

Correlation of the diagnostic properties of soil genetic units for harmonisation of soil map units

REINTAM Loit

Institute of Soil Science and Agrochemistry, Estonian Agricultural University
Viljandi Road, Eerika, 51014 Tartu, Estonia
Email: loit@eau.ee

Abstract

An albic horizon can be formed either as a result of lessivage, podzolisation, or reductomorphic processes. Lessivage (argilluviation) is accompanied by the formation of an argic and/or cambi-argic horizon below the clay-translocative horizon. The spodic humus-illuvial or Al-Fe-illuvial horizon is diagnostic for podzolisation in various sands. Noncalcareous deposits of loamy texture are characterised by an illuvial horizon without spodic properties, while colour differences between the B-horizon and parent material are absent. The products of the breakdown of primary and secondary minerals have been mostly removed from the soil in the form of simple solutions without the formation a clearly argic, not to mention a spodic horizon. Podzolisation does not develop in clays, because of poor water permeability and the weak downward removal of the products of pedogenesis. Seasonal stagnation of perched water and development of reductomorphic processes are characteristic of soils with heavy and/or bisequal texture. The light coloured albi-stagnic horizon with ferric mottlings is underlain by an argic horizon with marbling and mottlings in root channels and in residual or contemporary cracks. This is characteristic of Planosols and Stagnic Luvisols, which cannot be qualified as Albeluvisols. Albeluvisols should be diagnosed as eluvial-differentiated soils with an albic horizon. Albic tonguing should not be obligatorily diagnostic only for them, as it is diagnostic (except for Planosols and Podzols) for all eluvial soils with stagnic and surface gleying properties. To avoid incomprehensibilities in the process of SMU border harmonisation, it is first of all necessary to correlate disputable genetic conceptions. For distinguishing eluvial soil processes, comparative attention should be paid to plant associations and to the texture, chemistry and mineralogy of parent deposits.

Keywords: Albeluvisol, Luvisol, Planosol, Podzol, eluvial diagnostics.

Introduction

Soil map units represent a real outcome of the occurrence of different soils in particular administrative areas. To avoid possible disharmonies, their essential coordination at the borders of separate countries needs special attention. Border harmonisation of soil map units appears to be complicated in places where there have existed or still exist differences in the conceptual interpretation of soil genetic units. Obvious exaggeration of the prevalence of acid hydrolysis under the forest vegetation has led to an overestimation of the importance of podzolization in the soils of Eastern Europe. The overall “mechanical” renaming of derno-podzolic (sod-podzolic) soils as Podzoluvisols and further as Albeluvisols (Stolbovoi, 2000; Stolbovoi *et al.*, 2001) can hardly contribute to the solution of the problem of eluvio-illuvially differentiated loamy soils. In spite of certain border harmonisation (Batjes, 2001), there are actually great differences in the soil taxa used within the area covering the European Soil Database at the scale 1:1,000,000 (1999) and outside it (FAO–ISRIC, 2000). At the border, the polygons of Luvisols on the western side can be directly adjacent to the polygons of Podzoluvisols (Albeluvisols) and Podzols on the eastern side.

Such a situation is not in the least new. The monograph “Burozem Formation and Pseudopodzolization in the Soils of the Russian Plain” (Zonn, 1974) as well as a great number of individual publications of I. P. Gerasimov, S. V. Zonn and their schools have once and again demonstrated that the term of *sod-podzolic soil* does not define a uniform soil taxon which could be classified of one. Contemporary knowledge as well as several international classification keys indicate such significant genetic variety of these soils that they could not be uniformly converted into any international system. Nevertheless, derno-podzolic soils have been considered equivalent to either Luvisols (Jamagne, 1998) or Albeluvisols (Deckers *et al.*, 1998; Stolbovoi, 2000).

This paper focuses on some criteria that are important, proceeding from the experience related to soil genesis and mapping at different scale as well as from the generalisation of results, for the correlation of the diagnostic properties of eluvial-differentiated soils, aimed at the harmonisation of soil map units.

Material and Methods

During about four decades, soil genesis and diagnostics have served as the central topics of our research. Our conceptual interpretations are based on field (route, stationary, and geographic) and laboratory studies carried out not only in Estonia, but also in other regions of Eurasia. We have used methods well known in soil science worldwide. The results have been published in a large number of papers and transactions from 1956 to 2001. Also, there were ample opportunities during 1958–2001 to present the results at various scientific panels, discussions and tours in about forty countries of the world. The soils and their characteristics discussed in this paper have formed on reddish-brown till which is similar to other loamy Quaternary deposits of Europe.

Results and Discussion

An albic horizon and/or albic properties, characteristic of any eluvial-differentiated soil profile, can be formed either as a result of the translocation of clay without changes in its composition (Figure 1, 1st from left), or as a result of the transformation of clay with changes in its composition (Figure 1, 2nd from left), or as a result of iron reduction and the formation of secondary ferrous compounds with locally reoxidised ferric mottlings against a light-coloured background (Figure 1, 3rd and 4th from left). These processes have been repeatedly described in a number of scientific and classification issues.

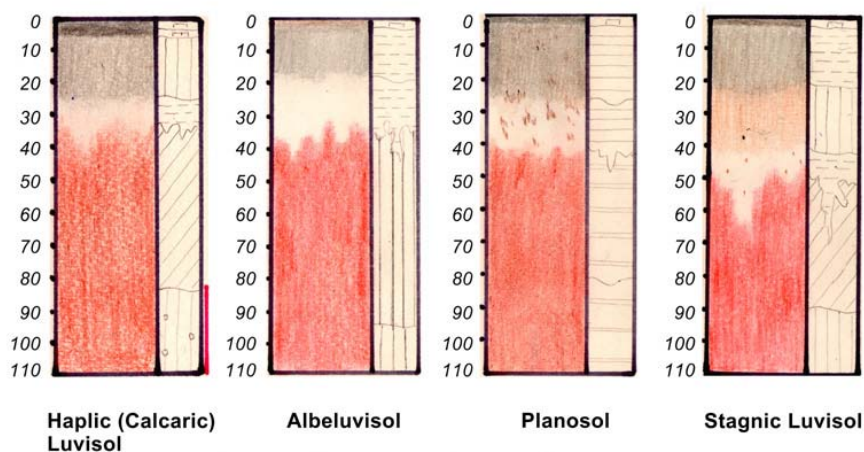


Figure 1. Comparison of eluvial-differentiated soils.

Also, the above regularities were concluded long before international systems became available in Estonia (Reintam, 1970, 1971a, 1971b). Only part of the eluvial-differentiated soils represented Derno-Podzols earlier and should represent Albeluvisols now.

An argic and/or a cambi-argic horizon below the clay-translocative horizon (Fig. 1, Luvisols) is diagnostic for lessivage (argilluviation), while a more or less expressed substantial balance between the A–Ew and Bt (Bw) horizon sequences is typical (Luvisol in Table 1). A spodic humus-illuvial (Bh) or Al-Fe-illuvial (Bs) horizon is diagnostic for podzolisation in various sands, while the deposits of loamy sand and/or sandy loam texture are characterised by an illuvial horizon without spodic properties (Fig. 1, Albeluvisol). Differences between the B-horizon and parent material are not revealed in colour but in slight tightening as a result of the illuviation of Al-pseudosols and amorphous silica. The products of the breakdown of primary and secondary minerals have mostly been removed from the soil in the form of simple solutions without accumulation and formation of a spodic horizon (Albeluvisol in Table 1).

The differences of principle between Luvisols on calcareous reddish-brown till and Albeluvisols on noncalcareous reddish-brown till are also expressed in the ratios of nonsiliceous iron oxide to the textural constituents (Table 2). Eluvic tonguing into the argic horizon, attributed only to Albeluvisols (ISSS/ISRIC/FAO, 1998; Driessen *et al.*, 2001), is sometimes encountered even in Luvisols on calcareous till, which can in no case be classified as Albeluvisols.

Table 1. Some genetic characteristics at the 95% significance level

Horizon	Clay, %	$\frac{\text{Silt + clay}}{\text{Clay}}$	$\frac{\text{SiO}_2}{\text{Fe}_2\text{O}_3}$	$\frac{\text{SiO}_2}{\text{Al}_2\text{O}_3}$	$\frac{\text{SiO}_2}{\text{Fe}_2\text{O}_3}$	$\frac{\text{SiO}_2}{\text{Al}_2\text{O}_3}$
	Luvisol on calcareous till					
A-horizon	7.9–9.1	2.5–2.9	83.7±2.9	13.7±0.3	10.8±0.3	3.3±0.05
Ew-horizon	8.6–10.0	2.4–2.6	83.4±3.2	13.9±0.4	10.1±0.2	3.2±0.05
Bt-horizon	16.8–18.4	1.6–1.8	53.6±1.4	11.3±0.3	9.6±0.2	3.4±0.04
C-horizon	12.4–13.8	1.9–2.1	66.9±1.8	12.4±0.2	10.8±0.3	3.6±0.06
Albeluvisol on noncalcareous till						
A-horizon	5.7–6.9	2.9–3.7	110.1±14.7	20.9±1.6	13.6±2.2	3.7±0.17
E-horizon	5.7–7.0	2.7–3.1	118.7±14.0	19.9±1.9	12.8±1.4	3.3±0.05
B-horizon	14.2–16.4	1.7–1.9	62.2±4.0	14.0±1.0	9.9±0.5	3.5±0.06
C-horizon	13.8–16.0	1.7–1.9	62.5±5.7	15.0±0.9	9.4±0.6	3.5±0.07

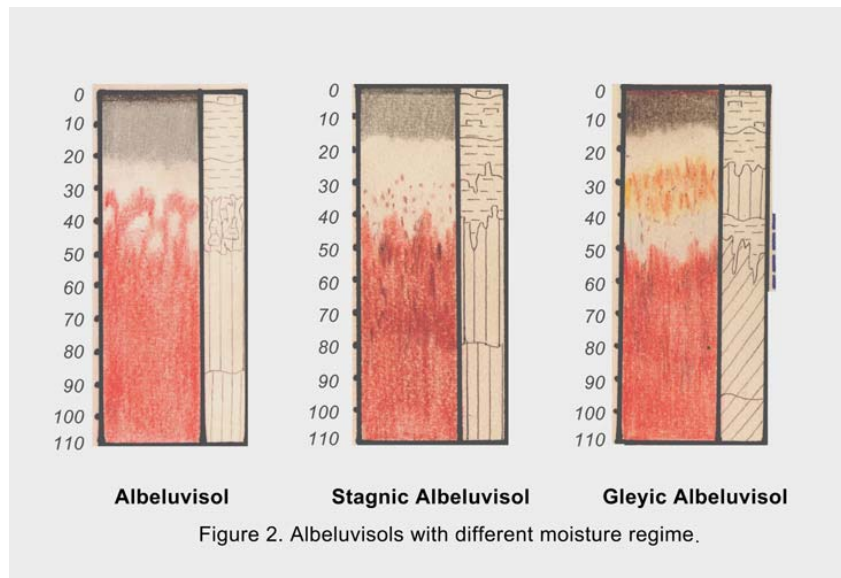
Table 2. Dithionite-extractable iron:clay ratio

Horizon	Luvisols		Albeluvisols	
	$\frac{\text{Fe}_2\text{O}_3 \text{ d}}{\text{clay}}$	$\frac{\text{Fe}_2\text{O}_3 \text{ d}}{\text{silt + clay}}$	$\frac{\text{Fe}_2\text{O}_3 \text{ d}}{\text{clay}}$	$\frac{\text{Fe}_2\text{O}_3 \text{ d}}{\text{silt + clay}}$
A	0.08	0.033	0.04	0.013
Ew (E)	0.07	0.030	0.04	0.014
Bt, Bwt (B)	0.07	0.040	0.07	0.038
C	0.07	0.037	0.06	0.032

According to our experience acquired not only from studies performed in the Baltic region, in the Far-East and Siberia, and on the Russian Plain, *etc.*, but also from comparison with similar objects in Western Europe and Northern America, the presence of an albic horizon should be the main qualifier for Albeluvisols. Light-coloured tongues of both periglacial and contemporary origin of stagnic processes and surface gleying in freeze–thaw cracks and root channels of different age are first of all characteristic of Stagnic Luvisols as well as of Stagnic Albeluvisols. Bisequal textured Stagnic Luvisols (Fig. 1 right) are widely spread throughout Europe. The presence of a brown-coloured Bw- (Bsv-) horizon (rich in amorphous sesquioxides, especially amorphous iron) between the A- and stagnic Ewg-horizons is specific for these soils. Its especially intensive development started under broad-leaved forests in the Litorina Sea Stage (Reintam, 1997). The stagnic tonguing at the juncture of layers of different texture is well pronounced, but the soils have no other properties characteristic of Albeluvisols, i.e. former soddy-podzolic soils.

Both Stagnic and Gleyic Albeluvisols have an albic horizon without stagnic and/or gleyic properties in the upper part of the eluvial subsection of their profile (Fig. 2). The presence of an albic horizon allows us to distinguish Albeluvisols from Luvisols, without obligation to qualify any soil with light-coloured tonguing as an Albeluvisol.

Podzolisation is impossible in loam and clay because of the lack of sufficient water permeability and downward removal of the products of pedogenesis. Therefore the genetic nature of Podzols on sandy parent materials is not disputable. Besides argilluviation, certain podzolic properties appear to develop as a result of the pedogenetic breakdown of clay minerals and the migration of soluble organo-metallic complexes on noncalcareous loamy materials in the formation of Albeluvisols. The outcome will be to some extent even similar to podzolisation (Table 3). Seasonal stagnation of perched water and development of pseudopodzolisation (Zonn, 1973) and ferrolysis (Brinkman, 1979) are characteristic of heavy and/or bisequal textured soils. A light coloured albi-stagnic horizon with ferric mottlings is underlain by an argic horizon with marbling and mottlings in root channels and in residual or contemporary cracks. This is characteristic of Planosols and Stagnic Luvisols (Baize, 1989, 1998; Deckers *et al.* 1998; Jamagne, 1998; Driessen *et al.*, 2001) that can hardly be qualified as Albeluvisols.



As with other processes, eluvial soil processes depend on plant associations and on the texture, chemistry and mineralogy of parent deposits (Reintam, 2000). Lessivage and automorphic Luvisols are characteristic of a rich, often calcareous weathering crust and a productive vegetation with an intensive turnover of substances (Table 3). Nemoral forests of the *Corylus*, *Hepatica*, *Aegopodium*, *etc.* site types represent the natural vegetation for them. Pseudopodzolisation and ferrolysis lead to the development of Stagnic Luvisols and Planosols under perched moisture conditions and a rich vegetation of *Hepatica*–*Oxalis* site types with *Galeobdolon*, *Mercurialis*, *Asperula*, *Aegopodium*, *etc.* No stagnic properties occur in the uppermost eluvial subsection of Albeluvisols under forests of the *Oxalis*–*Myrtillus* site type, while argilluviation is weak compared with Luvisols. Podzolisation and Podzols develop on poor sandy deposits under the low-productivity vegetation of the *Vaccinium*, *Myrtillus* and *Calluna* site types with a low-intensity turnover of substances. These regularities are valid also on bisequal substrates as well where also bisequal soils develop: sandy Podzols on the upper sandy section, and Stagnic Luvisols and/or Eutric Planosols on underlying loamy till (Reintam, 1999).

Against the background of well harmonised genetic concepts, border harmonisation must not present diagnostic difficulties. Differences in adjacent soil map units (SMU) are undoubtedly due to any disharmony in the identification of the largest soil component (prevalent soil) within a respective polygon (e.g. “western” Luvisols and “eastern” Albeluvisols). Disharmonies in the second largest soil component can also result from unharmonised genetic concepts. Therefore, comparative correlation should be specifically elaborated on the basis of available field properties. Base exchange capacity plays a great role in soil diagnostics but cannot be of paramount importance in distinguishing Luvisols from Albeluvisols.

Clearly, the total relative area of all soil components in a SMU must be 100%. Usually a minimum area has been fixed for each particular map. Our experience in the gradual generalisation of large-scale maps has confirmed the expedience of distinguishing a soil component “others” (“all the rest”) instead of using concealed information in largely generalised maps for the 10–15% area with a highly complicated soil mantle.

Table 3. Some genetic and ecological characteristics of eluvial soil processes

Characteristics	Lessivage	Pseudopodzolisation (ferrolysis)	Podzolisation
Eluvial horizon	Clay-translocative, weathered, 10YR6/4 (moist)	Fe-reductive albi-stagnic, ferrolytic, Fe- and clay-translocative, 10YR6/2 (moist)	Clay broken down, acid hydrolytic, albic, 10YR4/2 (moist)
Illuvial horizon	Clay-accumulative, cambi-argillic	Clay-accumulative, cambi-argillic	Spodic in sands, slightly spodic in till
Profile	A–Ew–Bwt(Bt)–C	A–Ewg–Bt(Bwt)–C or A–Bw–Ewg–Bt–C	A–E–Bh–Bs–C or A–E(EB)–B–C
Differentiation	Balance between A–Ew and Bt(Bwt)	Deferritized, ferrolytic, balanced	Impoverishment in clay, R ₂ O ₃ and bases
Clay fraction	Profile chemical homogeneity	Profile chemical homogeneity or enrichment in R ₂ O ₃	Broken down, R ₂ O ₃ eluvial-illuvial, base eluvial
Amorphous R ₂ O ₃	Topsoil accumulation	Accumulation in Bw and ferrous forms in Elg	Eluvio-illuvial
Humus	R ₂ O ₃ -humic-fulvic saturated, mollic or ochric	R ₂ O ₃ -humic-fulvic unsaturated, small amount of free fulvic acids, ochric (umbric)	Ochric, R ₂ O ₃ -fulvic unsaturated, big amount of free fulvic acids
Soil reaction	Neutral (acid)	Acid	Acid
Soil solution	Neutral to alkaline	Neutral, slightly acid	Acid
Parent material	Calcareous deposits	Heavy or bisequal textured deposits	Various sand, light-textured deposits
Biological turnover	Intensive, highly ashy, rich in Ca, N	Medium-intensive or intensive, moderately ashy, rich in N, Ca	Low-intensive, ash-deficient, poor in Ca

Conclusions

In spite of the availability of contemporary international handbooks and manuals for correlated classification of soils and for border harmonisation of soil maps, there occur numerous disharmonies in traditional genetic concepts, which make the solution of the actual harmonisation difficult. The nature of eluvial-differentiated soils in the temperate forest zone is one of the most actual issues. An albic nonreductomorphic horizon is specific for Albeluvisols. Except for Planosols and Podzols, light-coloured tonguing into the argic horizon is characteristic of all eluvial-differentiated soils with stagnic and surface gleyic properties. In fact, depending on profile characteristics and plant associations as well as on the composition of parent material, and hydrothermal relationships, former sod-podzolic (dermo-podzolic) soils in Central and Eastern Europe should be divided, according to WRB (1998), at least within five taxa: (1) automorphic Luvisols on calcareous and other base-saturated parent materials, (2) Stagnic and Gleyic Luvisols with reductomorphic properties on bisequal and heavy-textured parent materials, (3) Albeluvisols with a nonreductomorphic albic horizon on noncalcareous and base-unsaturated materials, (4) Planosols with textural discontinuity and without tonguing on bisequal and heavy-textured parent materials, and (5) Podzols on sands and other light-textured deposits. Special correlation of soil genetic units is essential for the harmonisation of soil map units even at the level of the second, third, *etc.* levels of soil components within particular polygons.

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