas with a perhumid climate, many elements are lixiviated (e.g. Mg, Ca, Si), but others accumulate *in situ* (e. g. Cr, Ni, Cu, Mn, Ti, V) and combine with the diverse iron oxide forms (e.g. Nalovic et Quantin, 1972; Anand and Gilkes 1987; Becquer *et al.,* 1995; Trolard *et al.,* 1995).

The third key: contamination induced by man
Diverse anthropogenic additions have much more recently been added to the pre-existing natural stocks: i) atmospheric fallout from origins both far or near; ii) trace elements brought unwittingly by fertilizer, sewage sludge or waste spreading. The extent of this contamination and its chemical nature clearly have no relationship with the taxonomic category of the receiving soil.

Distinguishing the natural from the anthropogenic – Why is this necessary?
“For environmental risk assessment the question of reactivity is of even greater relevance than the question of total concentration because it determines the mobility, human exposure and ecotoxicological importance of the elements. For proper environmental soil management it is of vital importance to be able to distinguish between natural pedogeochemical concentrations and anthropogenically elevated levels of TEs” (Mol *et al*., 2009). Thanks to this distinction, it is possible to obtain an initial assessment of possible dangers to human health, especially through phyto-availability to cultivated plants. Trace metals of anthropogenic origin are actually,

much more reactive species than those of natural origin, even when in abnormal abundance. In fact, the latter have been strongly adsorbed for millennia onto various solid phases or are co-precipitated with Fe or/and Mn oxy-hydroxides. The determination of local natural pedogeochimical concentrations (NPGC) and subsequently of the local level of contamination allows us not to declare as being "polluted" (with the serious socioeconomic or financial consequences which may ensue) a plot of ground in a context of strong natural anomalies. If necessary, it allows us to fix realistic and relevant target de-pollution values, suited to the geological and pedological context.

Distinguishing the natural from the anthropogenic – How?

Stratification by "soil series" or by parent material are two ways of simply and appropriately determining the local NPGC. The latter (Figure 2) requires sufficient geological knowledge and can only be done where these parent materials are sufficiently geochemically homogeneous.

The determination of the natural pedogeochemical background of a given soil series requires the ability to recognize it in the field and to characterise it. Between 25 and 50 soil samples must be analyzed for each soil series and these samples must be as little contaminated as possible. Therefore, the sampling must be organized by giving priority to i) soils which have remained under forest which, indeed, have also received atmospheric deposition but are free of agriculturally induced contamination; ii) deep horizons of cultivated soils, assumed to be uncontaminated. Some obstacles may sometimes occur: i) in some circumstances, contaminants did not remain in the surface horizon and went down to deeper ones (Sterckeman *et al*., 2000); ii) most mining or industrial areas are strongly contaminated over their entire surface. Fortunately, for each "soil series" strong natural relationships exist for most of the trace elements (e. g: zinc vs clay content or lead vs iron (Figure 2) or chromium vs nickel) which are useful as a base for reasoning. It must be noted that these approaches and reasoning require the use of analytical methods giving access to the really "total" contents, which requires the dissolution of silicates using hydrofluoric acid or by alkaline fusion.

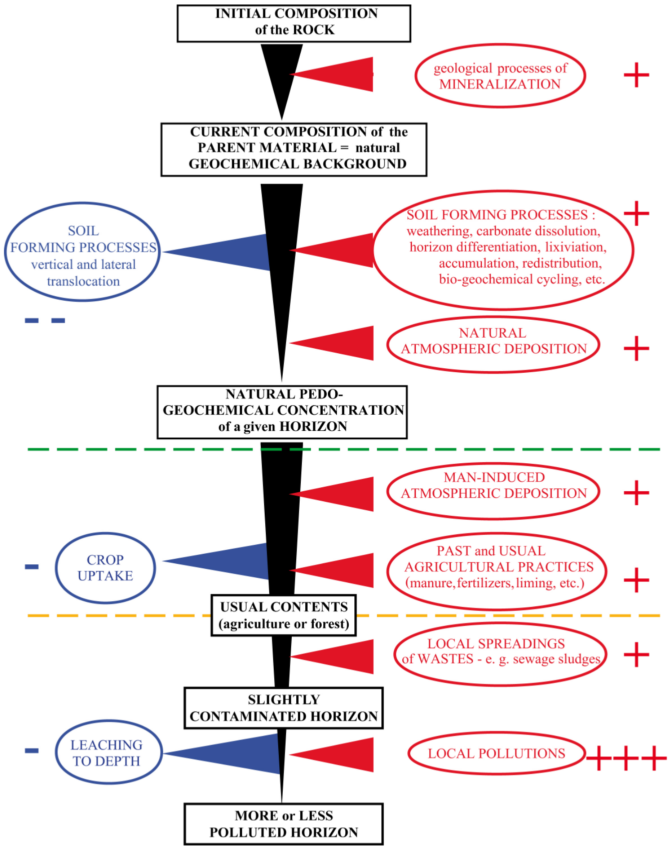

Figure 1. Progressive acquisition of trace element composition of a soil horizon: from the initially-formed rock to the ploughed surface horizon. On the right, in red: factors increasing the trace element contents. On the left, in blue: factors decreasing the trace element contents.

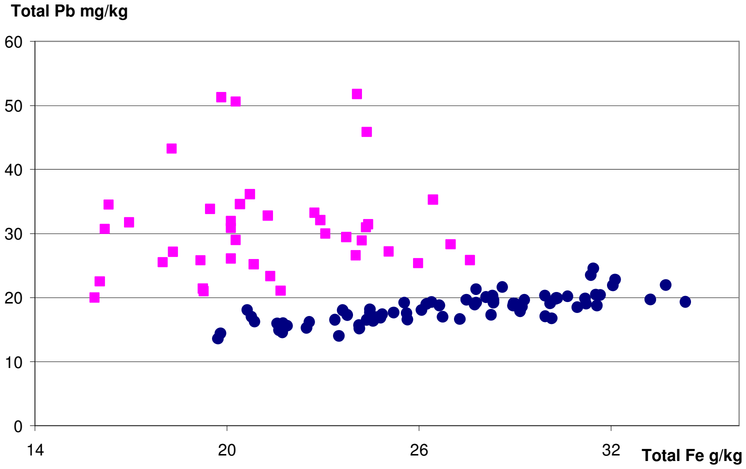

Figure 2. Cultivated soils developed from loess in the Northern France: relationship between total lead and total iron (Sterckeman *et al*., 2006). Pink squares represent the ploughed surface horizons, blue circles all types of deep horizons. The natural geochemical relationship between Pb and Fe is strong for all deep horizons because it is not modified by anthropogenic additions. The same does not apply to surface horizons, more or less contaminated by lead.

Conclusion

It would not be sensible to deal with trace element contents in soils (pedogenetical modifications brought about the geochemical inheritance, speciation, soil-plant transfers) without taking into account the basic concepts and knowledge acquired by pedology over more than a century. We have just seen that it is essential to take into account pedological information to optimize sampling strategy and interpretation of results. Moreover, when a contamination by trace elements is recognized, all information about soils contributes to a correct assessment of the dangers induced. Finally, we are, however, led to the conclusion that the highest taxonomic categories do not give us the right key.

References

Anand RR and Gilkes RJ (1987) Iron oxides in lateritic soils from Western Australia. *Journal of Soil Science*, **38**, pp. 607-622.

Baize D, Chrétien J (1994) Les couvertures pédologiques de la plate-forme sinémurienne en Bourgogne. Particularités morphologiques et pédo-géochimiques. *Étude et Gestion des Sols*, **1**, 2, pp. 7-27.

Baize D, Sterckeman T (2001) Of the necessity of knowledge of the natural pedo-geochemical background content in the evaluation of the contamination of soils by trace elements. *Science Total Environment*, **264**, pp. 127-139.

Becquer T, Bourdon E et Pétard J (1995) Disponibilité du nickel le long d'une toposéquence de sols développés sur roches ultramafiques de Nouvelle-Calédonie. C.R. Acad. Sci. Paris, pp. 585-592.

Doelsch E, Van de Kerchove V, Saint Macary H (2006) Heavy metal content in soils of Réunion (Indian Ocean). *Geoderma*, 134, pp. 119-134.

Gasser UG, Juchler SJ, Hobson WA & Sticher H (1995) The fate of chromium and nickel in subalpine soils derived from serpentinite. *Canadian Journal of Soil Science*, 75, n° 2, pp. 187-195.

IUSS Working Group WRB (2006) *World reference base for soil resources*. 2nd edition. Report No 103, FAO Rome.

Mol G, Spijker J and Klaver G (2009) The reactivity of trace element enrichments in the soil. Proceed. Intern. Symp. on Mineralogy, Environment and Health, 2009 September 17th - 18th. Univ. Paris-Est, pp. 22-24

Nalovic L et Quantin P (1972) Évolution géochimique de quelques éléments majeurs et traces dans un sol ferrallitique ferritique de Nouvelle-Calédonie issu de péridotites. *Cahiers ORSTOM, série Pédologie*, vol. X, n°4, pp. 389-410.

Prudente D, Baize D, Dubois J-P (2002) Le cadmium naturel dans une forêt du haut Jura français. In "Les Éléments traces métalliques dans les sols" (Ed. D Baize et M Tercé). pp. 53-70. INRA Éditions, Paris.

Rambeau C (2006) Cadmium anomalies in Jurassic carbonates (Bajocian, Oxfordian) in Western and Southern Europe. Ph.D Thesis. Université de Neuchâtel.

Soubrand-Colin M, Néel C, Bril H, Grosbois C, Caner L (2007) Geochemical behaviour of Ni, Cr, Cu, Zn and Pb in an Andosol–Cambisol climosequence on basaltic rocks in the French Massif Central. *Geoderma*, 137, pp. 340-351.

Sterckeman T, Douay F, Proix N & Fourrier H (2000) Vertical distribution of Cd, Pb and Zn in soils near smelters in the North of France. *Environmental Pollution*, 107 (3), pp. 377-389.

Sterckeman T, Douay F, Baize D, Fourrier H, Proix N, Schvartz C, Carignan J, (2006) Trace element distributions in soils developed in loess deposits from northern France. *Eur. Journal of Soil Science.* Vol. 57, 3, pp. 392-410.

Trolard F, Bourrié G, Jeanroy E, Herbillon AJ and Martin H (1995) Trace metals in natural iron oxides from laterites. *Geochimica & Cosmochimica Acta*, Vol. 59, No 7, pp. 1285-1297.

How soil forming processes determine viticultural zoning in Catalonia, Spain.

Josep Miquel Ubalde and Rosa Maria Poch

Department of Environment and Soil Science, University of Lleida, Lleida, Spain, Email jubalde@alumnes.udl.cat, rosa.poch@macs.udl.cat

Abstract
The aim of this paper is to analyze whether the soil forming processes determined in representative vineyard soils, through their effects on soil properties and classification, deserve to be considered in a viticultural zoning based on soil surveys. Many viticultural zoning studies are based on the relationships between grape and wine quality and certain soil properties or different soil forming factors, but there are no studies that consider possible relationships with soil forming processes. The study area produces high quality wines and is located in Priorat and Penedès viticultural areas (Catalonia, Spain). The studied soils belong to representative soil map units, which were determined according to the Soil Survey Manual (SSS 1993), at a 1:5,000 scale. A micromorphological study was undertaken in order to clarify or identify pedogenic processes. The soil forming processes, identified through morphological and micromorphological analyses, had direct effects on soil properties and soil classification. These properties, especially those related to the soil moisture regime, the available water capacity and the calcium carbonate content, had a direct influence on the type of management and quality of grapevine production. We show that the parent material or climate alone cannot be used in viticultural zoning, unless soil forming processes are taken into account.

Key Words
Soil genesis, micromorphological study, soil classification, Soil Taxonomy, vineyard soil, soil survey, viticulture

Introduction

In the last years, viticultural zoning studies have increased significantly in relation to the expansion of the international wine market. Viticultural zoning can be defined as the spatial characterization of zones that produce grapes or wines of similar composition, while enabling operational decisions to be implemented (Vaudour 2003). Among the various environmental factors and for a specific climate, soil is the most important factor on viticultural zoning, due to its direct effect on vine development and wine quality (Gómez-Miguel and Sotés 2003). There are several approaches through soil studies which are oriented to viticultural zoning, but the methods that provide more information are soil survey techniques, since they bring both the knowledge of spatial variability of soil properties and soil classification according to its viticultural potential (Van Leeuwen and Chery 2001). Soil survey methods based on Soil Taxonomy classification (SSS 1999) were useful for viticultural zoning studies at different detail levels (Gómez-Miguel and Sotés 2003; Ubalde *et al*. 2009).

Soil forming processes determine most of the diagnostic horizons and characteristics for the higher categories of Soil Taxonomy, thus the soil genesis is fundamental in order to classify soils and in viticultural zoning based on soil surveys. However, many viticultural zoning studies are based on the relationships between grape and wine quality and certain soil properties or different soil forming factors, namely climate, geology and topography, but there are no studies that consider possible relationships with soil forming processes. This fact may be due to difficulties in determining some of these processes, because soil genesis cannot be observed or measured directly and pedologists could differ about it (SSS 1999). Evidences of some soil forming processes can be detected only by microscopic studies, which require a specific training. Furthermore, some soil forming processes are not adequately addressed by the taxonomic system, especially those related to human activity (SSS 1999).

The aim of this paper was to analyze whether the soil forming processes determined in representative vineyard soils, through their effects on soil properties and classification, deserve to be considered in a viticultural zoning based on soil surveys. To our knowledge, this approach has never been addressed before.

Materials and methods

The study area is located in different protected viticultural areas of Catalonia: Priorat and Penedès. The area is enclosed approximately between 41º 3’ N and 41º 48’ N and between 0º 40’ E and 1º 53’ E. The altitude ranges between 220 m and 550 m. The vineyards are situated on the Catalan Coastal Range, an alpine folding chain

© 2010 19th World Congress of Soil Science, Soil Solutions for a Changing World

1 – 6 August 2010, Brisbane, Australia. Published on DVD.

formed by both massifs and tectonic trenches. Massifs consist of Palaeozoic slates and granites (Priorat region). Tertiary calcareous rocks outcrop in the tectonic trenches (Penedès region). The climate type is Mediterranean, characterized by a dry warm season during summer, even though there are differences in temperatures and precipitation according to the altitude and distance to the sea. The mean annual precipitation varies from 520 mm in Penedès to 589 mm in Priorat, showing seasonal variations. The Penedès region has an average annual temperature of 14.9 ºC, while that of the Priorat is 12.7 ºC. The soil moisture regime is xeric and the soil temperature regime is mesic (Priorat) or thermic (Penedès) (SSS 1999).

The studied soils belong to representative soil map units, which were determined according to the Soil Survey Manual of the Department of Agriculture of United States (SSS 1993), at very detailed scale (1:5,000). The density of soil observations was 1 observation by cm^2 of map, of which a sixth part corresponded to soil pits and the rest to soil auger holes. Details of the soil survey method are given in Ubalde *et al*. (2009). Moreover, a micromorphological study was undertaken in order to clarify or identify pedogenic processes which were difficult to detect with the naked eye. For the micromorphological study, thin sections were elaborated from undisturbed soil material according to Benyarku and Stoops (2005). Samples were taken from deep horizons, since surface horizons were disturbed by plowing. Generally, 1 or 2 samples were collected for each selected profile. Altogether, in this study, we described a total of 23 thin sections from 19 different profiles and 8 soil map units. The criteria of Stoops (2003) were used in thin section description.

Results and discussion

Soil forming processes in Priorat

The Priorat soils are Entisols, since the identified soil forming processes are not enough developed to determine any diagnostic horizon, except to an ochric horizon. In general, soils developed from granodiorites (Fig. 1) were classified as Xeropsamments, which are characterized by a texture coarser than loamy fine sand and less than 35 % of rock fragments. However, soils developed from very rubefacted granitic regolith (Fig. 2), were classified as Typic Xerorthents. These soils could not be classified as Alfisols, since evidences of illuvial clay is required for an argillic horizon, and in this case, the clay origin was the alteration of biotite. Moreover, these soils cannot be classified as inceptisols because the subsurface horizons maintain the rock structure, and consequently the criteria for cambic horizon are not accomplished. With respect to soils developed from slates, they are classified as Lithic Xerorthents, in spite of presenting a strongly exfoliated rock with intercalations of material enriched in illuvial clay (Fig. 3). There is a subgroup in the Alfisols, named Lithic ruptic-inceptic Haploxeralfs, which are defined by presenting a lithic contact and a discontinuous argillic horizon, horizontally distributed. However, in the studied soils, the thickness of material with illuvial clay was generally lower than 7.5 cm, so the criteria for argillic horizon were not accomplished.

In soils developed from slates, the available water capacity was moderate (56 mm between 0 and 40/50 cm depth), so the water retained by the clay-rich materials among the rock cracks was worth considering (16 mm until 200 cm depth) (Table 1). The presence of redoximorphic features related to clay features would indicate that clay accumulation was causing an alteration in the soil moisture regime. In soils formed from granodiorites, the available water capacity was very low (12 mm between 0 and 40 cm depth). These soils, in addition to shallowness, were composed practically by sand (Table 1), so that there were not particles of silt or clay to retain water. In order to obtain a high quality production, irrigation with low doses applied frequently is needed. The existence of rubefacted granodiorites with neoformed clay resulted in soils with finer textures, increasing three fold the available water capacity (32 mm between 0 and 34 cm depth) in comparison with the non-rubified Xeropsamment. Although irrigation is still necessary, water losses may be smaller. Another soil property improved with clay accumulations was the cation exchange capacity (CEC) of surface and deep horizons. In surface horizons, the CEC increased from 5.1 to 9.1 cmol/kg. This increase represents a substantial improvement of nutrient availability for the vine and the possibilities of development of soil structure and stability of soil aggregates, which is especially important in these soils poor in organic matter (contents lower than 0.5%).

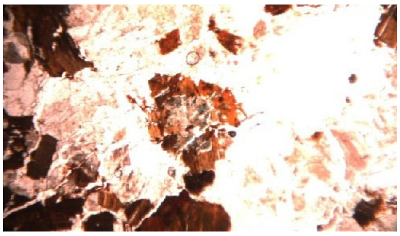

Figure 1. Mineral composition of granitic regolith, with mica alteration in the center of the picture (6.4 mm width, PPL).

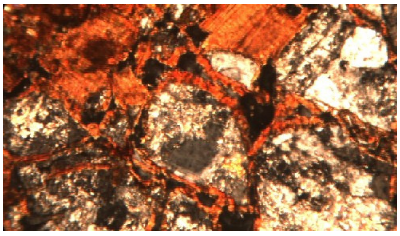

Figure 2. In situ clay neoformation in very rubefacted granitic regolith: microlaminated coatings (1.5 mm width, XPL).

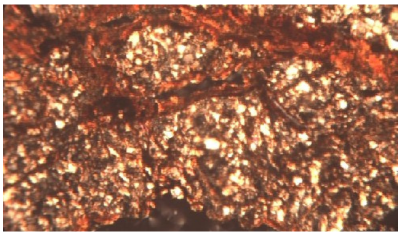

Figure 3. Clay illuviation in slates: clay infillings in cracks and clay coatings in pores (1.5 mm width, XPL).

Table 1. Analytical properties of representative vineyard soils in Priorat region *.

Horizon	Lower depth (cm)	Munsell color (moist)	pH (H_2O 1:2.5)	EC (dS/m)	Organic matter (%)	$CaCO_3$ (%)	CEC (cmol/kg)	Sand (%)	Silt (%)	Clay (%)	Textural class (SSS, 2006)	Bulk density (kg/m^3)	Coarse fragment (%)	Water retention 1/3-bar (%)	Water retention 15-bar (%)	AWC (mm)
Sandy, mixed, mesic, shallow, Typic Xeropsamments																
Ap_1	20	10YR5/4	8.6	0.12	0.1	trace	5.1	91.5	4.9	3.6	Sa	1520	trace	5	3	6
Ap_2	40	10YR5/4	8.6	0.11	0.1	trace	5.2	91.8	6.9	1.3	Sa	1556	trace	5	3	6
C	>160	-	8.4	0.08	trace	trace	4.6	95.5	3.6	0.9	Sa	-	-	4	3	-
Loamy, mixed, active, mesic, shallow, Typic Xerorthents																
Accumulations (34->150 cm depth): Clay coatings on sand grains.																
Ap_1	14	5YR4/5	8.3	0.17	0.5	trace	9.1	71,7	15,9	12,4	SaL	1355	trace	15	7	14
Ap_2	34	5YR4/5	8.4	0.14	0.1	trace	8.8	78,6	12,6	8,8	LSa	1608	trace	12	6	18
C	>150	5YR5/7	8.1	0.18	trace	trace	9.0	85,9	8,6	5,5	LSa	-	-	11	6	-
Loamy-skeletal, mixed, semiactive, mesic, Lithic Xerorthents																
Accumulations (40/50->200 cm depth): Clay coatings on rock cracks.																
Ap_1	15	10YR4/4	7.6	0.26	3.5	trace	12.7	69.5	19.8	10.7	SaL	1569	48	21	8	16
Ap_2	40/50	10YR4/4	7.7	0.22	1.9	trace	12.0	71.1	18.3	10.6	SaL	2105	37	18	8	40
R/Bt	200	2.5Y5/4	7.7	0.21	0.4	trace	15.0	53.6	27.8	18.6	SaL	1920	20	22	11	16

* EC: electrical conductivity; CEC: cation exchange capacity; Textural classes: Sa: sand, LSa: loamy sand, SaL: sandy loam; AWC: available water capacity.

Soil forming processes in Penedès

Most of the Penedès soils are classified as Inceptisols, because of enough carbonate or gypsum accumulations leading to calcic, petrocalcic or gypsic horizons. Generally, they are classified as Typic Calcixerepts, Petrocalcic Calcixerepts and Gypsic Haploxerepts, respectively. However, not all soils with carbonate accumulations could be classified as Calcixerepts, since they did not meet the criteria for a calcic horizon: some soils only showed incipient accumulations, or presented too low $CaCO_3$ content. Generally, these accumulations led to cambic horizons, and soils were classified as Typic Haploxerepts. Even in some cases, where carbonate accumulations were not visible at the naked eye, a cambic horizon could not be determined, and soils were classified as Entisols. Table 2 shows the analytical properties and the description of accumulations in a soil with a well-developed calcic horizon (Typic Calcixerept, Fig. 6), a soil with incipient accumulations of carbonates (Typic Xerofluvent, Fig. 4 and 5), as well as a soil with a gypsic horizon (Gypsic Haploxerept).

The soil forming processes in Penedès were marked by the accumulation of secondary carbonates, which could be highly evolved, as it was indicate by the types of accumulations and their morphology (Table 2). This evolution was reflected in the calcium carbonate content, which could exceed 75%, and in carbonate cementations. The evolution of carbonates in these soils may be a limiting factor for grapevine cultivation. High contents in calcium carbonate can cause a weakening in non-resistant vines, due to iron chlorosis. The main consequences are rickets, foliage destruction, reduced production and even the death of the plant. These problems may be mitigated by the choice of resistant rootstocks, such as 41B and 140R. Furthermore, very intense processes of carbonate accumulation, leading to a micromass cementation, may constitute a limitation for the development of the root system. Moreover, carbonate accumulations in the form of nodules increase the coarse fragment content, and thus reduce the available water capacity. In the deep horizons of a Typic Calcixerept, a loss of 29.7 mm of available water capacity can be quantified, considering a volume of 20% of carbonate accumulations. However, the main implications of carbonate accumulations on vineyard management are related to rootstock selection and ploughing, which should not be too deep to prevent the outcrop of calcic horizons to the surface.

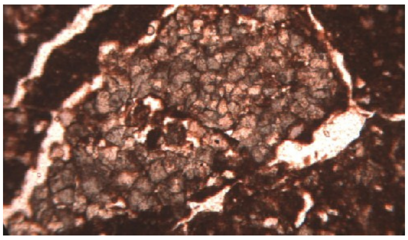

Figure 4. Citomorphic calcite nodules in Typic Xerofluvents:. (1.5 mm width, PPL).

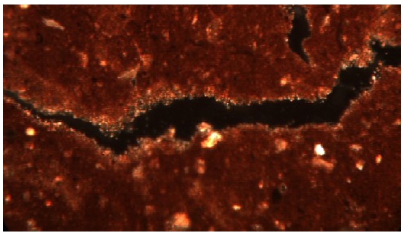

Figure 5. Acicular crystals and microsparite hypocoating in Typic Xerofluvents (1.5 mm width, XPL).

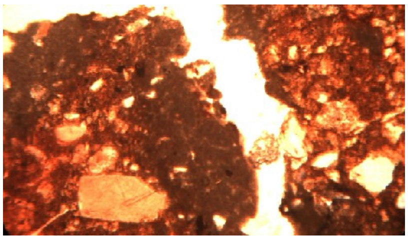

Figure 6. Well-developed carbonate accumulations in Typic Calcixerepts (1.5 mm width, PPL).

Table 2. Analytical properties of representative vineyard soils in Penedès region *.

Horizon	Lower depth (cm)	pH (H_2O 1:2.5)	EC (dS/m)	Organic matter (%)	$CaCO_3$ (%)	Gypsum (%)	CEC (cmol/kg)	Sand (%)	Silt (%)	Clay (%)	Textural class (SSS, 2006)	Bulk density (kg/m^3)	Coarse fragment (%)	Water retention 1/3-bar (%)	Water retention 15-bar (%)	AWC (mm)
Fine, mixed, semiactive, thermic, Typic Xerofluvent																
Accumulations (40-95 cm depth): Microscopic micritic calcite nodules and microesparitic calcite hypocoatings. Whole soil hypocoatings.																
Ap1	12	8.2	0.20	1.6	31	trace	17.5	18.2	40.7	41.1	SiC	1368	0	27	15	20
Ap2	40	8.2	0.25	1.2	33	trace	16.9	18.0	40.6	41.4	SiC	1773	0	27	15	60
Bw	95	8.0	0.66	0.5	31	trace	17.2	11.5	40.8	47.7	SiC	1772	0	27	16	107
Coarse-loamy, carbonatic, thermic, Typic Calcixerept																
Accumulations (30/50->160 cm depth): Macroscopic coatings on pores, geopetal ciment and nodules. Slight carbonate cementation. Microscopic acicular crystals, micrite and microsparite hypocoatings, microsparite and quesparite infillings, micrite and sparite nodules.																
Ap1	15	8.6	0.18	1.4	76	trace	4.5	60.1	29.1	10.8	SaL	1198	46	16	7	9
Ap2	30/50	8.6	0.18	1.2	73	trace	4.4	60.3	28.4	11.3	SaL	1196	37	17	8	17
Bkn	160	8.3	0.60	0.3	69	trace	3.9	60.5	30.9	8.6	SaL	1390	34	13	4	98
Coarse-loamy, mixed, active, thermic, Gypsic Haploxerept																
Accumulations (38-85 cm depth): Gypsum crystals and gypsum coatings on pores.																
Ap1	12/20	7.9	2.29	1.2	31	26	10.2	39.2	55.3	5.5	SiL	1700	5	27	14	34
Ap2	38	7.9	2.29	1.0	30	29	9.2	40.4	56.0	3.6	SiL	1800	10	27	15	43
By	85	8.0	2.33	0.3	25	35	7.5	48.0	46.0	6.0	SaL	1600	5	23	14	64

* EC: electrical conductivity; CEC: cation exchange capacity; Textural classes: SaL: sandy loam; SiL: silt loam; SiC: silty clay; AWC: available water capacity.

Conclusions

In the influence area of the Catalan Coastal Range, a high variety of soil forming processes takes place, in relation to the existing differences in soil forming factors. The soil forming processes, identified through morphological and micromorphological analyses, had direct effects on soil properties and soil classification. These properties, especially those related to soil moisture regime, available water capacity and calcium carbonate content, had a direct influence on the type of management and quality of grapevine production. We showed that the parent material or climate alone cannot be used in viticultural zoning, unless soil forming processes are taken into account.

References

Benyarku CA, Stoops G (2005) ‘Guidelines for preparation of rock and soil thin sections and polished sections’. Quadern DMACS 33. (Department of Environment and Soil Science, University of Lleida: Lleida, Spain)

Gómez-Miguel V, Sotés V (2003) Zonificación del terroir en España. *Terroir-Zonazione-Viticoltura: trattato internazionale Phytoline,* 187-226.

SSS (1993) ‘Soil Survey Manual.’ (Soil Conservation Service, United States Department of Agriculture Handbook 18)

SSS (1999) ‘Soil Taxonomy: a basic system of soil classification for making and interpreting soil surveys’. 2nd. Edition. (USDA Soil Conservation Service. Agricultural Handbook nº 436. US Government Print Office: Washington)

Stoops G (2003) ‘Guidelines for analysis and description of soil and regolith thin sections’. (Soil Sci. Soc. Am.: Madison)

Ubalde JM, Sort X, Poch RM (2009) Application of a very detailed soil survey method in viticultural zoning in Catalonia, Spain. *J. Int. Sci.Vigne Vin* **43:2**, 55-66.

Van Leeuwen C, Chery P (2001) Quelle méthode pour caractériser et étudier le terroir viticole : analyse de sol, cartographie pédologique ou étude écophysiologique ? *Un raisin de qualité : de la vigne à la cuve, nº Hors Série du J. Int. Sci. Vigne Vin*, 13-20.

Vaudour E (2003) ‘Les terroirs viticoles. Définitions, caractérisation, protection’. (Ed. Dunod: Paris)

New A Horizon Protocols for Topsoil Characterization in Canada

Catherine A. Fox[A], Charles Tarnocai[B], and Gabriele Broll[C]

[A]Agriculture and Agri-Food Canada, GPCRC, Harrow, Ontario, Canada, Email catherine.fox@agr.gc.ca
[B]Agriculture and Agri-Food Canada, ECORC, Ottawa, Ontario, Canada, Email charles.tarnocai@agr.gc.ca
[C]University of Vechta, Vechta, Germany, Email gbroll@ispa.uni-vechta.de

Abstract
A new framework for addressing topsoil characterization was developed to provide enhanced capability in A horizon lowercase suffixes for tracking changes and impacts from environmental and anthropogenic stressors especially at landscape and watershed scales. Critical to sustaining agricultural crop and forestry production, the A horizon is the first mineral horizon to respond to these stressors leading to topsoil changes in physical, chemical and biological processes and soil properties. A new system comprised of four levels of lowercase suffixes was developed as an outcome of workshops held in Canada and Germany, review by soil classification and mapping experts and field testing. The first level of new lowercase suffixes identifies genetic processes and impacts from anthropogenic/industrial activities; the second level records the kind of primary soil structure; the third level, range classes of per cent organic matter; and, the fourth level, range classes for pH (0.01 M $CaCl_2$). Examples of the new A horizon lowercase suffixes are shown for selected Canadian soils. The new framework will provide enhanced taxonomic protocols for topsoil characterization of A horizons when undertaking detailed monitoring and assessment studies in determining the effectiveness of remedial measures and beneficial management practices.

Key Words
Horizon suffixes, soil profile descriptions, soil taxonomy, soil change, soil functioning, climate change

Introduction
The A horizon is the dominant portion of the topsoil (upper 30 cm) and the most critical for crop and forestry production. It is essential that its chemical (i.e. nutrients), physical (i.e. morphology), and biological (i.e. soil biota) functioning is ensured for long-term sustainability of food and livestock production and for maintaining forested areas for economic and recreational needs. The A horizon is the first mineral horizon of the topsoil to be impacted by 1) changes in the kinds, duration and intensity of cropping and tillage management systems, forestry, or anthropogenic/industrial activities and 2) changes in climate that can lead to a range of impacts on soil physical, chemical and biological properties and soil functioning.

In many classification systems, in agricultural soils, the A horizon is frequently described as an Ap horizon and, in undisturbed areas, as an Ah. From a taxonomic perspective, major changes in physical, chemical or biological soil properties are not easily included as part of the A horizon designation. Currently, there is no mechanism to capture the essence of such changes in the A horizon designation; the Ap or Ah horizon would still be described taxonomically as either an Ap or Ah. This restricts detailed field characterization especially at watershed scale where remedial soil measures or beneficial management practices have been introduced and one is required to identify major changes in soil properties across the landscape.

We have hypothesized that enhanced horizon designations for soil properties will provide improved capability for tracking changes from environmental and anthropogenic/industrial stressors. This paper will present a new framework for addressing A horizon lowercase suffixes for topsoil characterization.

Methods
Workshops were held both in Canada and Germany during 2008-2010 to define enhanced A horizon lowercase suffixes with respect to identifying critical physical, chemical, biological and anthropogenic processes and attributes. Based on field expertise, reviews of soil horizon descriptions, pedon information and literature sources, new lowercase suffixes for the following A horizon properties were identified: 1. genetic properties 2. soil structure, 3. organic matter and 4. pH. In addition, a framework for lowercase suffixes has been developed, reviewed by experts in soil classification and mapping, and field tested to refine the new system. This new system for A horizon lowercase suffixes is based on information obtained from both field observations and laboratory analyses.

Results

The new system for enhanced A horizon lowercase suffixes based on a framework of levels is shown in Table 1.

Table 1. Enhanced taxonomic protocols for A horizon description of properties.

First Level	Second Level	Third Level	Fourth Level
Genetic Process: Physical, chemical, biological, or anthropogenic	[Soil Structure]	(% Organic Matter)	{pH in 0.01 *M* $CaCl_2$}
Select lowercase suffix(es) as needed to describe the important soil process(es) observed: Choose from: b; ca; d; e; g; h; i; k; n; o; p; q; r; s; sa; u; w; y; z [A] See lowercase suffix definition below.	[pl]: platy [pr]: prismatic [cpr]: columnar [bk]: blocky [abk]: angular blocky [sbk]: subangular blocky [gr]: granular [cr]: crumb [sg]: single grain [m]: massive	(xl) Extremely Low (< 2%) (lw) Low (2 to < 5 %) (m) Medium (5 to < 9 %) (h) High (9 to < 17 %) (vh) Very High (> 17 to < 29%)	{xa} Extremely Acid pH < 4.5 {sa} Strongly Acid pH > 4.6 ≤ 5.5 {wa} Weakly Acid pH > 5.6 ≤ 6.5 {n} Neutral pH > 6.6 ≤ 7.3 {c} Calcic pH > 7.4 ≤ 8.4 {k} Alkaline pH > 8.5
Example syntax: Ah Ap	Example syntax: Ah[cr] Ap[bk]	Example syntax: Ah[cr](h) Ap[bk](xl)	Example syntax: Ah[cr](h){xa} Ap[bk](xl){wa}

[A] Definition of lowercase suffix

b: Buried soil horizon; ca: Secondary carbonate enrichment; d: Enriched with displaced B or C materials; e: Eluviation of clay, Fe, Al or organic matter; g: Gleying with grey colours and/or prominent mottles; h: Enriched in organic matter (> 2% to < 29 %; % OM = 1.728 x % Organic C); i: Anthropogenic transport of materials from habitation/industrial activities; k: Presence of carbonate; n: Prismatic or columnar structure with Ca:Na ≤ 10; o: Formed through mass movement of soil on slopes; p: Affected by agricultural activities; q: Prominent fungal hyphae and mats throughout; r: Affected by forestry activities such as logging; s: Presence of salts, gypsum; sa: Secondary enrichment of soluble salts; u: Affected by soil fauna activity throughout; w: Disturbed by natural blow down of trees; y: Affected by cryoturbation related to permafrost; z: Frozen layer.

Framework protocols for assigning A horizon lowercase suffixes (Refer to Table 1):

1. **First level**: The first level identifies the dominating processes observed related to genetic soil development (i.e. physical, chemical and biological processes) and anthropogenic activities. Following the horizon designation, choose the lowercase suffix that characterizes the most dominant process (i.e. Ah, Ap, Ae). Choose additional suffixes according to the next most prominent process(es). For example, Aphu identifies an A horizon under agricultural cultivation enriched by organic matter with prominent evidence of faunal activity.

2. **Second level**: Soil structure was selected for the second level as structure was deemed an essential indicator relating to information about pore and aggregate formation and the soil's potential for surface water and air infiltration. The kind (or type) of primary soil structure is recorded within square brackets following the first level lowercase suffixes; i.e. Aphu[gr] identifying granular primary structure. The lowercase suffixes for structure were limited to primary structure. Primary structure observations tend to be more stable with time and to be more representative of major morphology patterns influencing overall pores and aggregates. In addition, primary structure information is recorded in soil databases for most soils. The detailed profile description and soil database are always available, if needed, for additional information pertaining to size and grade of soil structure and any secondary structures.

3. **Third level**: Organic matter status is entered at the third level to provide information that relates to the soil's potential for nutrients, carbon sequestration and promotion of soil biota populations and biological activity. The per cent organic matter is recorded as a range class using round brackets and is placed following the structure lowercase designation: i.e. Aphu[gr](m) identifying a medium organic matter status within range of 5 to 9%. Note: the conversion factor is as follows if organic carbon data is available: % OM = 1.728(% OC).

4. **Fourth level**: Soil reaction class: pH is recorded as the fourth level lowercase suffix providing information relating to the soil's chemical influence on nutrient availability and mineralization as well as identifying the limitations on soil habitat for supporting specific soil fauna and micro-organisms. Following the third level lowercase suffix designation, pH is recorded as a range class within curly brackets (or braces): i.e. Aphu[gr](m){n} identifying a neutral pH range.

Table 2 shows some examples of applying the new framework for A horizon lowercase suffixes

Table 2. Application of new A horizon lowercase suffixes to selected Canadian soils.

Examples: Selected Canadian Soils (WRB-FAO classification in brackets)	[A] CSSC-98 Designation and Depth (cm)		New Enhanced A Horizon Designation
1. Rego Dark Brown Chernozem (Calcic Kastanozem) Lethbridge, Alberta; lacustrine sediments; loam; dryland agriculture with irrigated cropland. (Peters et al. 1978)	Apk	0-20	Apkh[sbk](lw){c}
2. Orthic Black Chernozem (Haplic Chernozem); Porcupine, Alberta; glacial till; clay loam; native pasture. (Peters et al. 1978)	Ah	0-14	Ah[pr](h){n}
3. Orthic Turbic Cryosol (Gelic Cambisol); Yukon; mixed loess and alluvium; cleared forest; agricultural field. (Tarnocai et al. 1993)	Ahy	0-5	Aphy[gr](h){n}
4. Gleyed Eluviated Dystric Brunisol (Gleyic Cambisol); Kentville, Nova Scotia; glacial till; sandy loam; agricultural forage crops. (Acton et al. 1978)	Ap1	0-11	Aph[pr](m){wa}
	Ap2	11-25	Aph[pr](lw){wa}
	Aeg	25-29	Aeg[sbk](xl){sa}

[A] Soil Classification Working Group (1998).

The new lowercase suffixes bring valuable additional information with respect to kind of soil structure, extent of organic matter, and pH status for better understanding of the A horizon. One now has enhanced information for the Rego Dark Brown Chernozem that the A horizon is enriched with low amount of organic matter; has as primary soil structure subangular blocky structure; and has a calcic pH status. Within the context of irrigated cropland, from the A horizon designation, one can interpret that monitoring may be required for crop growth conditions with increased pH and low organic matter and the potential for irrigated water loss through structural cracks. The Orthic Black Chernozem under native grasslands has prismatic primary structure, high organic matter and neutral pH status common for chernozemic A horizon. The Orthic Turbic Cryosol is an example from a forested location cleared for cropland; the new enhanced A horizon designation identifies the agricultural activity and forest history with high organic matter status. The Gleyed Eluviated Dystric Brunisol has three A horizons. The enhanced lowercase suffixes for the Ap1 and Ap2 horizons indicate enrichment in organic matter from the parent material and are both similar with respect to primary soil structure, and pH status. However, the organic matter range class differs for the Ap1, with medium class, and for the Ap2, a low organic matter class; hence, the numerical suffixes (1 and 2) in the new A horizon designation were not included.

Conclusion

International and national soil classification systems have hardly considered improved characterization protocols for topsoils. The FAO Draft (1998) for enhanced surface horizon descriptions is available for international verification and assessment for suitability for inclusion into national systems such as the review by Broll et al (2006) from the German context. The FAO Draft (1998) presents terminology and coding to provide enhanced soil names for topsoil characterization. The new framework with four levels of lowercase suffixes will now further the capability for enhancing topsoil characterization by including critical information about the A horizon with respect to soil development and attributes related to primary soil structure, organic matter and pH.

In applying the framework of enhanced A horizon lowercase suffixes, detailed field and chemical databases can be accessed to establish baseline properties for A horizons with relation to the different classifications levels from soil order to soil types. The lowercase suffixes within the new A horizon designation framework will be key for providing enhanced information for making field and mapping interpretations related to the extent of water infiltration properties and availability of nutrients, potential for organic carbon sequestration and soil conditions for promoting soil biodiversity. The new framework will provide enhanced taxonomic protocols for undertaking detailed monitoring and assessment studies of topsoils at landscape and watershed scales to track changes and record impacts from environmental and anthropogenic stressors.

Acknowledgments
Great appreciation is extended to colleagues at the Topsoil Characterization Workshops held at AAFC-GPCRC, Ontario and University of Vechta, Germany, especially R. Heck, M. Bosold, H-J. Brauckmann, G. Milbert, M. Joschko, U. Graefe, and H-C. Fründ. Funding was received from AAFC-Research Branch, peer-review project.

References

Acton CJ, Beke GJ, Day JH, MacDougall JI, Marcoux R (1978). 'Guidebook for a soil and land use tour of Eastern Canada, Tour 1 and 10.' 11th Congress International Society of Soil Science, Edmonton, Canada (Eds. DF Acton, LS Crosson) (Saskatchewan Institute of Pedology: Saskatoon) 188 pp.

Broll G, Brauckmann H-J, Overesch M, Junge B, Erber C, Milbert G, Baize D, Nachtergaele F (2006). Topsoil characterization – recommendations for revision and expansion of the FAO-Draft (1998) with emphasis on humus forms and biological features. *Journal of Plant Nutrition and Soil Science* **169,** 453-461.

Food and Agriculture Organization of the United Nations (1998) 'Topsoil characterization for sustainable land management.' (Land and Water Development Division, Soil Resources, Management and Conservation Service: Rome) www.fao.org/AG/aGL/agll/wrb/topsoil.stm.

Peters TW, Shields JA, Ellis JG (1978) 'A tour to observe soil landscapes and cropping systems in Central and Southern Alberta and Southwestern Saskatchewan, Tours 5 and 13.' 11th Congress International Society of Soil Science, Edmonton, Canada (Eds. DF Acton, LS Crosson) (Saskatchewan Institute of Pedology: Saskatoon, SRI No. 652) 171 pp.

Soil Classification Working Group (1998) 'The Canadian system of soil classification.' (Agriculture and Agri-Food Canada: Publ. 1646, Revised) (NRC Research Press: Ottawa), 187 pp.

Tarnocai C, Smith CAS, Fox CA (1993) 'International tour of permafrost affected soils: The Yukon and Northwest Territories of Canada.' (Agriculture Canada, Research Branch: Ottawa, Canada), 197 pp.

Physical, chemical, and morphological characteristics of forest soils in the Keroudkenar Region of Northern Iran

Ahmadi Tofigh[A] and Saravi Vida[B]

[A]Faculty of Agriculture, Islamic Azad University of Iran (Chalus Branch), Email t1350a@gmail.com
[B]Islamic Aazd University of Iran (Babol Branch), Email s1351v@yahoo.com

Abstract
This Study was carried out of in four stages:(1) collecting of information and records,(2) field Sampling,(3) soil tests, and(4) analysis of results and conclusions. During stage 1, data and information related to climatology, pedology, topography and silviculture were collected. And entered into a Geographic Information System (Arc View GIS Software). Considering the slope aspect, and elevation a map of land-forms was created. Then for each land forms, Plots 2500 meters in size were identified. In the field, Soil pits were dug in the center of each plot and at its four corners, and micro plots were established for identifications and collection of the plants species present. The soil profiles corresponding to each landform were analyzed and their characteristics and vital activities (organisms and plant roots) were examined. Each soil horizon was sampled for physical and chemical tests. The samples of soil and plants were sent to the laboratory for analysis and identification. Physical analysis of the soil included the measuring of soil color, structure, consistency, and the presence or absence of clay films. Chemical analysis of the soils included, potassium, phosphorus, calcium, magnesium, organic maters contents, and electrical conductivity. The results show that the soils of this region are largely acidic neutral their textures vary from clay to sandy clay loam and the surface soil horizons contains large aggregates with strong consistency. The dry color of the soil is largely brown. The nutrients elements occur in satisfactory quantities. The results of this study showed that the plants of this region are growing on nine types of soils as follows: Typic Paleudalfs, Lithic Vermudolls, Inceptic Hapludalfs, Typic Dystrudepts, Typic Hapludalfs, Humic Dystrudepts, Typic Udorthents, Inceptic Haplorendolls, Lithic Udorthents.

Key Words
North of Iran, soil chemistry, Soil physical properties, soil type, Keroudkenar forest

Introduction

Forests are considered as one of the largest and most splendid vegetation on earth .Accumulation of trees, shrubs, and other plants and small and large animals in certain habitats are not by chance at all. Our Caspian forests, which are consider deciduous hard- wood forests, covered the northern edge of the Alborz mountains in a narrow strip from Astra in Guilan Province up to Golidage in the east of Golestan Province from seacoast up to > 2500 meters above sea level. They contain more than 80 tree and shrub species.

Material and methods

This study was carried out in Keroudkenar - catchments in the southeast region of Nowshar city and starts [from sea level and finally ends up at Koleak pastures][s11] .The total area of the catchments is 1090.8 hectares. The purpose of this research was to determine some of the physical and chemical characteristics of the soil in this forest, the qualities of the trees based on the changes in soil types, and classification of the soil down to the subgroups level of Soil Taxonomy. These tasks were carried out in four phases as follows: 1- information and background collection, 2- field sampling, 3- soil testing and 4- statistics analysis.

Results

The masses of trees in the forests of Keroudkenar watershed are classified in categories of soils as follows : Entisols,Inceptisols,Mollisols and Alfisols and nine subgroups : Lithic Vermudolls, Inceptic Hapludolls,Typic Dystrudepts, Typic Hapludalfs,Lithic Udorthents,Inceptic Haplorendolls, Typic Paleudalfs,Humic Dystrudepts,andTypic Udorthents. The pH of these landforms vary from moderately to weakly acid .The texture of the most of the soils under investigation is clay to clay loam. And the structure of the soil surface horizons contains mainly aggregates with strong consistency. The color of the soil in dry state of horizons of excavated profiles is largely brown .In terms of other nutrients elements; they are in rather satisfactory condition.

Table 1. Results of physical and chemical analysis of soils surface horizons from eighteen profiles from the Keroudkenar region (of Northern Iran).

Horizon	Depth	Sand	Silt	Clay	Texture	OC	OM	C/N	T.N	P	K	Ca	Mg	EC	Color	No	pH
		%				%				ppm		meq/l		ds/m			
A	0-23	15	35	50	C	3.6	6.2	15.6	0.23	12	210	3.6	1.8	0.033	10YR3/3	1	7.2
A	0-20	13	37	50	C	3.3	5.6	38.8	0.085	8	130	1.2	1.2	0.023	7.5YR5/4	2	6.5
A	0-20	27	32	41.2	C	2.93	5.04	8.18	0.358	8.2	190	2.4	0.5	0.015	10YR4/3	3	5.9
A	0-22	32	35	33	C.L	2	3.45	6.8	0.291	9	200	1.2	0.6	0.017	10YR4/3	4	5.7
A	0-21	43.2	30.3	26.5	L	2.4	4.13	18.7	0.128	13.5	230	1.01	0.6	0.018	10YR3/3	5	5.5
A	0-23	39	27	34	C.L	2.02	3.48	8.3	0.241	12	302	1.8	0.7	0.09	10YR4/3	6	5.7
A	0-10	36.56	28.64	34.8	C.L	3.75	6.45	4.8	0.78	16	239	6.8	1.6	0.071	10YR4/4	7	6.5
A	0-17	36.56	36.64	26.8	C.L	3.84	6.6	4.3	0.89	14	220	5	1.88	0.237	10YR4/3	8	6.5
A	0-22	26.4	43.24	30.36	C.L	3.72	6.39	6	0.62	15	240	2	1	0.08	10YR3/2	9	5.9

Table 2. The results of physical and chemical analysis of representative soils from 18 profiles in the study area located in the Namkaneh region (of Northern Iran).

horizon	Depth	pH	Sand	Silt	Clay	texture	OC	OM	C/N	T.N	P	K	Ca	Mg	Ec	Soil color	NO
			%				%				ppm		meq/l		ds/m		
A	0-25	6/8	27/12	32/72	40/16	C	3/45	5/93	6/3	./55	13/5	308	5/76	2/44	0.059	10YR3/2	10
A	0-24	6/8	35/2	28	36/8	C.L	3/61	6/22	4	0.92	14	230	4/6	0.4	0.031	10YR3/2	11
A	0-20	6	37	33	30	C.L	3/61	6/21	5/7	0.63	15	320	1/8	0.6	0.071	7.5YR3/2	12
A	0-20	7	30/2	23/64	46/16	C	3/78	6/5	7/25	0.521	8	169	4/8	0.2	0.056	5YR3/2	13
A	0-20	6/8	30/56	17/64	51/8	C	3/45	5/9	5/5	0.623	9	127	6	1/36	0.027	10YR4/3	14
A	0-20	7/1	30	27/64	42/16	C.L	3/585	6/16	8/5	0.42	6	135	5/8	1	0.036	10YR3/2	15
A	0-25	7/2	46/24	26/36	27/4	L	3/87	6/67	10	0.38	6	142	6	2	0.1	10YR4/2	16
A	0-10	7/7	21/12	28/28	50/6	C	3/75	6/45	17/8	0.21	18	200	4/8	0.4	0.074	7.5YR3/2	17
A	0-30	6/5	32/4	43/6	24	C.L	3/6	6/2	11/2	0.32	19	160	6/4	2	0.152	7.5YR4/1	18

References

Ahnert F (1970) A comparison of theoretical slope models with slopes in the field, Z. *Geomorphology Supply* [s12] **99**, 88-101.

Augusto L, Ranger J, Binkley D, Rothe A (2002) Impact of several common tree species of European temperate forests on soil fertility. *Ann. For. Sci.* **59**, 223-253.

Binkley D, Sollins P, Bell D, Sachs D, Myrold D (1992) Biogeochemistry of adjacent conifer and conifer hard wood stands. *Ecology* **73**, 2022-2033.

Boerner REH and Koslowsky SD (1989) Micro site variation in soil chemistry and nitrogen mineralization in a beech-maple forest soil. *Biology and Biochemistry* **21**,795-80.

Bonito GM, Coleman DC, Hairnes BL, Cabera ML (2003) Can nitrogen budgets explain differences in soil nitrogen mineralization rates of forest stands along an elevation gradient, forest. *Ecology & Management* **179**, 563-574.

Dijkstra FA (2001) Effects of tree species on soil properties in a forest of the Northeastern United States, Wageningen University, and 119pp.

Ficher RF,Binkley D (2002) Ecology and management of forest soils (Third edition) John Wiley & Sons, Inc., 489pp.

Harrison AF, Howard PJA, Howard DM, Howard, DC, Hornung MG (1995) Carbon[strong][s13] in forests soils. Forestry, 68, 335-348.

Keys to Soil Taxonomy, 2003. USDA-NRCS, Washington, D.C.

Smith GD (1975) Soil moisture regimes and their use in soil taxonomic. Field soil water region, S.S.S.A.Special Publication No.5., Madison, Wisconsin, USA.

Problematic WRB classification of the so called "erubáz" soil, a volcanic soil type of Central Europe, Hungary

Balázs Madarász[A]

[A]Department of Physical Geography, Geographycal Research Institute, Hungarian Academy of Sciences, Budapest, Hungary, Email madaraszb@mtafki.hu

Abstract
Today, the trend of re-evaluation of national and international soil classification systems carries new requirements on the recognition of soil genetic processes and their evaluation. The harmonization of the WRB and the national soil classification systems is frequently problematic, especially in the case of the small local soil groups of the national systems. The erubáz soil is a shallow soil influenced by the volcanic parent material in the Hungarian soil classification system. In the WRB the Andosols reference group assemblages the shallow volcanic soils with special physical, chemical and mineralogical properties. This study reveals the relationship between the erubáz soils and the Andosols, and makes an attempt on the WRB classification of the erubáz soils.

Key Words
Soil classification, WRB, Andosol, erubáz, Central Europe

Introduction
Development of the soil science in Hungary started in the end of the 18th century. In the 1950's a new – and still used – genetic soil classification system was created by Pál Stefanovits (Stefanovits and Szűcs 1961). During the formation of this system he considered and evaluated the former soil classifications and included the novel results of soil science and information on the soils of the neighbouring countries. Biological, chemical and physical properties of the soils have been reviewed as these are the basis of the soil formation processes.
The so called "erubáz" soil is a shallow soil influenced by the parent material in the Hungarian soil classification system, developed on volcanic lithology. In spite of the detailed and thorough investigations of the former decade this soil is one of the less studied and most neglected soil types of the Hungarian soil science (Barczi 2000; Fehér *et al*. 2006; Fehér 2007; Madarász 2009), because it occurs in small patches dispersed in the hilly regions of Hungary, mostly on areas unsuitables for agriculture.

The denomination erubáz and the first description of the soil were created by von Hoyningen (1930), in connection with the soil classification of soils in North- and Middle-Germany. It is the amalgamation of the expressions "eruptive" and "basic", which reflects well that this soil type occurs mainly on basic volcanic rocks, however it has been described on more acidic rocks as well. Later the name was adopted by Kubiëna (1953) in his work entitled "Guide and system of European soils". This book was used by Stefanovits during the genetic soil classification in Hungary.

Volcanism had a special role in the Miocene-Pliocene evolution of the Carpathian basin. Volcanic rocks occur in a more or less continuous arch following the inner side of the Carpathian mountain chain, but they occur practically in the entire area of the basin system. Today, the formerly extensive volcanic fields are restricted to smaller areas (Karátson 1999). Accordingly, erubáz soils occur in small spots in a mosaic-like pattern on a large variety of volcanic rocks dispersed throughout the country. On the basis of the volcanic rock types 15 profiles were designated for a thorough study.

The World Reference Base for Soil Resources (WRB 2006) is a soil correlation system is a correlation-based soil classification system, where the volcanic soils form the so called Andosols reference group, with characteristic physical, chemical and mineralogical properties. The Andosols are intrazonal soils, which typically develop on pyroclastic parent materials rich in volcanic glass, mostly on tuff (Neall 1985). Presently, the tendency of reconsideration of national and international soil classification systems brings about new requirements on the recognition of soil-genetic processes and their evaluation. The increasingly popular WRB provides a good basis for the scientists working in different parts of the World to find a common language. This study aims at the WRB classification of the Hungarian erubáz soils and at finding out whether the erubáz soil type and the Andosols reference group corresponds to each other.

© 2010 19th World Congress of Soil Science, Soil Solutions for a Changing World

Methods

For the description of the studied soil profiles the FAO (1990) standard was used. Denomination of the genetic soil horizons occurred using the works of Szodfridt (1993) and Stefanovits *et al.* (1999). Laboratory analysis of the samples was carried out in the Geographical Research Institute of the Hungarian Academy of Sciences using the valid standards. Pedogenic Fe_d- and Al_d-components (Mehra and Jackson 1960) were extracted using natrium-dithionite solution. Components (Al_o, Fe_o, Si_o) of amorphous and weakly crystallized oxides (e.g. ferrihydrite) were dissolved using ammonium-oxalate (Schwertmann 1964). Al_p- and Fe_p-content attached to the organic phase of the soil was assessed by a solution created by pyrophosphate-selective extraction. The Fe-, Al- and Si-contents were determined using atom-adsorption spectrophotometer (AAS). Mineralogical and soil-mineralogical analysis of the samples occurred by a PHILIPS PW 1710 instrument with x-ray diffraction method in the Geochemical Research Institute of the Hungarian Academy of Sciences. WRB classification of the profiles was done using the WRB (2006) guidebook.

Results

According to my studies (Madarász 2009) general properties of the erubáz soils are as follows:
This soil develops normally on basic or neutral rocks, but it occurs on acidic lithology as well. Accordingly it was described on basalt, andesite and their tuffs and on rhiolite tuff as well, typically on the top surfaces and ridges, where extreme microclimatic conditions are controlling soil formation. Their average depth is 40 cm. Their structure is granular, crumby, rarely dusty, humus formation is strong and their pH is slightly acid. Texture of the erubáz soils is mostly loam, seldom sandy or clayey loam, their colour is dark, blackish and are rich in organic material (up to 8-10%). The high organic material content is due to the extreme microclimatic conditions, which leads to humus accumulation. The organic material and the clay minerals form a strongly bonded humic horizon. In accordance with the parent material and as a consequence of the sporadic but sometimes significant loess addition, the dominant clay mineral is the illite, but occasionally the presence of smectites is also considerable. The most important exchangeable cation is the calcium, the base saturation is low. Their flora has developed in accordance to the intensity and type of anthropogenic intervention. At deforested location closed meadows, while at other places, in function of the altitude, nicely developed oak and beech forests are found.

After a detailed analysis of the erubáz soils my second purpose was to find out whether this volcanic soil is corresponding to the Andosols group of the WRB. However the Andosols have developed on fresh volcanic ash, they were found on older volcanic material (Bäumler R 2004; Garcia-Rodeja *et. al.* 2004; Quantin 2004), and they were described at several locations in the Miocene volcanic rocks of the neighbouring countries, as well (Perepelita *et al.* 1986; Jurani 2002; Jakab *et al.* 2004, Füleky *et al.* 2006; Fehér 2007). However the erubáz soils and the Andosols have several similar features (structure, humus content, colour, mineral composition, etc.), their relationship could not be verified during the diagnostic classification.
Most important criteria of the Andosols is the presence of the andic or the vitric horizons. According to the laboratory analysis, the Hungarian erubáz soils do not fulfil the requirements of the andic horizon. Their $Al_o+1/2Fe_o$ content remains well under 2%, which is one of the most important threshold values for an andic horizon. Values of phosphate-retention (max. 38%) remain also remain well under the needed percentage (70% <). The 0.9 g/cm^3 bulk density value is reached only by some samples. All these facts exclude the presence of the andic horizon in any of the profiles.

The vitric horizon can be regarded as a weakly developed andic horizon, which may grow into an andic horizon with time. Generally it forms as a consequence of weak weathering. Most of my samples correspond to the criteris of this diagnostic horizon (allophane content, bulk density, etc.), but they are unable to fulfil the most important feature, the 5% ≤ volcanic glass content. As there is no volcanic glass in the mineral assemblage of the Hungarian erubáz soils, no vitric horizon can be described in them. Consequently, it can be stated on the basis of my laboratory analysis, field observations and morphology that i*t is impossible to insert the Hungarian erubáz soils in the Andosol reference group of the WRB*. Nonetheless, their integration in any other WRB reference group is also problematic.

Following the criteria-system of the WRB diagnostic horizons (the first level of classification) only the mollic horizon could be determined for most of the erubáz profiles. For two profiles, where the parent material is more porous a relatively deeper soil has developed, therefore besides the mollic horizon, argic and cambic horizons were identified as well.

The second level of classification is the determination or the reference group on the basis of the diagnostic horizons. Some soils with a depth shallower than 25 cm and have no diagnostic horizon but the mollic, were classed as Leptosols. Where an argic or a cambic horizon was also present were included in the Luvisol and in the Cambisol groups. Most of the profiles, however, belong to the Phaeozem group because of their single mollic horizon and base saturation above 50%.

The above described features suggest that it is not possible to insert the erubáz soils into a single WRB soil group. Most of the typical erubáz soils belong to the Phaeozems, which comprise the mineral-soils of steppe areas. Formation of these soils is controlled by the climate and by the vegetation, therefore they do not reflect the effect of the volcanic parent material, in other words this group is not representative of the erubáz soils. Formation of the Leptosols depends primarily on the morphology, as these are soils of high altitude areas with sloping surface. As a consequence of the slope, the soil particles are removed from their place of formation. Accordingly skeletal parts in these soils may exceed 80%. These characteristics are not suitable for the typical erubáz soil, they are suitable for only a few and special erubáz profiles where the depth is small and thus the soil almost falls into the skeletal soil (Lithosol) category.

At the other boundary of the erubáz soil group are situated the profiles where besides the mollic horizon another diagnostic horizon (argic, cambic) is also present. These soils, in accordance with their diagnostic properties developed due to local conditions, can be included in different reference groups, like the Luvisols and the Cambisols. However, neither of these can reflect the characteristic features of the erubáz soils. The Luvisols are mineral soils of wet, forested areas, and their formation is controlled mainly by the climate and the vegetation. Their most important feature is the texture-differentiation. Their equivalents in the Hungarian soil classification system are the brown forest soils with clay illuviation. The Cambisols are characterized primarily by their young age, they show the first signs of development of horizons. In the Hungarian system the brown earth soil group can be included in this cluster.

On the other hand, it is undoubted that some peculiar features of the erubáz soils point towards the chernozem soils: both have black colour, high humus content and deep humic horizon and frequently granular structure. Nevertheless there is no doubt, that erubáz soils do not belong to the chernozem group.

Conclusion

Criteria-system of the WRB emphasizes the steppe-like features of the erubáz soils, while the effect of the volcanic lithology is faded out. Consequently, WRB classification of individual erubáz profiles is possible, but the characteristic features of the erubáz soil group are not corresponding to any of the WRB reference groups. The erubáz soils, because of the diagnostic threshold values, could not be inserted in the Andosol groups, where shallow soils influenced by volcanic parent material are assembled. Majority of the profiles fulfilled the criteria of the Phaeozem group, however inclusion of the erubáz soils in this group of steppe-like mineral soils is not adequate.

Accordingly, complete substitution of the national, genetic soil classification systems by a modern, global soil classification system is not reasonable, as during categorization, important characteristics of special soils of local importance – like the erubáz soils of Hungary – may be ignored by the global sytem.

References

Barczi A (2000) Soils of the Tihany-peninsula (in Hungarian). 125 p (Bakonyi Természettudományi Múzeum, Zirc).

Bäumler R (2004) Soil development processess in non-volcainic Andosols. *Rala Report* **214.** 72–73.

Buzás I (1988) Soil- and agrochemistry analysis methodologies 2 (in Hungarian). pp. 37–41 (Budapest, Mezőgazdasági Kiadó).

Buzás I (1993) Soil- and agrochemistry analysis methodologies 1 (in Hungarian). pp. 37–41 (Budapest, INDA 4231 Kiadó).

FAO (1990) Guidelines for soil description. FAO–ISRIC 3rd (revised) edition. 70 p.

Fehér O, Füleky Gy, Madarász B, Kertész Á (2006) Morphologic and diagnostic features of seven soil profiles developed on volcanic rock according to the national soil classification and the WRB (World Reference Base for Soil Resources, 1998) (in Hungarian). *Agrokémia és Talajtan* **55**, 347–366.

Fehér O (2007). Examination of natural and human impacts on soil conditions in some typical regions of the Carpathian basin (in Hungarian). PhD thesis, 134 p (Szent István University, Gödöllő).

Füleky Gy, Jakab S, Fehér O, Madarász B, Kertész Á (2006) Soils of volcanic regions of Hungary and the Carpathian Basin. In 'Soils of Volcanic Regions in Europe' (Eds A Arnalds, F Bartoli, P Buurman, H Óskarsson, G Stoops, E Garcío-Rodeja). pp. 29-42 (Springer, Berlin).

García–Rodeja E, Taboada T, Martínez–Cortizas A, Silva B, García C (2004) Soils with andic properties developed from non-volcanic materials. Genesis and implications in soil classification. *Rala Report* **214**. 74–75.

Hoyningen HPF (1931) Die Bodentypen Nord- und Mitteldeutschlands. *Jahrbuch der Preußischen Geologischen Landesaustalt* **51.** 524–564.

Jakab S, Füleky Gy, Fehér O (2004) Environmental conditions of Andosols formation in Transylvania (Romania). Soils of the Gurghiu volcanic chain. *Rala Report* **214**. 65–66.

Jurani B (2002) Volcanic soils of Slovakia. In 'COST 622 Meeting: Soil Resources of European Volcanic Systems in Manderscheid/Vulkaneifel 24.–28. April 2002'. pp. 21–22 (Mainz, Rheinische Naturforschende Gesellschaft).

Karátson D (1999) Erosion of primary volcanic depresions int he Inner Carpathian Volcanic Chain. *Zeitschrift für Geomorphologie* **144.** 49–62.

Kubiëna WL (1953) Bestimmungsbuch und Systematik der Böden Europas. 392 p (Madrid).

Madarász B (2009) Complex soil study of the Hungarian erubáz soils, with special emphasizs on their clay-mineralogical composition (in Hungarian with English summary). PhD thesis,. 134 p (Loránd Eötvös University).

Mehra OP, Jackson ML (1960) Iron oxide removal from soils and clays by dithionite-citrate systems buffered with sodium bicarbonate. *Clays and Clay Minerals* **7.** 317–327.

Neall VE (1985) Parent materials of Andisols. Proc. Sixth Int. Soil Classif. Workshop, Chile and Ecaudor. Part 1. 9–19.

Perepelita V, Florea N, Vlad L, Grigorescu A (1986). Asupracriteriilor de diagnostic ale andosolurilor si solurilor andice din Muntii Carpati. *Bucharest Anale I.C.P.A*., **47.** 125–139.

Quantin P. (2004) Volcanic soils of France. *Catena* **56.** 95–109.

Schwertmann U (1964) Differenzierung der Eisenoxide des Bodens durch Extraktion mit saurer Ammoniumoxalat–Lösung. Zeitschrift für Pfalnzenernährung, *Düngung und Bodenkunde* **105**. 194–202.

Stefanovits P, Filep Gy, Füleky Gy (1999) Soil science (in Hungarian). 470 p (Mezőgazda Kiadó, Budapest).

Stefanovits P, Szücs L (1961) Genetic soil map of Hungary and its explanation (in Hungarian). pp. 34–35 (OMMI 1961).

Szodfridt I (1993) Forest Site Survey (in Hungarian). pp. 176–179 (Mezőgazda Kiadó, Budapest).

World Reference Base for Soil Resources (2006) World Soil Resources Reports 103. 132 p (FAO Rome).

Soil classifications: their origin, the state-of-the-art and perspectives

Pavel Krasilnikov[A,E], Richard W. Arnold[C] and Juan-José Ibáñez[D]

[A]Institute of Biology, Karelian Research Center RAS, 185610, Petrozavodsk, Russia, Email kras@bio.krc.karelia.ru
[B]Lab. Edafología 'Nicolas Aguilera', Facultad de Ciencias, UNAM, 04510, D.F., México, Email pv@hp.fciencias.unam.mx
[C]Retired Scientist, Ex-Director of USDA Soil Survey, USDA-NRCS Washington, DC, USA, Email ct9311@aol.com
[D]CIDE-CSIC, Albal, Valencia, 46470, Spain, Email choloibanez@hotmail.com

Abstract
The classification of soils originated from three main sources: from early empirical soil surveys, from folk soil classifications and from scientific theory of pedology. The first soil classifications reflected their origin in different extent, and still remain certain features of their initial sources. The actual situation in soil classification is discouraging, mainly due to the diversity of national soil classifications, extreme complexity of developed soil taxonomies and, as a result, to the loss of public interest in soil classification. Recently suggested roadmap to the Universal Soil Classification seems to be the main challenge in the recent history of soil classification.

Key Words
History of pedology, soil diagnostics, classification structure.

The origin of soil classification
People were managing soils for ages. Of course, from the very beginning of the agrarian civilization they noted that the soils are different (Yaalon 2008). This knowledge then was then used by the governors for evaluating land value and, consequently, the taxes. The earliest known soil classification system in the world can be find in an ancient Chinese book *Yugong* (2,500 y.b.p.), where soils of China were classified into three categories and nine classes based on soil color, texture and hydrologic features; the classification was used for land evaluation (Gong Zitong 1994). Ancient name for Egypt – *Kemet* means fertile black alluvial soils, while *Deshret* means red desert land. About 3,000 y.b.p. different arable soils had different cost in Egypt: "*nemhuna*" soils cost 3 times more than "*sheta-teni*" soils (Krupenikov 1981). This tradition continued in newer times. For example, in Russia a systematic survey of folk soil knowledge was started in the 16th century, when special books were created to evaluate soil resources of the state; these books were prepared by interviewing the peasants about the quality and productivity of their lands. These books mainly included short characteristics of soils, like *poor sandy soil*, *clayey stony soils, fat loams* etc. Later, in 19th century, the survey became more regular, and perennial data were published in a series of books "Materials on Statistics of Russia", where a number of local folk soil names for soils were listed. The materials were also used for preparing first soil maps of Russia, which, in fact, were based on ethnopedological survey.

Somewhat different approach existed in Western Europe and the United States in 18th – 19th centuries. Agronomic science developed independently from folk knowledge; farmers' perception was very conservative, while progressive agronomy could answer the challenges of growing population with new technologies and the use of fertilizers. Thus, the "progressive" scientific knowledge was somewhat opposed to "conservative" traditional knowledge. The soil was studied both in the field and in laboratories, and it was classified by *ad hoc* empirical parameters, such as texture, visible or measured organic matter percentage, and nutrients content. This agrogeological approach was soon extended from surface samples to a sequence of layers during seminal early soil surveys in the United States (Simonson 1989). However, these works lacked a scientific basis, a theory that explained the origin and distribution of soils. The methods and even terminology were borrowed from relative scientific disciplines, such as sedimentary geology and agronomy. The classification was not systematized; it was just a nominal list for individual groups of soils. In the US, the folk classification was not aggregated in the "scientific" taxonomy also because of the absence of the sources of indigenous knowledge: the native population has been displaces and generally not very interested in soil agriculture, and newcomers did not develop yet a system of soil knowledge.

In Russia, the development of soil classification was somewhat different. In 1883 Russian geologist presented his doctoral thesis "Russian Chernozem" (Dokuchaev 1967) that proposed a scientific theory of soil formation. The approach was not completely new: earlier a number of workers already suggested the system of vertical soil horizons (Darwin to be noted as the most well-known scientists who used A/B/C/D sequence of soil horizons).

Also Dokuchaev's theory on soil dependence on climate and other environmental factors repeated some ideas of earlier researchers, such as Lomonosov, Thaer and Hilgard. However, only after Dokuchaev's works a holistic theory was created, explaining the genesis and geographical distribution of soils. Thus, the first classification of Russian soils was based on the overall theory of soil genesis and soil geography. The influence of folk soil knowledge on Russian classification is often disregarded. The names of soil types were mainly borrowed from folk soil classifications: the words *chernozem*, *solod*, *solonetz*, *rhendzina* were used by Russian, Ukrainian and Polish peasants for ages. However, not only the words were accepted, but also the central concepts of soil units, the archetypes were included in the classification.

The existing scientific classifications developed from these three main sources: folk knowledge, empirical soil study and from scientific theory. Every soil classification has elements of indigenous concepts, empirically collected data and of scientifically-based grouping. It is expected that the combination of these three components should lead to harmony. Unfortunately, it just causes a kind of historical bias that complicates actual scientific classifications.

How we lost our way in broad daylight

Due to historical reasons, almost every school of pedology has its own classification. In fact, more than one natural soil classification can exist, i.e. there is no unique "true" classification to be discovered. The existence of numerous national soil classifications is a serious problem of perception of soil science by other specialists. To some extent it is related to the differences in soil cover in different countries that leads to distinguishing different archetypes as a basis for classification. Modern biology and geology originated in medieval time in Europe, and later was distributed all over the world in a "semi-mature" state. Soil science was distributed in a rudimentary state, and was often developed independently in different countries. Sokolov (1978) noted that the lack of a uniform classification resulted from the fact that soil science was relatively young and similar to an "infant disease" it would be overcome in the near future. Some researchers proposed the US Soil Taxonomy as a world classification; others hoped that the Soil Map of the World Legend by FAO-UNESCO (or, later, WRB) would replace national classifications. However, the period of the 90-th dashed these hopes. National schools did not try to integrate, but intensified activities to update and revise their classifications. In these years new versions of classifications were proposed in New Zealand (Hewitt, 1992), China (Gong Zitong 1994), Australia (Isbell 1996), Russia (Shishov *et al.* 1997), France (AFES 1998) and Brazil (EMBRAPA 1999). However, what resulted was the development of improved quantitative diagnostics to support the designation of units and their classification in hierarchical systems.

Apart of the variety of classifications there are a number of other problems that aroused with the progress of soil classifications, which are extreme complexity, costly and time-consuming diagnostics, and ambiguous, complex and confusing terminology. Each of the problems can be explained in its historical perspective. The complexity resulted from the need to compress soil data for mapping; every soil polygon had to represent as much information, as possible. In fact, developed soil classifications practically replaced soil names by brief soil descriptions. Every soil name was meaningful, and a complete soil name included practically all the soil characteristics important for pedologists. In parenthesis we should note that this information was often useless for practical users, because soil features important for agriculture, such as nutrients availability and hydrophysical characteristics, were usually variable and taxa-independent. The uncontrolled growth of information saturation of classifications resulted in their extreme complexity. Even the authors of soil classifications already cannot classify a soil without consulting their manuals. Is it what we wanted?

The extensive diagnostics needed for soil allocation in the taxonomic scheme is somewhat related to the complexity of classifications. Also it was logical continuation of a generally productive approach that declares that we should classify soils by the measurable attributes and not on the basis of our doubtful ideas on soil genesis. Initially the task seemed simple: we had to find soil properties that corresponded to certain central concepts of soils (archetypes). However, soon it was discovered that the properties that seemed to be the most evident for a certain group, are not unique and might be found in some other groups. It is useful to consider the concepts of divergence and convergence (Rozanov 1977). Divergence means that soils formed under similar conditions in different places commonly exhibit variable properties due to local factors. Convergence means that different pedogenic processes under different environmental conditions might lead to similar soil properties and morphology. For example, such processes as podzolization, clay eluviation and surface gleying generally lead to the formation of a bleached, clay depleted surface horizon. Thus, the presence of a bleached surface horizon cannot be used as an only diagnostic criterion for soil classification. Less evident, every time more and more sophisticated criteria were proposed to delimitate soil groups. Nowadays a user of soil classification applies long and complex definitions for allocating soils in taxonomic groups even without clear understanding of the origin and significance of these criteria.

The terminology used in soil classifications may be divided into two groups: traditional (indigenous and common folk terms) and artificial terms. The principle of including folk soil names (*podzol*, *chernozem*, *gley* etc.), as well as stylized terms (*krasnozem*, *burozem*) in scientific classifications was used by Dokuchaev and his followers. Dokuchaev did not collect these terms himself rather he used soil names from existing publications such as the “Statistic Materials of Russia” which contained numerous folk names for soils. He understood that folk names could not be converted directly into scientific terms (Krasilnikov 1999) but should be determined more strictly because in folk tradition different soils could be grouped under the same name, or the same soil was named differently in other localities. As a result, scientific terms, which have originated from folk terminology, often differ significantly in their meaning from the original concept. The other option for constructing scientific soil terminology was to apply completely new artificial names. It was first proposed by Guy Smith (Banfield 1984) while preparing the 7th Approximation, a new American soil classification system. Guy Smith considered that old traditional soil names were confusing, and with the help of philologists developed a completely new system of soil terminology; a wide group of philologists participated in the development of soil nomenclature that was mnemonic (Heller 1963). In addition, the levels in the taxonomy are recognizable by the number of syllables of the base words and the “ic” ending of modifiers. The idea was brilliant and could work very well if the system remained the only artificial nomenclature. Unfortunately soon a number of “clones” of the US classification terminology appeared, and now some of the artificial terms cause almost the same confusion as traditional ones. For example, the name Histosols is used both in the US Soil Taxonomy and in the classifications of Cuba, China and in World Reference Base; the problem is that the definitions and diagnostic criteria for this group vary in different classifications. Attempts to avoid confusion by modifying slightly the names, like in Australian classification (Isbell 1996) (*Vertosols* instead of *Vertisols*, *Podosols* instead of *Spodosols*) only increased the chaos. Some modified terms, once used in one national classification, were then introduced independently in the other classifications, also with different definitions. The same term *Vertosols* used in Australian soil classification was also used in Chinese and Romanian taxonomies. Actually there are more than 3,000 soil names only on the highest levels of world soil taxonomy, most of them absolutely inexplicable for non-specialists.

Out of the dead end

The crisis of soil classification resulted in serious doubts of the perspectives of soil classification at all. Currently soil classification has moved from the nucleus to the margin of the attention of soil science community as environmental issues of terrestrial ecosystems have gained prominence. In the last decades developments in digital mapping now facilitate combining various information layers, somewhat replacing traditional soil classification based maps. Even in soil genesis and soil geography studies researchers commonly speak in terms of pedogenetic processes and particular soil characteristics rather than the use of formal soil names. For many purposes mathematical ad-hoc classifications work better than more general basic classifications. Does it mean that we should leave soil classification behind?

To answer this question we should remember the functions of classification in natural sciences in general and in soil science in particular. These functions are: arrangement of our knowledge about the Universe, development of common language for the communication among the specialists, presentation of soil information in a compact form (e.g. for mapping) and simplification of education. The development of technology produced novel methods of visualization of soil information. The GIS-based soil maps include several layers with soil properties, important for the users, instead of extensive soil names, which need explanation. Definitely the use of digital soil maps is a big challenge in soil geography that reduces the importance of classification for practical soil mapping. However, the other functions of soil classification cannot be replaced by high technology. Soil classification is a mirror of our knowledge about the soil, and the structure of soil classification depends on our current system of concepts and ideas about soil genesis, geography and functioning. Then, the communication among the scientific community requires common language. We use names in our everyday activity, and we need them in science. To a great extent the existence of specific terminology determines the identity of science. Without soil classification all the pedology may be reduced to chemistry, physics and biology. Finally, the education on any level requires simple systems of presentation of information. If we teach the students on the basis of independence of soil properties, they would be easily confused and lost in the chaos of soils. Classification permits simple and structured explanation of soil phenomena.

However, the present situation is very unfortunate. We believe that a Universal Soil Classification System should be accepted. Soil classification harmonization and, finally, acceptance of a uniform classification is a priority task in pedology. The main features of the future soil classification should be its simplicity, flexibility, universality, clear terminology and functionality. It should have options both for expert and expert-independent diagnostics and a convenient structure for databases and GIS.

There are a number of obstacles, both objective and subjective, on the way to the Universal Soil Classification. The clog of traditions and habits is very strong. Most people honestly believe that their classification system is the best just because they are used to it from studentship. The possible option is introducing the Universal Soil Classification in university programs as a parallel system. Also certain ambitions of national schools of pedology exist. Most people believe, may be correctly, that they know their local soils much better than external specialists. The only way to overcome this problem is wide international cooperation, something like that existed when the FAO map was prepared. One of the strongest arguments against the acceptance of uniform soil taxonomy was that the change of classification would make obsolete all the existing soil maps made with older national systems. However, an introduction of a new national classification system, usually quite different from the older one, would lead to the same problem. We propose developing a long-term road map for the Universal Soil Classification: we should avoid claiming that the national schools of pedology should immediately change their classifications. The best way is using a natural change of old outdated systems that occurs every 20-25 years. We should propose accepting a universal system instead developing a new national classification.

References

AFES (1998) 'A Sound Reference Base for Soils' (The «Referentiel pedologique»: text in English). (INRA: Paris, France).

Banfield JF (Ed) (1984) 'Guy D. Smith discusses Soil Taxonomy'. (Soil Science Society of America Publication: Madison, WI).

CRG-CST (2001) 'Chinese Soil Taxonomy'. (Science Press, Beijing–New York).

Dokuchaev VV (1967) 'Selected works of V.V. Dokuchaev, V. I - Russian Chernozem'. (Israel Program of Scientific Translations, Jerusalem).

EMBRAPA (1999) 'Sistema Brasileiro de clasificação de solos'. (Embrapa Produção de Informação: Brasília – Embrapa Solos: Rio de Janeiro)

Gong Zitong (Ed) (1994) 'Chinese soil taxonomic classification (First proposal)'. (Institute of Soil Science, Academia Sinica: Nanjing)

Heller JL (1963) The nomenclature of soils, or what's in a name? *Soil Science Society of America Proceeding* **27**, 216-220.

Hewitt AE (1998) 'New Zealand soil classification'. 2nd edition. (Landcare Research Science Series No. 1, Maanaki Whenua — Landcare New Zealand Ltd, Dunedin, Lincoln, Canterbury, New Zealand)

Isbell RF (1996) 'Australian Soil Classification'. (CSIRO Land and Water: Canberra, Australia).

Krasilnikov PV, Arnold RW, Ibáñez JJ, Shoba SA (eds) (2009) 'A handbook of soil terminology, correlation and classification'. (Earthscan: London).

Krupenikov IA (1981) 'History of Soil Science'. (Nauka Press: Moscow, Russia) (in Russian)

Shishov LL, Tonkonogov VD, Lebedeva II, Gerasimova M. (2004) 'Classification and Diagnostics of Soils of Russia'. (Oykumena: Smolensk). (in Russian)

Simonson RW (1989) 'Historical highlights of soil survey and soil classification with emphasis on the United States, 1899-1970'. (International Soil Reference and Information Centre, Technical Paper no. 18: Wageningen, The Netherlands)

Rozanov BG (1977) 'Soil Cover of the Globe'. (Moscow State University Publishers: Moscow, Russia). (in Russian)

Shishov LL, Tonkonogov VD, Lebedeva II, Gerasimova MI (2004) 'Classification and diagnostics of soils of Russia', (Oykumena: Smolensk, Russia). (in Russian).

Sokolov IA (1978) On basic soil classification, *Pochvovedenie* **8**, 103-107 (in Russian)

Yaalon DH (2008) Classification: Historical Developments. *Encyclopedia of Soil Science* **1**, 1-3.

Properties of soils in the rehabilitated degraded tropical lowland and hill dipterocarp forests in Peninsular Malaysia

Arifin Abdu[A, B], Md. Zaidey Abd. Kadir[A,C], Zahari Ibrahim[C], Mohd Zaki Hamzah[A], Hazandy Abdul Hamid[A,B], Affendy Hassan[D], Mohd Effendi Wasli[E], Khairul Hafiz Yusof[A], Shamshuddin Jusop[F] and Nik Muhamad Majid[A]

[A]Faculty of Forestry, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia, Email arifinabdu@putra.upm.edu.my
[B]Institute of Tropical Forestry and Forest Product, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
[C]Forestry Department Peninsular Malaysia, 50660 Kuala Lumpur, Malaysia
[D]School of International Tropical Forestry, University Malaysia Sabah, Sabah, Malaysia
[E]Faculty of Resource Science and Technology, University Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia
[F]Faculty of Agriculture, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia

Abstract
A study was conducted to characterize the soil properties of two rehabilitated major forest types in Peninsular Malaysia, representing lowland and hill dipterocarp forests located at Bidor and Kinta Forest Reserves, respectively. Twelve soil profiles were dug both in rehabilitated lowland and hill dipterocarp forests including two profiles in natural forest as the control were selected at each site. The significant effect of rehabilitation forests could be seen by the accumulation of organic matter in the uppermost layer, which was assumed to be at an intermediate stage of mineralization. The soils at both sites were acidic, having low activity clay resulting in low CEC, available P, total nitrogen and exchangeable bases, but high in exchangeable Al. High exchangeable Al was the main cause of soil acidity, associated with high rainfall in the humid tropical region. The main source of negative charge was the organic matter, which affect the CEC, PZSE and σ_p values which influence the soil fertility status. The soils are considered as strongly weathered, almost devoid of 2:1 type clay minerals. Kaolinite and gibbsite dominate the clay fraction of the soils at both sites. It is imperative that soil properties should be taken into consideration during rehabilitation of degraded forestland in tropical rainforests.

Key Words
Clay minerals, deforestation, lowland and hill dipterocarp forests, rehabilitation, soil fertility

Introduction
Tropical rainforest is an enormous complex ecosystem existed on the earth surface (Whitmore, 1998). They are prevailed at unprecedented rate by human activities due to overexploitation of forest areas through deforestation, excessive logging and shifting cultivation, leading to degradation of forestland. In Peninsular Malaysia, lowland and hill dipterocarp forests are regarded as the most important forest types which consist of many valuable timber trees (Appanah and Weinland, 1994). However, such forests have been deteriorating due to anthropogenic human activities such as the conversion of its natural forest to other land use types and excessive forest harvesting resulting in degraded forestland or secondary forests. Rehabilitation of degraded forestland becomes very important in order to curtail the loss of soil nutrients and poor vegetation stock as well as for environmental concern. In Malaysia, rehabilitation of degraded forestland due to abandoned shifting cultivation has been successfully implemented under the ecosystem rehabilitation in Sarawak (Ishizuka *et al.,* 2000) and degraded forest land due to excessive harvesting by the enrichment planting technique in Peninsular Malaysia (Appanah and Weinland, 1993; Arifin *et al.,* 2008; Affendy *et al.,* 2009). Rehabilitation of tropical rainforest on severely degraded land requires an acceleration of knowledge on soil science towards understanding the effective soil conservation and sustainable forest management. However, most of the previous studies have emphasized the growth performance of planted species along with the planting technique with less concern on the soil characteristics in particular morphological, physico-chemical and clay mineralogical properties. This study was conducted in the Multi-Storied Forest Management System, a technical cooperation project between the Forestry Department Peninsular Malaysia (FDPM) and Japan International Cooperation Agency (JICA) to elucidate the soil properties of degraded forestland under rehabilitation forest in comparison to an adjacent natural forest at lowland and hill dipterocarp forests in Perak, Peninsular Malaysia.

Materials and Methods
Study sites
This study was conducted at the Multi-Storied Forest Management System (MSFS), a joint collaborative project between Government of Malaysia and Japan. Under these projects, two sites were selected namely Bidor and Kinta Forest Reserve, Perak, Peninsular Malaysia. The Bidor Forest Reserve, located at (4° 07' N and 101° 37'

E), is classified as lowland dipterocarp forest having altitude ranging from 10 to 30 m above sea level (asl). The Kinta Forest Reserve located at (4˚ 40’ N and 101˚ 60’ E), is classified as hill dipeterocarp forest with a steep mountainous region 35 to 45 degree and elevation ranging from 400 to 700 m asl. The relative humidity at the Bidor site varies from 70 to 98% and less than 50% during wet and dry period, respectively. The average annual precipitation is 3,050 mm and the mean temperature is approximately 28.5 °C (1990 to 2002) and that of Kinta site the average annual precipitation, temperature and humidity from (1990 to 2002) are 2500 mm, 25.5˚ C and 92.4 %, respectively.
The soil at Bidor Forest Reserve is derived from sedimentary and metamorphic rocks and unconsolidated materials, while the soil at Kinta is derived from granite. The native tree species at both sites are dominated by dipterocarp and non dipterocarp species. However, both of the areas have been subjected to forestland degradation by the excessive logging and abandoned plantation of *Acacia mangium,* which is consequently regenerated into secondary forest as in Bidor site.

Soil sampling
Soil survey and sampling were carried out from August to October 2009 at Bidor and Kinta sites. A total of twelve soil profiles were dug; there were six profiles at Bidor and Kinta, respectively. The soil profiles were described accordingly, followed by soil sampling according to a depth of 0-20 cm, 20-40 cm, 40-60 cm, 60-80 cm, 80-100 cm, 100-120 cm and 120-150 cm. The soils at the Bidor site namely in the respective site hereafter designated as B1 and B2 at plot A, B3 and B4 at plot B and B5 and B6 at adjacent natural forest. The B1 and B2 profiles were located at a relatively high area (upper slope) of rehabilitated secondary forests with various dipterocarp species in 1995. The B3 and B4 profiles located at a lower slope was an area of fast growing tree plantations of *Acacia mangium* in the late 1980s. In addition, B5 and B6 profiles were situated at adjacent natural forest. The soil profiles at Kinta hereafter designated as K1 and K2 at the line planting technique (lower slope) and soil profiles at gap planting technique of K3 and K4 (upper slope), and K5 and K6 at adjacent natural forest were dug. The K1 and K2 profiles were located an elevation of 450 m asl with a relatively stable lower slope of less than 10 degree, whereas the K3 and K4 profiles were situated at the upper slope with an elevation of 550 m asl, respectively and slope of less than 40 degree. The adjacent natural forest (K5 and K6 profiles) was dominated by dipterocarp and non dipterocarp species. The slope and elevation at the adjacent natural forest were 35 degree and 650 m asl, respectively.

Soil analyses
The samples were air-dried and passed through a 2 mm mesh sieve for physico-chemical properties. Particle-size distribution was determined by pipette method. Soil pH was measured with a glass electrode using a soil to solution (H_2O or 1 M KCl) ratio of 1:5 hereafter denoted as pH_w and pH_k, respectively. Electrical conductivity (EC) was measured using the supernatant at soil to water ratio of 1:5. Total carbon (TC) and total nitrogen (TN) contents were determined by a dry combustion method using NC analyzer. Available P was determined by the Bray II method (Bray and Kurts, 1945). The contents of exchangeable bases (Ca, Mg, K and Na) were extracted twice with 1 M ammonium acetate at pH 7.0. The CEC was determined by the steam distillation method. Exchangeable Al, H and NH_4 were extracted with 1 M KCl. The amount of NH_4 was measured using the indophenols blue Bray II method (Mulvaney, 1996). The point of zero salt effect (PZSE) and the residual charge at PZSE (σp) were measured by the modified salt titration method of STPT (Sakurai *et al.,* 1988). The amounts of Al and Fe soluble in ammonium oxalate (Alo and Feo) were extracted by the method of Mackeague and Day (1966). The amounts of Al and Fe soluble in dithionate-citrate system buffered with sodium bicarbonate (Ald and Fed, respectively) were extracted by the method of Mehra and Jackson (1960). The concentration of extracted Fe and Al were determined by sequential plasma spectrometry. Clay mineral composition was identified by X-ray diffraction analysis using CuKα radiation.

Table 1. Physico-chemical, charge and clay minerals properties of the soils in Bidor and Kinta sites.

Plot	Depth	pH_w	pH_k	T-C	T-N	C/N	CEC[a]	Exchangeable cations: Ca	Mg	K	Na	Al	H	ECEC[b]	Al.S[c]	Av.P	Clay	Silt	Sand	PZSE	σ_p[d]	Clay minerals: HIV	It	Kt	Gb	Qz
	(cm)			(g kg^{-1})		ratio	……(cmol$_c$ kg^{-1})……									(mgP kg^{-1})	……(%)……									
B1	0-20	4.55	3.99	21.7	1.53	14.2	4.81	0.22	0.12	0.08	0.06	1.57	0.43	2.05	76.59	11.9	10.5	2.9	86.6	3.70	0.80	-	-	+++	++++	±
	20-40	4.65	4.41	10.8	1.17	9.2	3.41	0.06	0.04	0.05	0.05	1.31	0.39	1.51	86.75	8.6	12.9	3.3	83.9	4.02	0.51	-	-	+++	++++	±
	40-60	4.85	4.52	5.0	0.54	9.3	2.48	0.09	0.03	0.06	0.05	1.43	0.34	1.66	86.14	7.6	20.5	3.8	75.8	4.02	0.40	-	-	+++	++++	±
B2	0-20	4.45	3.56	25.3	1.65	15.3	5.20	0.25	0.11	0.09	0.10	1.34	0.32	1.89	70.90	13.2	19.2	4.5	76.3	3.54	1.12	-	±	+++	++++	±
	20-40	4.53	3.61	15.4	1.34	11.5	3.54	0.21	0.12	0.09	0.05	1.32	0.21	1.79	73.74	10.4	17.1	4.9	78.0	3.45	0.98	-	-	+++	++++	±
	40-60	4.40	3.50	10.2	1.21	8.4	4.90	0.19	0.09	0.07	0.04	1.12	0.20	1.51	74.17	12.1	12.6	5.4	82.0	4.12	0.67	-	-	++	++++	±
B3	0-20	4.45	3.97	39.8	3.86	10.3	12.10	0.29	0.15	0.12	0.09	2.31	0.58	2.96	78.04	23.1	10.2	4.6	85.2	3.15	1.20	-	-	+++	+++	±
	20-40	4.58	4.45	21.3	2.43	8.8	13.50	0.26	0.11	0.10	0.06	2.11	0.39	2.64	79.92	21.0	8.9	3.6	87.5	4.08	0.90	±	±	+++	+++	±
	40-60	4.57	4.49	40.2	3.54	11.4	11.80	0.23	0.12	0.07	0.04	1.86	0.26	2.32	80.17	25.6	15.4	4.5	80.1	4.49	0.43	±	±	+++	+++	±
B4	0-20	4.76	4.45	35.5	2.34	15.2	12.80	0.23	0.18	0.15	0.12	2.22	0.35	2.90	76.55	25.4	15.0	6.5	78.5	3.23	1.65	±	-	+++	+++	±
	20-40	4.80	4.20	34.2	2.12	16.1	10.30	0.21	0.17	0.08	0.06	1.81	0.21	2.33	77.68	20.3	12.8	7.5	79.7	3.56	1.23	-	-	+++	+++	±
	40-60	4.90	4.60	28.0	2.09	13.4	9.98	0.19	0.16	0.07	0.07	1.34	0.33	1.83	73.22	22.1	9.0	7.8	83.2	4.32	0.98	±	±	+++	+++	±
B5	0-20	4.23	3.82	47.7	5.18	9.2	15.60	0.29	0.21	0.15	0.10	4.13	0.56	4.88	84.63	29.4	4.5	5.5	90.0	3.54	1.87	-	±	++	+++	+
	20-40	4.50	4.42	36.5	4.71	7.7	14.32	0.25	0.19	0.12	0.09	3.39	0.42	4.04	83.91	25.6	8.6	11.5	79.9	4.54	1.34	-	-	+++	++++	+
	40-60	5.07	5.01	32.3	3.15	10.3	12.12	0.14	0.18	0.09	0.07	2.18	0.28	2.66	81.95	20.5	9.8	12.3	77.9	4.40	1.09	-	-	+++	++++	+
B6	0-20	4.30	3.65	44.8	4.23	10.6	14.20	0.31	0.24	0.19	0.12	3.68	0.32	4.54	81.06	26.5	14.0	6.2	79.8	3.25	2.76	±	±	++	++++	+
	20-40	4.42	3.92	30.6	3.40	9.0	12.10	0.26	0.20	0.17	0.08	3.30	0.24	4.01	82.29	21.0	18.8	6.0	75.2	4.08	1.85	±	±	+++	++++	+
	40-60	4.56	4.32	21.6	2.34	9.2	10.50	0.19	0.18	0.16	0.07	3.45	0.19	4.05	85.19	18.9	7.0	7.6	85.4	4.15	1.60	±	±	+	++++	+
K1	0-20	4.21	3.54	26.5	3.45	7.7	12.50	0.32	0.15	0.10	0.06	4.12	0.89	4.75	86.74	12.5	35.8	8.9	55.3	3.30	1.60	±	±	++++	++	+
	20-40	4.31	3.71	21.0	2.89	7.3	9.60	0.12	0.10	0.08	0.05	3.87	0.75	4.22	91.71	11.2	36.5	8.4	55.1	3.65	0.80	±	±	++++	++	+
	40-60	4.70	3.93	6.7	2.16	6.5	6.61	0.09	0.07	0.05	0.04	3.58	0.60	3.83	93.47	9.0	37.1	10.5	52.4	3.78	0.60	±	±	++++	+++	+
K2	0-20	4.35	3.42	22.4	3.12	7.2	14.20	0.28	0.18	0.15	0.08	5.23	1.10	5.92	88.34	11.3	38.2	11.1	50.7	3.25	1.89	-	-	++++	+	±
	20-40	4.52	3.58	18.5	3.05	6.1	10.10	0.26	0.14	0.11	0.06	5.12	0.96	5.69	89.98	10.4	39.3	11.9	48.8	3.43	1.45	±	-	++++	++	+
	40-60	4.69	3.80	10.6	2.85	3.7	11.20	0.21	0.12	0.11	0.05	4.56	0.89	5.05	90.30	10.1	43.2	13.2	43.6	3.67	1.32	-	±	++++	+	+
K3	0-20	4.23	3.86	36.0	2.70	13.3	10.62	0.17	0.13	0.11	0.05	2.62	0.33	3.07	85.24	10.9	31.0	8.3	60.8	3.40	2.00	±	±	++++	++	±
	20-40	4.30	4.12	14.8	2.45	6.0	6.01	0.16	0.08	0.04	0.03	2.53	0.42	2.84	89.08	6.6	35.4	9.0	55.6	3.70	0.75	±	±	++++	++	±
	40-60	4.33	4.14	10.7	2.39	4.5	7.81	0.06	0.03	0.06	0.04	2.39	0.23	2.58	92.64	9.0	36.8	9.6	53.5	3.92	0.60	±	±	++++	++	+
K4	0-20	4.34	3.63	30.4	2.54	12.0	16.50	0.21	0.19	0.13	0.10	3.45	0.42	4.08	84.56	16.5	43.2	10.2	46.6	3.70	1.76	+	+	++++	++	±
	20-40	4.50	3.76	28.9	2.21	13.1	7.40	0.19	0.17	0.11	0.09	3.32	0.34	3.88	85.57	13.2	44.5	14.3	41.2	3.65	1.31	+	+	++++	++	±
	40-60	4.55	3.80	19.9	2.01	9.9	6.50	0.17	0.14	0.08	0.12	3.10	0.29	3.61	85.87	10.1	40.3	9.6	50.1	3.98	1.21	±	±	++++	++	+
K5	0-20	4.34	4.20	53.0	3.21	16.5	20.70	0.52	0.32	0.29	0.18	4.23	0.52	5.54	76.35	23.4	34.4	7.6	58.1	3.92	1.70	+	+	++++	++	±
	20-40	4.61	4.21	14.5	2.77	5.2	12.23	0.35	0.23	0.22	0.13	3.76	0.43	4.69	80.17	17.2	35.1	7.7	57.2	3.98	0.65	+	-	++++	+	±
	40-60	4.72	4.37	13.2	1.89	7.0	10.30	0.14	0.20	0.20	0.10	3.42	0.39	4.06	84.24	15.9	36.9	6.6	56.5	4.00	0.30	+	-	++++	++	±
K6	0-20	4.15	4.10	46.9	3.89	12.1	18.30	0.42	0.29	0.19	0.12	4.56	0.65	5.58	81.72	31.3	39.8	9.6	50.6	3.45	1.45	+	+	++++	±	±
	20-40	4.32	4.07	40.8	2.56	15.9	15.40	0.29	0.22	0.14	0.10	4.21	0.43	4.96	84.88	26.5	43.1	10.3	46.6	3.87	1.34	+	+	++++	±	±
	40-60	4.26	4.12	38.7	2.21	17.5	9.70	0.21	0.25	0.11	0.07	3.41	0.30	4.05	84.20	22.7	44.5	10.9	44.6	3.90	1.05	+	+	++++	±	±

[a]Cation exchange capacity
[b]Sum of exchangeable Ca+Mg+K+Na
[c]Al saturation; exchangeable Al/ECECx100
[d]Residual charge at PZSE
[e]HIV: hydroxy-interlayered vermiculite, It: illite, Kt: kaolin minerals, Gb: Gibbsite, Qz: quartz
±: 0-5%, +;5-20%, ++: 20-40%, +++:40-60%, ++++:>60%

Results and Discussion

The main features of the soil morphological properties at the study sites appeared to be highly weathered, with deep solum. The most significant morphological difference between the soils at Bidor and Kinta sites was soil texture, presumably related to the parent materials. In terms of physico-chemical properties, the textural composition of the soils at the study sites seems to be affected by the weathering processes of the parent materials. Apparently, soils at both sites can be divided into two textural classes based on the clay and sand contents. In the Kinta site, clay content was more pronounced, attaining a value of more than 30 %, while sand content was less than 60 %. The pHw and pHk values both in the lowland and hill dipterocarp forests were low with the values tended to increase with depth. It seems that the soil acidity of the area undergoing rehabilitation is not much different from that of the natural forest. The lower pH values at the surface layer across the study sites correspond to the larger amounts of organic matter in the topsoil, reflecting organic matter is responsible for acidity through litter decomposition. In general, the contents of total carbon, nitrogen, exchangeable bases were low but high in exchange Al resulting in high level of Al saturation. Moreover, the contents of Al, Fe Si oxides throughout the profiles were low indicating strongly leached out under heavy rainfall in tropical region. The PZSE and σp were low throughout the profiles both in the lowland and hill dipterocarp forests. The clay mineral composition in lowland was dominated by gibbsite and kaolinite, while that of hill forest dominated by kaolinite and gibbsite to a lesser extent of 2:1 type minerals, indicating strongly weathered soils.

Conclusions

Rehabilitating degraded tropical rainforest such as in the present study requires sufficient knowledge on soils towards better soil and forest management. High level of Al saturation with predominance of kaolin minerals and gibbsite are the main cause of low fertility status both in rehabilitated and natural forests. Since the soils are highly weathered which result in low fertility status, input of fresh organic matter from the trees by means of forest rehabilitation is an important effort to improve degraded tropical forests. Characterizing the soil in terms of physico-chemical properties, charge characteristics and clay mineralogical composition need to be taken into consideration prior to establishment of forest rehabilitation.

References

Affendy H, Aminuddin M, Razak W, Arifin A, Mojiol AR (2009) Growth increments of indigenous species planted in secondary forest area. *Research Journal of Forestry* **3(1),** 23-28.

Appanah S, Weinland G (1993) Planting Quality Timber Trees in Peninsular Malaysia. *A review.* Malayan Forest Records No. 38. Forest Research Institute Malaysia, Kepong, Kuala Lumpur, Malaysia. 247 p.

Arifin A, Tanaka S, Jusop S, Majid NM, Ibrahim Z, Wasli ME, Sakurai K (2008b) Assessment on soil fertility status and growth performance of planted dipterocarp species in Perak, Peninsular Malaysia. *Journal of Applied Sciences* **8(21),** 3795-3805.

Bray RH, Kurtz LT (1945) Determination of total, organic and available forms of phosphorus in soils. *Soil Sci.* **59**, 39-45.

Ishizuka S, Sakurai K, Kendawang JJ, Lee HS (2000) Soil characteristics of an abandoned shifting cultivation land in Sarawak, Malaysia. *Tropics* **10**(2), 251-263.

Mehra OP, Jackson ML (1960) Iron oxide removal from soils and clays by dithionite-citrate system buffered with sodium bicarbonate. *Clays Clay Minerals* **7**, 317-327.

Mulvaney RL (1996) Nitrogen-Inorganic forms. In: Method of Soil Analysis. Part 3-Chemical Methods. (Eds. Sparks DL, Page AL, Helmke PA, Loeppert RH, Soltanpour PN, Tabatabai MA, Johnston CT, Sumner ME), pp. 1123-1184. Soil Sci. Soc. America, Inc. and American Soc. Agronomy, Inc., Wisconsin.

Sakurai K, Ohdate Y, Kyuma, K (1988) Comparison of salt titration and potentiometric titration method for the determination of zero point charge (ZPC). *Soil Science & Plant Nutrition* **34,** 171-182.

Whitmore TC (1998) An introduction to tropical rain forests, 2nd edition. Oxford University Press, Oxford, 282 p.

Updating the soil map of Réunion island: methodology and problems to be overcome

Frédéric Feder[A,C] and Gérard Bourgeon[B]

[A]CIRAD, UPR Recyclage et Risque, Saint-Denis, La Réunion, F-97408 France.
[B]CIRAD, UPR Recyclage et Risque, Montpellier, F-34398 France.
[C]Corresponding author. Email frederic.feder@cirad.fr

When old soil maps are updated to answer present environmental concerns, many problems of interpretation can appear. The assessment of the groundwater vulnerability on the western slope of la Réunion Island (Indian Ocean) led us to review and evaluate the available data on soils. At the end of this census, the critical analysis of the existing soil maps and data showed that they were not directly utilizable for our study and that was primarily due to pedological concepts and associated classifications which are no more used (old French classification, CPCS) on the one hand, and to the lack of georeferenced data on the other. We therefore carried out a new soil survey of our study area covering 428 km^2 (ca. 20 % of the total island area; Figure 1). We identified 30 types of soils corresponding to subdivisions of the reference groups (RSGs) of the WRB, which we have grouped into fourteen pedopaysages (Figure 2).

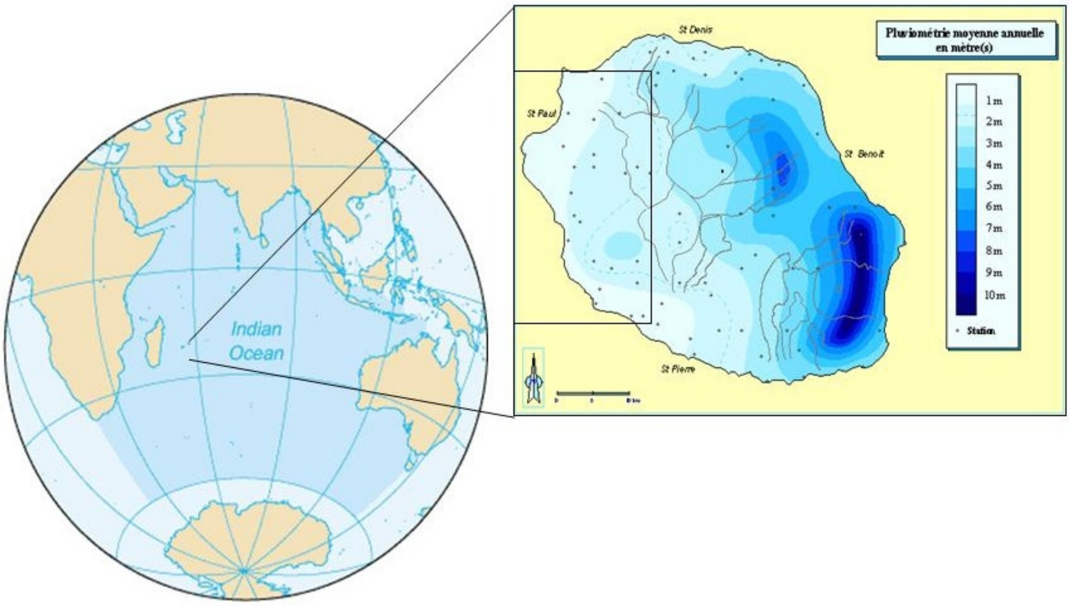

Figure 1. Localisation of Réunion island (Indian Ocean) and the studied area on the western slope of Piton des Neiges.

The upper part of the slope is marked, from the top to about 900 m, by the process of andosolization. The process of podzolization is superimposed on it under forest between 1600 and 1800 m. The remaining part of the slope is characterized by large organic matter contents, decreasing downwards (Table 1). The degree of saturation of the soil exchange capacity makes it possible to distinguish a mid-altitude zone, where Umbrisols dominate, from a lower zone, with Phaeozems and associated soils. To each altitudinal section thus corresponds a well developed type of soil associated with an incompletely developed type (Cambisol) presenting the same pedogenic tendency (Figure 2).

Recent changes in the knowledge and classification of the soils developed on volcanic materials under topical climate, as well as progress in the dating of the volcanic events explain both the fast obsolescence of the old soil maps in the case presented here (Table 2). Some of the problems encountered during this study will probably again arise during the completion of the soil map of la Réunion island (the regional computerized soil data base) and possibly for those of other overseas French territories.

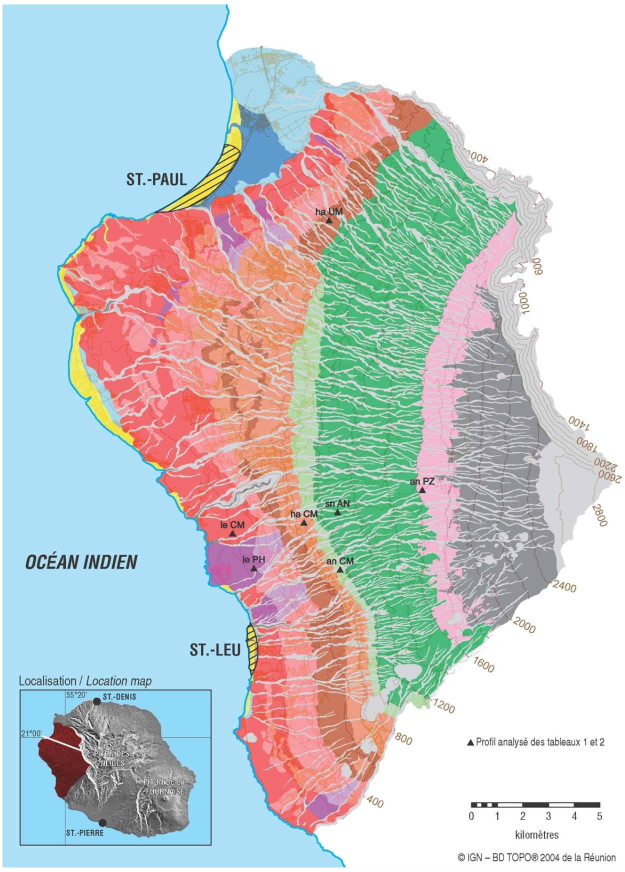

Figure 2. The new soil map.

Table 1. general properties of selected pedon: andic Podzol, 1630 m ; silandic Andosol, 1110 m ; haplic Umbrisol, 640 m ; andic Cambisol, 1064 m ; haplic Cambisol, 830 m ; leptic Cambisol, 131 m ; leptic Phaeozem, 262 m.

Catena	pH eau	pH KCl	$C_{org.}$ g/kg	$N_{tot.}$ g/kg	CEC cmol/kg	TS [a] %	Color Munsell
Andic Podzol (1630 m)							
0 – 5/20 cm	4.5	3.6	144	10.8	45.2	5	7.5 YR 3/4
5/10 – 10/30 cm	4.4	3.3	67	4.0	23.8	4	2.5 YR 5/1
10/30 – 20/30 cm	4.3	3.5	141	9.9	52.3	3	5 YR 3/2
20/30 – 70 cm	4.7	4.6	103	5.3	53.5	1	10 YR 4/4
70 – 135 cm	5.1	5.3	19	1.2	26.9	1	10 YR 4/6
Silandic Andosol (1110 m)							
0 – 7/15 cm	6.3	5.3	139	11.4	57.5	30	7.5 YR 3/2
7/15 – 40/50 cm	5.9	5.4	66	3.7	42.8	9	10 YR 4/4
40/50 –130/140 cm	5.4	5.8	16	1.0	22.2	3	7.5 YR 4/4
Andic Cambisol (1064 m)							
0 – 35 cm	5.1	4.5	40	4.4	36.1	24	10 YR 3/4
35 – 95 cm	5.7	5.2	11	0.9	28.6	18	7.5YR43
95 – 135 cm	5.3	4.7	8	0.6	35.7	11	10 YR 4/3
Haplic Cambisol (830 m)							
0 – 40 cm	5.4	4.7	31	3	28.1	19	7.5 YR 4/3
40 – 75 cm	6.0	5.0	29	3.3	25	34	7.5 YR 4/4
75 – 215 cm	6.0	5.6	12	1.1	24	19	7.5 YR 4/4
Haplic Umbrisol (640 m)							
0 – 30 cm	5.2	4.8	31	3.1	26.0	29	10 YR 3/2
30 – 80 cm	5.3	4.8	25	2.7	25.8	28	7.5 YR 3/2
80 – 150 cm	5.7	6.7	6	0.6	24.2	31	10 YR 3/3
Leptic Phaeozem (262 m)							
0 – 50 cm	6.9	6.0	25	2.4	22.7	85	7.5 YR 3/2
Leptic Cambisol (131 m)							
0 – 15 cm	6.6	5.3	20	1.6	26.1	85	5 YR 3/4
15 – 40 cm	7.2	5.8	4	0.4	36.3	76	2.5 YR 3/4
40 – 85 cm	7.1	5.6	2	0.2	36.5	75	2.5 YR 3/6

Table 2. Synthetic comparison of the pedological studies realized on the study area. Used prefix : vi (vitric), an (andic), sn (silandic), ha (haplic), le (leptic). Used Reference Soil Group: AN (Andosols), PZ (Podzols), UM (Umbrisols), CM (Cambisols), PH (Phaeozems).

Altitude (m)	Riquier (1960)	Zebrowski (1975)	Raunet (1988)	Cette étude (2009)
1850 et +	Sols ferrallitiques beiges organiques et sols à mascareignite, lithosols organiques	Podzols	Affleurements et Andosols vitriques	vi AN
1800 - 1850				
1750 - 1800			Andosols désaturés à mascareignite	an PZ
1700 - 1750				
1650 - 1700				
1600 - 1650				
1550 - 1600	Sols ferrallitiques beiges		Andosols désaturés perhydratés	sn AN
1500 - 1550		Andosols		
1450 - 1500				
1400 - 1450				
1350 - 1400				
1300 - 1350				
1250 - 1300				
1200 - 1250			Andosols désaturés	
1150 - 1200				
1100 - 1150				
1050 - 1100				
1000 - 1050				sn AN, an UM et an CM
950 - 1000				
900 - 950				
850 - 900	Sols ferrallitiques bruns et sols ferrallitiques brun-rouges	Sols ferrallitiques andiques		ha UM et ha CM
800 - 850				
750 - 800				
700 - 750				
650 - 700			Sols bruns andiques	
600 - 650		Sols ferrallitiques		
550 - 600				
500 - 550				
450 - 500				ha PH et le CM
400 - 450			Sols bruns et affleurements	
350 - 400	Lithosols			
300 - 350		(no data)	Sols bruns ferruginisés	le PH et le CM
250 - 300				
200 - 250				
150 - 200				
100 - 150				
50 - 100				
0 - 50			Sols vertiques et affleurements	