The Composition, Heterogeneity, Humus Status and Environmental Protection Value of Mineral Soils in Estonia

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ABSTRACT

The composition and properties of soil cover in three experimental areas in Estonia were analysed in terms of soil forming processes and land management practises. These areas were Jõgeva (JEA), Kuusiku (KEA) and Olustvere (OEA). Pedodiversity, humus forms and agrochemical status were analysed within seven arable land parcels. The soil cover of JEA was relatively homogenous. Dominant soil species were *Cutanic Luvisols* and *Haplic Cambisols* and the dominant soil texture of epipedons were slightly stony (pebbley) loams. The soil of KEA was much more heterogeneous, with five contrasting soil species in terms of soil genesis and four soil moisture states. The soil species in KEA were *Mollic Gleysols*, *Haplic Cambisols*, *Gleyic Luvisols* and *Rendzic Cambisols* (with relatively heterogeneous soils textures; from sands to loams). OEA was predominantly *Stagnic Albeluvisol*, with the topsoil texture consisting of sandy loam textures. In terms of soil species and properties JEA is representative of Central Estonian, OEA of South Estonian and KEA of North Estonian pedo-ecological conditions. These areas are generally representative of arable soils of the eastern part of the North European Plain. Soil cover is treated as a medium through which it is possible to improve the environmental status of an area. The 'environment protection value' (EPV) of soils were evaluated and detailed EPV categories were derived. Soils of JEA have high EPV due to neutral to slightly acid reaction, optimum humus contents, high cation exchange capacity, sufficient soil depth and the physical properties of subsoils are optimal. The EPV of KEA soil cover is less, due to high content of rock fragments in soil and and low biological activity within epipedons.

Key Words: humus cover types (pro- humus forms), pedodiversity, soil suitability for crops, field experimental area, taxonomical conversion, soil representativeness

INTRODUCTION

Depending on local pedoecological conditions (topography, diversity of soil parent materials or geodiversity, and meteorological conditions) patterns of soil and plant cover are very diverse (Ibáñez *et al.*, 1998; Guo *et al.*, 2003; Lin *et al.*, 2007; Panagos *et al.*, 2010; Kasparinskis and Nikodemus, 2012). Natural ecosystems are largely formed due to synergistic mutual interactions between soil and plant systems. However, natural ecosystems are influenced by many factors, including site-specific ecological conditions. Agricultural land use and the formation of agro-ecosystems depend foremost on the suitability of soils for the cultivation of feed and food crops. Usually, the most fertile soils of a region, which present minimal constraints for agricultural land use, are selected for long-term arable use.

Compared with conventional fields, the requirements for the selection of a soil experimental area (EA) are more precise. EA soil cover should correspond to local pedoecological conditions and represent the dominant soil types of the region. In addition, fields should be as homogeneous as possible. For detailed interpretation and application of practical experimental research results, knowledge of the properties of the soil cover of EAs, on ecological interactions of soil covers and on the characteristics of soil functions is essential. Our analysis showed that available information is usually insufficient. Generally, available information includes the names of soil species and varieties, plough layer pH, humus and total nitrogen (N) content, soil texture, and content of plant available potassium (K) and phosphorus (P). In some cases, soil morphological description has been achieved, which gives a good overview of soil diagnostic horizons, subsoil textures and parent materials. Large databases are available, which enable detailed evaluations of soil properties and versatility (Doran and Jones, 1996; Blum, 2002).

Generally, soil texture is a stable soil propery. This includes the particle-size distribution of both the fine-earth and coarse-earth fractions, in both the topsoil and subsoil. Stable properties include land topography and the nature and properties of superficial (1-2 m depth) regolith. Other soil properties are more dynamic and greatly influence soil functions and productivity. These properties may be substantially changed by land use and tillage. These properties include topsoil humus and plant available nutrient contents, acidity and, depending on soil management, agrochemical and biochemical status. Soil moisture conditions are regulated by drainage and irrigation.

Arable field experiments usually aim to develop tillage and fertilization techniques to optimize the soil environment to provide crops with the conditions needed for their successful growth and development. Natural soil systems provide similar functions (Dobrovolskij and Nikitin, 1990). Soil cover fulfils many other functions, essential for good environmental health. These include decomposition and transformation of organic matter, conserving biological diversity, and neutralizing and rendering harmless ksenobiotic substances (Blum, 2002; Carter, 2002; Kõlli *et al.,* 2004). Soils are critical for carbon cycling and profoundly influence soil carbon distribution patterns and the carbon sequestration capacity of soil cover (Post and Kwon, 2000; Guo and Gifford, 2002). Soil functions are inter-related with the properties of soil species (varieties), regional climatic conditions, land use, agro-technology and the soil management regime (Pierzynski *et al*., 2000).

Detailed research of the soils of selected EAs and monitoring of soil properties and process dynamics enables more detailed and multidimensional interpretation of plant cover and to elucidate mutual inter-relationships' between soil and plant systems. These relations may be used as a theoretical basis for the integrated interpretation of soils as dynamic and integral components of ecosystems. We propose that a pedocentric approach can be useful in understanding the form and function of ecosystems.

In the presented investigation, four themes are studied. These are: (1) soil cover composition and the pedoecological conditions influencing their formation, (2) the morphology of dominant soils representative of national (Estonia) and regional (eastern sections of the North European Plain) conditions, (3) soil cover pedodiversity and soil contrast, and (4) humus cover types (pro-humus forms).

MATERIALS AND METHODS

Location and pedoecological conditions of experimental areas

For analysis of soil cover composition, large scale (1:10,000) digital soil maps (with related soil contour data) were analysed of three areas: Jõgeva Plant Breading Institute (JEA), Kuusiku Experimental Centre (KEA) and Olustvere Experimental Station (OEA) (Land Board, 2001; Fig. 1). For extraction of soil data from large scale digital soil maps the program MapInfo Professional 9.5 was used. Data were statistically analysed using Microsoft Excel. Analysis and field research in the three EAs were performed within seven arable land parcels. JEA had three land land parcels, KEA three and OEA one. For demonstration of EA soil distribution patterns, black-and-white soil map excerpts for four land parcels are presented in Figs. 2, 3, 4 and 5.

In local government administrative terms, JEA is located in Jõgeva County, KEA in Rapla County and OEA in Viljandi County. According to the agro-soil districts (ASD) schema, elaborated for characterization of regional soil cover composition (Kokk and Rooma, 1974), JEA belongs to Adavere, KEA to Mahtra-Haimre and OEA to Viljandi ASD. Considering collected soil survey data on soil cover composition within specific ASDs, it is possible to make a preliminary evaluation of regional pedoecological characteristics and to evaluate the correspondence of EA soil covers to their environment. The areas of all EAs embrace only some of the whole ASD area. Some general pedoecological characteristics of ASDs and associated EAs are given in Table I.

Table I. General pedoecological characteristics of selected experimental areas (EA) within agro-soil districts (ASD)

Characteristics (% of area)	Adavere (JEA)	Mahtra-Haimre (KEA)	Viljandi (OEA)
Influenced by paludification (%)	23.6	20.0	15.5
Texture of mineral soils: l/sl/ls/s[a)], (%)	2/14/83/1	12/36/48/4	16/48/35/1
Moisture conditions: pn/g/G[b)], (%)	33/32/35	46/23/31	35/33/32
Influenced by erosion (%)	<0.5	<0.5	2.5
Fluvisols (%)	0.7	0.7	3.0

a) In the formula the denotations of fine-earth codes are: l: sand, sl: loamy sand & sandy loam, ls: loam, and s: clay.
b) Moisture conditions of mineral soils are: pn: well drained or aeromorphic, g: endogleyic and G: epigleyic or hydromorphic soils.

On the basis of landforms, topography and location, JEA belongs to the Vooremaa accumulative upland region. The landscape consists of glacial deposits from the last glacial period, especially drumlin fields. Situated on the northern part of this region, JEA is characteristic of localities with gently undulating calcareous till plains, with some mounds and oblong hills. KEA is located on the southern part of the Harju Plateau. It is characteristic of heterogeneous mixed plains composed of glacial till, limestone and former glacial lakes. OEA is situated on the northern part of the Sakala Upland, which is an undulating abraded upland till plateau, divided by pre-Quaternary valleys. OEA is representative of gently undulating abraded and outwashed non- and slightly calcareous till plains, with some mounds (Arold, 2005). The Quaternary cover and landforms are directly related to soil parent materials. For JEA it is yellow-brown slightly stony (pebbly) loamy till. KEA parent materials are white-grey pebble till and fine sand sediments originating from glacial lakes. Within OEA, parent materials are reddish-brown loamy tills.

All moist and wet soils of all three EAs were artificially drained during the period 1966-1987, in accordance with the demands of field crops. Their status in 1996-2001 ranged from satisfactory to good (Agricultural Board, 2004). In terms of precipitation and thermal resources, the most favourable conditions are found in OEA (Table II).

Table II. Agroclimatic resources of the three experimental areas (EA)

EA	Mean temperature[a)] (ºC)		ΣºC >10[b)]		Precipitation[a)] (mm)		Duration of summer[a)] (days)
	year	July	in air	in soil	in year	months V–VIII	
JEA	4.7	16.5	1650–1750	1950–2050	660	278	90
KEA	4.9	16.3	1700–1750	1900–2000	742	273	90
OEA	5.3	16.8	1800–1900	2000–2200	736	285	95

a) Data source: Jaagus (2002), summer is taken as the number of days with a mean temperature >13^{o}C.
b) Sum of plant active temperatures (>10ºC), (Kivi, 1976).

Soil cover composition according to Estonian Soil Classification

For comparative analysis, the soil species codes used in Estonian Soil Classification (ESC), given on large scale soil maps, were converted into the World Reference Base for Soil Resources (WRB) system soil names (Land Board, 2001; IUSS WG WRB, 2006; Table III).

Table III. List of EAs soil species codes and names according to Estonian Soil Classification and World Reference Base for Soil Resources

No	Code (ESC)	Soil names (WRB)	Code (WRB)	Dominance[a)] JEA	KEA	OEA
1	Kr	Rendzic Leptosol (endoskeletic)	LPrz		d	
2	K	Rendzic Cambisol	CMrz	a	d	
3	Ko	Haplic Cambisol	CMha	d	d	
4	KI	Cutanic Luvisol	LVct	d		
5	LP	Stagnic Albeluvisol	ABst	a	a	d
6	Lk	Umbric Albeluvisol (endoarenic)	ABum			sd
7	Korg	Endogleyic Cambisol (endoskeletic, drainic)	CMgln-skn		a	
8	Kog	Endogleyic Cambisol (calcaric, drainic)	CMgln-ca	a	a	
9	KIg	Endogleyic Luvisol (drainic)	LVgln	sd	d	a
10	LPg	Endogleyic Stagnic Albeluvisol (drainic)	ABst-gln	a		a
11	Gk	Rendzic Gleysol (endoskeletic, drainic)	GLrz		a	
12	Go	Mollic Gleysol (calcaric, drainic)	GLmo	a	d	a
13	GI	Luvic Gleysol (drainic)	GLlv		a	
14	Go1	Saprihistic Gleysol (arenic, drainic)	GLhi-sa		sd	

a) Dominance: d: dominant, sd: subdominant, a: associated species.

The genetic horizon designations used in soil profile formulae are: A: humic, El: eluvial, Ea: albeluvial, Egl: glossic, B: illuvial, Bw: formed by argillization *in situ*, Bt: formed by eluvial clay accumulation, G: gley, g: gleyed horizons and C: parent material.

The particle-size composition of topsoils on soil maps and their relative distribution by EAs and arable land parcels is given according to ESC (by Katchinski, 1965) in Table IV, along with the texture formulae (Astover *et al.*, 2013). In these formulae, separate soil layers are classified in terms of the particle-size composition of: (1) fine-earth (particles with diameter <1.0 mm) and (2) coarse fractions (1-10 cm). In the formulae for denoting fine-earth l denotes sand, pl: fine sand, sl: loamy sand, $ls_{1:}$ coarse loam, $ls_{2:}$ medium loam, and for precision of fine-earth character, t: silty and kr: gravelly (particles with diameter 1-10 mm). The codes of coarse fractions (given in formulae before the fine-earth code) are: r: ryhk (an Estonian term, meaning angular fractions of calcareous origin), v: pebble (rounded calcareous pebbles), v^{o}: granitic pebble (rounded fractions of granitic stones) and p: massive limestone. The coarse fraction content (given by the lower index of the code) are: 1: very slightly (2-10% of volume), 2: slightly (10-20%), 3: moderately (20-30%) and 4: strongly (30-50%) ryhky (r) or pebbly (v, v^o) fine-earth. For better understanding of the particle-size composition of fine-earths to international readers, their names and codes are given later according to WRB. However, coarse fractions are reported in terms of ESC, as the classification principles of ESC and WRB are very different and therefore difficult to convert (FAO, 1990; Astover *et al.*, 2013).

Table IV. Textures of experimental area soil cover and their distribution by arable land parcels (%)

No.	Formula of soil texture by ESC [a)]	JEA I	JEA II	JEA III	KEA I	KEA II	KEA III	OEA I	Main soil species by WRB
1	$v_1ls_135\text{-}50/v_1ls_230\text{-}50/r_1ls_1$	48	36	74	3	-	-	-	LVct
2	$v_1ls_130\text{-}50/v_1ls_220\text{-}30/r_2ls_1$	33	41	-	-	-	-	-	CMha
3	$v_1ls_130/tls30/r_1ls_1$	10	5	12	-	-	-	-	LVct
4	tsl50-70/tls,ls	8	-	-	-	-	2	-	ABst
5	$tsl40\text{-}70/v_1ls_120\text{-}40/r_1ls_1$	-	14	-	-	-	-	-	LVct, LVgln
6	$v(r)_1ls_{1\text{-}2}30\text{-}80/r_2ls_1$ [b)]	1	-	10	37	-	-	-	CMha, CMgln-sk, CMrz
7	$r_{1\text{-}2}ls25\text{-}40/r_{3\text{-}4}ls$	-	2	-	22	12	-	-	CMrz, LPrz
8	$v_1ls_140\text{-}80/p$	-	-	-	12	-	-	-	CMrz
9	$r_3ls10\text{-}30/r$	-	-	4	12	88	-	-	LPrz
10	krsl20-40/pl+60 [c)]	-	-	-	-	-	41	-	GLmo, LVgln, GLlv
11	pl+50-75 [c)]	-	-	-	2	-	41	-	GLlv, GLhi-sa
12	$v_{1\text{-}2}liiv$	-	-	-	-	-	9	-	GLrz
13	$v°_1sl50\text{-}70/v°_1ls_2$	-	2	-	5	-	-	67	ABst
14	$v°_1ls_130/v°_1sl35/ls_2$	-	-	-	-	-	-	23	ABst
15	$v°_1sl50\text{-}100/liiv$	-	-	-	-	-	-	9	ABum
16	plsl22-30/sl(tsl) [b)]	-	-	-	7	-	6	-	LVgln, GLmo

a) In full soil texture formulae the limits of horizon depths are given, but usually the soil particle-size composition was investigated to 1 m depth.
b) The share in brackets codes is <20%.
c) '+' after fine-earth codes indicates effervescence.

Explanation of terminology

The meanings of the terms widely used in the Estonian soil science literature are:
Land parcel is a relatively large land unit used in the Estonian Cadastral system.
Soil cover (direct translation from Estonian) or soil mantle embraces the solum or superficial earth layer, which is influenced by soil-forming processes and is important as a partly renewable natural resource. Soil cover depth extends from the surface to the C or to the middle of the BC horizon. Soil cover consists of humus cover (topsoil) and subsoil layers.
Humus cover (topsoil or epipedon; used in Estonia instead of humus form) encompasses an active superficial soil component, within which most carbon cycling occurs. On mineral agricultural soils the humus cover consists of humus and/or raw humus horizons.
Soil species is the unit of ESC identified by soil genesis.
Soil variety is the subdivision of soil species, divided on the basis of soil texture.
Soil contour is solid lines delineating the distribution of soil species or soil varieties on soil maps.
Soil association is an assemblage of two or more soil species within a designated geographical unit, recurring in different patterns across the area (landscape, soilscape). The share of soil species within a soil association may be very variable. There are the dominant (typical) and associated (codominant) soil species, by which the soil associations can be described and named. In reality, soil cover can be viewed as a continuum. The division into discrete contours of soil species (varieties) and associations is an artificial process. For practical purposes, it is useful to simplify this complexity. The structure and distribution of soil associations are determined by the soil forming factors.
Pedodiversity is a variation of soil cover properties (characterized in our work by soil species and varieties) within a specified area. Ibáñez *et al.* (1995) introduced ecological diversity indices as measures of pedodiversity. In practical terms, it means that the soil species (varieties) richness is the number of different soil taxons separated after ESC and abundance is the areal distribution of that number of soil species (varieties). Pedodiversity is a function of soil formation (Ibáñez *et al.*, 1998, 2012).

Environmental protection value (EPV) of soils is the capacity of a soil cover to maintain or/and enhance the environmental quality of an area and promote its ecosystems health, due to the functions of the soil cover. Thus, soil cover is not treated as a passive component of ecosystems, but as an active component. Soil cover has some capacity to sustain or ameliorate ambient environmental quality and its health. The EPV of soils may be evaluated separately in terms of specific aspects.

Materials and methods used in comparative analysis

In comparative analysis of soil cover heterogeneity several properties are considered. These include the number of soil species and varieties per area, mean area of soil contours, and the presence of soil horizons with varied textural composition. The stages of soil litho-genetic and moisture heterogeneities, and soil contrasts were estimated using the Estonian normal soils matrix tables (genesis and moisture conditions; Kõlli *et al.,* 2008). The heterogeneity and contrast of top- and subsoil texture was estimated on the basis of soil texture matrixes.

In the analysis of EA soil cover, humus status, agrochemical status and environmental protection ability were used. These were gathered between 1996-2000 using humus transects (Rannik and Kõlli, 2013). The quality and variability of soil humus status within experimental fields was studied in detail, considering humus concentration (g kg^{-1}), humus cover thickness (cm) and humus stocks (Mg ha^{-1}). In all, 38 soil profiles (JEA 21, KEA 12, OEA 5) were described by internationally accepted methods (FAO, 1990) and at 364 points the dominant soil humus thickness and humus content were determined.

To characterize soil cover within EAs, comparative analyses were performed of the fabric of the profiles of the dominant soil varieties. These were compared with model profiles, which are average weighted profiles typical of Estonian soil varieties (Kokk and Rooma, 1978; Kõlli *et al*., 2008). In analysis of the humus status of soils within EAs, the database 'Pedon' was used as a baseline. To assign soils to agro-groups and evaluate their suitability for crops, several published sources were consulted (e.g. Kõlli, 1994; Kõlli *et al.*, 2004). The EPV of soils was evaluated on the basis of four EPV aspects (biological, physical, soil climate and substratum) on a four stage rating scale (0: absent, 1: weak, 2: average and 3: good). The total synthesis of the EPV of soil was calculated as the sum of the four aspect scores. Five EPV classes were identified (I: very good, II: good, III: satisfactory, IV: poor, and V: very poor).

Methods of chemical analyses

Humus content was determined by wet digestion of carbon with acid dichromate (by Tjurin), soil reaction (pH_{KCl}) in 1 M KCl 1:2.5 using a Jenway 3071 pH-meter and extractable acidity by titration with 0.1 M NaOH after adding 1 M CH_3COONa solution (Vorobyova, 1998). The basic cations were determined by 1 M CH_3COONa extraction procedure (Soil …, 1992). Cation exchange capacity (CEC) was calculated according to the sum of bases and extractable acidity. The stocks of humus per humus cover were calculated on the basis of A-horizon thickness, humus content (concentration) and soil bulk density. For determination of plant available P and K the Mehlich-3 method was used. Calcium (Ca) and magnesium (Mg) were determined spectrometrically by atomic absorption after extraction by 1 M ammonium acetate (pH 7.0) solution. The particle-size composition of fine-earth (particles with diameter <1.0 mm) was determined by the Kachinski pipette-method (Kachinski, 1965).

RESULTS

Soil species and soil cover

Soil covers within the three EAs are fairly heterogeneous (Figs. 2, 3, 4 and 5). The data on soil species distribution according to land parcels shows that the soil cover of JEA is more homogeneous than that of KEA (Table V). The dominant soil species on all three land parcels within JEA are *Cutanic Luvisols* (LVct). Within the soil cover of JEA, LVct alternates between *Haplic Cambisols* (CMha) and drained *Endogleyic Cambisols* (CMgln-ca), which together occupy 25-36% of soil cover. This alternation depends on variations in the depth of calcareous materials. In terms of pedogenesis, the two dominant soil species (LVct, CMha) are very similar. *Endogleyic Luvisols* (LVgln), CMgln-ca and *Stagnic Albeluvisols* (ABst) are all located on the lower parts of the landscape.

Table V. Soil species of the the soil cover of experimental areas, subdivided by land parcels

EA	Land parcel No	Land parcel Area (ha)	Decreasing order of soil species (code[a)] and percentage)
JEA	I	222	LVct 56 > CMha 27 > LVgln 8 > ABst 7 > GLmo 1 > CMgln-ca 1
	II	138	LVct 47 > CMha 36 > LVgln 16 > GLmo 1
	III	24	LVct 74 > CMha 13 > CMgln-ca 12 > CMrz 1
KEA	I	57	CMha 43 > CMrz 26 > LPrz 12 > CMgln-skn 7 > LVgln 5 = ABst 5 > CMgln-ca 2
	II	4	LPrz 88 > CMrz 12
	III	126	GLmo 64 > LVgln 17 > GLhi-sa 10 > GLlv 5 > GLrz 3 > CMgln-ca 1
OEA	I	63	ABst 86 > ABum 9 > ABst-gln 3 > GLmo 1

a) For soil names by WRB see Table III.

In KEA the three arable land parcels differed substantially. The most heterogeneous soil cover is characteristic of land parcel I, which is located on highest northern part of KEA (Fig. 3). The differences between soils here are considerable. This variability is expressed in several properties. These include genetically (from *Leptosols* to *Albeluvisols*), moisture conditions (from droughty to moist), calcareousness (from strongly calcareous to non-calcareous) and subsoil texture (ryhky loam, ryhk and limestone). High heterogeneity is also expressed by the large number of soil species.

The largest land parcel (III) in the southern part of KEA is dominated by artificially drained *Gleysols.* The dominant species are *Mollic Gleysols* (GLmo) and *Luvic Gleysols* (GLlv) (Fig. 4). These are associated with drained LVgln and *Saprihistic Gleysols* (GLhi-sa), which occupy a modest extent. On the smallest arable land parcel (II) *Rendzic Leptosol*s (LPrz) are the dominant soil species and are similar to the associated *Rendzic Cambisol*s (CMrz). On OEA, *Stagnic Albeluvisols* (ABst) are dominant, and *Umbric Albeluvisols* (ABum) are present (Fig. 5).

The genesis and profile fabric of the dominant EA soils

During field work in JEA, we identified LVct *(Cutanic Luvisols).* Representative profiles (given in decreasing order of their share) were: A–El–Bt–C > A–ElBt–Bt–BC > A–El–ElBt–BC = A–El–ElBt–B–C. Therefore, within JEA there is clear visible evidence of the vertical illuviation of clays. This feature is proved by the presence of light coloured *eluvic* (El) and *argillic* illuvial (Bt) horizon *sequum* in soil profiles. Within JEA different transitional horizons may be found. LVgln typifies the presence of subsoil redoximorphic features. The fabric of the second dominant soils within JEA (CMha) is typical. A–Bw–C and A–Bw–BC–C profiles are present in equal quantities, where the Bw-horizon is formed by *in situ* argillization. On the JEA periphery there are limited ABst (~4%) and GLmo (<1%) profiles, which are typical of corresponding soil species.

The CMha of parcel I within KEA are genetically less developed compared with the same soil species in JEA, indicated by their thinner Bw horizon. Typical profiles are A–Bw–C or A–ABw–Bw–C. In KEA, CMrz (typical profiles A–(Bw)–C or A–AC–C) have characteristic undeveloped Bw-horizons or slight mottling beneath the A-horizon. LPrz profiles are dominant on parcel II and their A–C profiles are poorly developed. Profiles formed on drained wet sediments in KEA parcel III are *Rendzic Gleysols* (GLmo, CMgln-ca, GLhi-sa and GLrz). They are all undeveloped or pedogenetically poorly differentiated. The main discriminating property is the process of saturation with secondary carbonates. Soil pH is the main characteristic differentiating these soils (i.e. unsaturated soils have pH_{KCl} <5.6).

The dominant soil cover of OEA consists of typical ABst (by ESC) profiles: A–Elg–B–C. Slightly podzolized ABum profiles (A–Ea–B–C) occur only in sandy areas. The comparisons between EA soil cover genesis and functions may be explained using soil qualifiers (Table VI).

Soil cover texture

Most formulae of soil texture have two or three layers, but some have only one layer (No 11 and 12 in Table IV). Each texture combination (formula) is logically connected with specific soil species. Besides data presented in Table IV, 5-6 additional texture combinations were found in EAs. This provides further evidence of relatively high soil texture heterogeneity, but they are not detailed here due to their small share of soil cover. For better understanding to international readers, the generalized particle-size combinations of dominant EA soils are presented in decreasing order using the short formulae according to WRB (without soil cover thickness):

JEA: $\mathbf{v_1}$L/$\mathbf{v_1}$SCL/$\mathbf{r_1}$L (45%) > $\mathbf{v_1}$L/$\mathbf{r_2}$L (32%) > $\mathbf{v_1}$L/SiL/$\mathbf{r_1}$L (5%) = $\mathbf{v_1}$SL/$\mathbf{r_1}$L (5%) > SL/SiL (4%);
KEA: FS (28%) = LS/FS (28%) > $\mathbf{v_1}$L/$\mathbf{r_2}$L (11%) > LS (7%) > $\mathbf{r_3}$SL/r (6%) > ($\mathbf{v_{1\text{-}2}}$)S (5%) > $\mathbf{r_2}$L/$\mathbf{r_{3\text{-}4}}$SL (4%);
OEA: $\mathbf{v°_1}$SL/$\mathbf{v°_1}$SCL (67%) > $\mathbf{v°_1}$L/$\mathbf{v°_1}$SL/SCL (23%) > $\mathbf{v°_1}$LS/S (9%).

In these formulae, coarse fractions are given in bold text for separate soil cover layers, according to ESC. Fine-earth textures are according to WRB (with upper case letters; SL: sand, FS: fine sand, LS: loamy sand, SL: sandy loam, L: loam, SCL: sandy clay loam, and SiL: silty loam).

From these data it may be concluded that the textures of the superficial soil cover of JEA and OEA are relatively homogeneous, but substantially differentiated by the calcareousness of subsoils. In contrast, the texture of the soil cover of KEA is very heterogeneous. We analysed the ratio of humus cover texture (sand:loamy sand: sandy loam:loam). For the three EAs the ratios are: JEA 0:0:11:89, KEA 37:39:7:17 and OEA 0:9:68:23. Thus, it is possible to conclude that the texture of JEA is homogeneous and has optimum agronomical properties. The texture of OEA is lower quality, by approximately one stage. The texture of KEA varies considerably (from sand to loam). Clay-rich textures are absent in all three EAs.

In terms of coarse fraction contents (absent:slight to moderate:strong) the humus cover textures are: JEA 6:93:1, KEA 72:18:10 and OEA 1:99:0. This indicates the problems of KEA are related to the high coarse fraction contents. Subsoil textures (coarse:sandy:loamy) are JEA 1:0:99, KEA 7:76:17 and OEA 0:9:91. Again, this emphasizes the low environmental quality of KEA soils. On JEA mineral lands, loamy soils are dominant, with superficial slightly gravelly (pebble, ryhky) loam above slightly and moderately gravelly loam. In accordance with variations in the depth of calcareous material in LVct, loamy CMha and CMgln-ca are recognised. The topsoil texture of CMha is similar to that of LVct. The dominant texture of CMha subsoil is moderately gravelly loam.

The soil texture of the higher northern part of KEA parcel I is typical of North-Estonia’s light grey till soils, which are very rich in coarse, angular, broken limestone fragments. Here the dominant soil is slightly gravelly loam over moderately gravelly loam. Moderately gravelly loams above strongly gravelly loam, and strongly gravelly loam above ryhk (pebbles), may be found. These latter textures are also characteristics on parcel II. On KEA parcel III fine sands, loamy sands containing coarse fragments and loamy sands rich in secondary carbonates are dominant and present in varying combination. Clay-rich or fine textured sediments are present in subsoil, in limited amounts. Approximately 7% of the superficial layers were enriched in the course of tillage with rounded limestone pebbles.

OEA is dominated by small quantities of granitic pebbles (gravelly) sandy loams above sandy clay loams. To a lesser extent, loams on sandy clay loams and loamy sands on sands can be found. The first two textures are highly suitable for agricultural practises, while the second two textures are unsuitable.

Pedodiversity and soil contrast

The high soil heterogeneity on KEA is proved by it having most soil species, varieties and texture combinations (Table VII). The number of soil varieties per soil species is fairly uniform, at 1-3. The pattern of soil cover is more varied on KEA, indicated by more contours per 10 hectares (2.8-5.6) and relatively small area surrounded by each soil contour (1.8-3.6 ha). In terms of soil cover variation, JEA and OEA are similar.

Soil contrasts were analysed at two levels. At the first level (contrast 100) all soil varieties were taken into account. At the second level (contrast 90) only dominant soil species and textures were taken into account (i.e. associated soil varieties with total area <10% were excluded). The first number in the contrast formula characterizes moisture conditions, the second soil genesis and the third texture. In the case of texture, both topsoil and subsoil textures were taken into account. The number zero (0) in the formula indicates that there is no contrast or the soils are similar in terms of the analysed properties. Number 1 in the formula means that soils are near or adjacent in soil property matrixes. The greater the number in formulae, the more distant soils are in terms of their properties and thus the greater their dissimilarity, divergence and contrast. Our proposed concept of soil contrast accords with McBratney and Minasny (2007). They proposed that a suitable and effective measure of pedodiversity is mean taxonomic distance between soil types of a specific area (also called Rao's quadratic entropy).

Table VII indicates that the greatest contrast is characteristic of the soil cover of KEA and is validated by three aspects (moisture regime, genesis and texture). The only exception is parcel II, but its area is very small. The soil contrasts of JEA and OEA are similar and characteristic of the broad region they represent.

Humus and the agrochemical status of soils

Type of humus cover is a qualitative indicator of soil humus status (Table VIII). Humus cover types are determined on the basis of soil variety, humus content, coarse fractions in A-horizons and selected agrochemical characteristics. The types of humus cover on arable land are derived from both soil cover properties (moisture conditions, calcareousness and soil forming factors) and management techniques (including intensity of cultivation, drainage and liming). The humus cover of both JEA and OEA is predominantly well drained (with optimum moisture regime) eluviated humic moder. Neutral mild humose cover is abundant on parcel I of both

JEA and KEA and has excellent agronomical properties. The neutral mild humus covers do not require liming. The eluvic moder humus covers requires periodic liming and fulvic moder humus cover requires systematic liming. The use of eutrophic and mesotrophic raw-humus soil cover is impractical without artificial drainage. The quality of skeleti-calcaric mild humus covers is decreased by high soil coarse fractions, which is exceptionally high in *Rendzic Leptosols*.

Quantitative parameters of soil humus status include depth of A-horizons, humus concentration and the humus stock in humus cover. Determinations of the dominant soil humus status are presented in Table IX. These are achieved using humus transect methods. The acidity (pH_{KCl}) of EA humus horizons accords with soil genetic properties and texture (Table X). The same is valid for Ca content. There are generally low Mg contents in well drained arable soils in KEA and OEA. Plant available phosphorus (P) content is high in well drained JEA and OEA arable soils, but low in all dominant soils in KEA. There are high available potassium (K) contents in KEA soils.

Table VIII. Humus cover types of the dominant soil species of the three experimental areas and their distribution by land parcels (%)

Humus cover type[a)]	JEA			KEA			OEA
Name	I	II	III	I	II	III	I
Eluvic moder humic	71	63	74	10	-	17	90
Neutral mild humic	28	36	26	52	-	1	-
Eutrophic raw-humic	1	1	-	-	-	77	1
Skeleti-calcaric mild humic	-	-	-	38	100	-	-
Mesotrophic raw-humic	-	-	-	-	-	5	-
Fulvic moder humic	-	-	-	-	-	-	9

a) By Estonian classification.

Table IX. Data on the humus status[a)] of the three experimental areas (EA) investigated by the humus transects method

EA	*Soil*	n	Humus content, ($g\ kg^{-1} \pm SE$)	Thickness of A horizon, (cm ± SE)	Humus stock, ($Mg\ ha^{-1} \pm SE$)	Bulk density, ($Mg\ m^{-3}$)
JEA	LVct	110	24.0±0.95	32.2±0.59	114±7	1.48
	CMha	70	24.0±0.43	29.0±0.00	100±2	1.44
KEA	GLmo	21	42.0±1.31	38.0±0.87	131±7	0.82
	CMha	12	33.0±0.49	29.0±1.39	133±8	1.39
	CMrz	15	38.2±1.81	26.5±0.64	133±9	1.31
OEA	ABst	25	14.9±0.54	36.0±0.96	77±5	1.44

a) Mean ±(SE) standard error.

Table X. Data on agrochemical status[a)] of the dominant soil species in the three experimental areas

KA	Soil	n[b)]	pH_{KCl}	Ca	Mg	P	K	$H_{8,2}$	S	T
				mg kg^{-1} ± SE[c)]					cmol kg^{-1} ± SE[c)]	
JEA	LVct	11	6.2±0.1	1404±51	158±10	137±18	164±24	1.8±0.2	8.4±0.3	10.2±0.2
	CMha	7	6.3±0.2	1395±57	167±12	180±18	175±12	1.6±0.3	8.4±0.4	10.1±0.2
KEA	GLmo	4	7.1±0.1	1779±124	197±13	45±11	307±60	1.0±0.1	10.6±0.9	11.5±0.9
	CMha	4	6.5±0.3	1385±162	91±10	36±14	646±164	2.3±0.9	9.0±1.0	11.1±0,4
	CMrz	4	7.1±0.1	1616±69	83±4	56±10	263±26	0.7±0.1	10.4±0.4	10.9±0.6
OEA	ABst	5	5.3±0.4	877±181	63±8	140±13	95±26	2.8±0.7	5.1±0.9	7.9±0.4

a) $H_{8.2:}$ extractable acidity.
b) n: number of soil samples.
c) Mean ± standard error (SE).
S: sum of basic cations.
T: cation exchange capacity (CEC).

Productivity, suitability for crops and environment protection value of dominant soils

The dominant soils of all three land parcels of JEA belong to agro-group A22. The well-drained loamy texture and high productivity of arable soils in this agro-group are universally suitable for crops (Table XI). The most important associated soils (7-11%) of JEA are moist drained variants of the dominant soils (LVgln and CMgln-ca). These belong to agro-group A41 and are characterized by half a class of lower productivity.

Due to the heterogeneous soil cover of KEA, it is better to treat its dominant soil properties in terms of individual land parcels. On the largest (KEA parcel III) the drained *Gleysols* (GLmo and GLlv), with drained moist LVgln and drained saturated histic GLhi-sa, belong to quality class VI-VII. The productivity of KEA is substantially lower than that of JEA soils. Lower productivity is also characteristic of the soils of OEA, when compared with JEA soils.

Soil suitability for crops is partly characterized by soil belonging to one of the following agro-suitability groups: A: universally suitable, B: moderately suitable and C: with limited suitability. The value of soils is also estimated by its suitability for specific crops (barley, potatoes and field grasses). The soils of JEA belong to A-agro-group, but on OEA both B and C-agro-group soils are present. Agro-groups are directly connected to the suitability of soil for specific crops. By scientifically matching crops with suitable soils, it is possible to arrange more effective and sustainable land uses.

The biological (or active) aspect of the EPV of soils is directly connected with soil productivity and biological activity and characterized by the intensity of soil organic matter (SOM) decomposition and humification processes (Table XI). The physical (or passive) aspect of soil EPV depends firstly on clay and humus stocks (soil plasma) in the soil cover. This includes diverse materials which have either entered the soil system due to physical proceeses (in which case the soil acts as a filter) or physicochemically (by absorption of substances in the soil colloid complex). Therefore, to calculate passive aspects of the EPV of a soil cover, data on soil specific surface area and CEC are required.

Table XI. Data characterizing the productivity, suitability for crops (SFC) and environmental protection value (EPV) of the dominant soil species within the three experimental areas

Experimental area	JEA			KEA							OEA	
Soil	LV ct	CM Ha	LV gln	GL mo	CM ha	LV gln	CM rz	GL hi-sa	LP rz	GL lv	AB st	AB um
Agro-group	A22	A22	A41	B33	A22	B31	A1	C6	C1	B33	A21	B11
Quality points[a)]	62	61	56	51	63	49	53	36	37	45	57	48
Quality class	IV	IV	V	V	IV	VI	V	VII	VII	VI	V	VI
SFC: barley	10	10	9	7	10	8	9	6	6	7	9	6
SFC: potato	9	9	8	8	9	8	8	4	4	8	10	7
SFC: grass leys	9	9	9	9	9	8	7/10[b)]	10	4/8[c)]	9	9	5/9[d)]
EPV: active	3.3	3.2	2.8	2.2	3.2	2.3	2.7	1.4	1.5	2.1	2.8	2.4
EPV: passive	3.3	3.3	3.0	2.2	2.9	2.3	2.6	2.0	1.9	2.2	2.8	1.9
EPV: pedoclimate	3.1	3.1	2.9	1.9	3.0	2.7	2.8	1.4	1.9	1.8	2.8	2.6
EPV: substratum	3.1	3.0	3.1	2.5	2.1	2.4	1.7	2.2	1.4	2.4	2.9	2.6
EPV: total	12.8	12.6	11.8	8.8	11.1	9.7	9.8	7.0	6.7	8.5	11.3	9.5
EPV: class	I	I	II	III	II	II	II	III	III	III	II	II

a) Valid only in well drained status soil.
b) SFC: melilot.
c) SFC: alfalfa.
d) SFC: lupin.

Soil EPV depends to a great extent on soil temperature, humidity, aeration and redox regimes. In terms of the relationship between EPV and soil climate, EPV depends both on macroclimate and local microclimate. EPV is also influenced by natural drainage and artificial drainage, created during land hydro-amelioration. The fourth factor influencing EPV is the thickness and textural composition of materials beneath the soil cover. This substratum acts as an additional protective filter. Filtered material consists of pollutants contaminating regolith ground-water (i.e. nitrates and water soluble organic substances). According to the summarized data, the soils and soil cover of JEA generally have very good EPV (Class I) and are better than the other two EAs (Table XI). The EPV of OEA soil cover is generally good (Class II class). The lower (i.e. satisfactory to good EPV, Classes II-III class), is characteristic of KEA.

DISCUSSION

Pedodiversity

Soil cover composition, functioning and diversity (pedodiversity) depend on regional climatic conditions and geodiversity (Ibáñez *et al.,* 1998; Phillips and Marion, 2005; Soil Atlas of Europe, 2005; Krasilnikov *et al.,* 2007; Jeffry *et al.,* 2010). Soil cover pedodiversity is also substantially influenced by land management (Fisher *et al.,* 2002; Lubowski *et al.,* 2006).

As pedodiversity is a function of soil formation (Ibáñez *et al.,* 1995, 1998; 2012), the pedodiversity of local soil cover depends directly on soil forming conditions. The soil covers of the three studied EAs, within which macro-climatic conditions are similar, originated from different geological facies. The correspondence of the soil covers of the EAs to regional pedoecological conditions is revealed by comparing data presented in Table V on soil cover composition within EAs with ASD data (Kokk and Rooma, 1974). The dominant arable soil varieties in decreasing order are, according to ASD data: in Adavere (JEA): LVct L(SL) > CMha L > LVgln L > CMgln-ca L; in Mahtra-Haimre (KEA): CMha L, SL > CMrz L, SL > LVct LS; and in Viljandi (OEA): ABst SL/SCL > LVgln L, SL/L > ABst-gln SL/SCL. This comparison shows the arable mineral soils of the selected EAs are representative at the regional scale.

The pedodiversity of soil cover is very closely connected with soil forming processes. The yellow brown loamy till in JEA is typical of Central Estonia. The soil contains relatively little limestone, and the proportions of fine sand and coarse silt are approximately equal (Kokk and Rooma, 1978). Depending on carbonate and clay contents, alternatively with lessivage in LVct, the process of argillation (formation of secondary clay *in situ*) occurs in CMha (Reintam, 1997).

The rendzic soils (LPrz and CMrz) of KEA are formed on strongly calcareous stony till. Humic topsoils have relatively high humus contents. Generally, the calcareousness of rendzic soils is >10%. LPrz and CMrz profiles are thin and skeletal. Gleysols are formed on light-textured marine sediments from transgressions of the Baltic Sea over flat lowlands. Their properties depend on the chemical composition of soil water and of associated automorphic soils. Without artificial drainage, they are subject to paludification processes (forming of raw humus or peaty humus cover and strongly gleyed subsoil).

The ABst on OEA are formed on bisequal deposits experiencing the seasonal stagnation of perched water on the junction of horizons with different textures. They are characterized by white-coloured stagnic eluvial (Elg) horizons rich in ferric concretions, or they are formed via pseudopodzolization processes (Reintam, 1999).

The synergistic interactions of the biodiversity of fauna and soil organisms should be linked with pedodiversity (Zare Chahouki *et al.,* 2008; Turbe *et al.,* 2010; Cardinale *et al.,* 2011; Ibáñez *et al.,* 2012). The conservation and maintenance of biodiversity requires understanding of the linkages between geodiversity, pedodiversity and biodiversity (Serrano and Ruiz-Flano, 2007; Jeffery *et al.*, 2010; Kasparinskis and Nikodemus, 2012; Köster and Kõlli, 2013). We postulate that a pedocentric perspective on ecoystem functions can yield valuable information on biodivisity and local environmental heterogeneity.

An ecosystem approach, pedocentric viewpoint and pedo-ecological equivalence

For effective land resource management at the ecosystem level, it is important that all compartments of soil cover and its properties are taken into account, including their heterogeneity and pedodiversity, at detailed soil taxonomic level (Goodland, 1995; Haygarth and Ritz, 2009). Therefore, we propose that the sustainable use of national soil resources should be based on the ecosystem approach and be at soil species level. This is similar to approaches adopted for evaluation of regional flora and fauna resources.

In the pedocentric viewpoint, the soil cover of natural areas is the main determinant of the formation of plant communities and their species composition (Rossiter, 1996; Kasparinskis and Nikodemus, 2012; Köster and Kõlli, 2013). In arable areas, soil cover composition is the main factor influencing the choice of suitable agricultural crops (Kõlli, 1994; Fisher *et al.,* 2002). Thus, comprehensive knowledge of soil cover properties and quality are the main prerequisites in developing environmentally-friendly management of local land resources (Carter, 2002; Lubowski *et al.,* 2006; Panagos *et al.,* 2010).

In soil dependent (pedocentric) natural resource management, it is important to follow the principles of pedo-ecological equivalence and to systematically use adequate local research information. Alternatively, comparison may be made with other geographical regions with similar soil conditions. Thus, it is essential to develop appropriate protocols to convert data from local classification systems to more widely used WRB systems. Conversion enables both comparisons of local and international observations and to use extensive international databases in relation to local pedo-ecological conditions.

The soil species of ESC (as the most detailed unit in terms of soil genesis) can usually be converted into the WRB system, with few anomalies. A much more complex task is the harmonization of soil textural compositions (separated in ESC as soil varieties), mainly due to the considerable differences (in size and fraction names) in determining soil coarse fractions. This problem can also be resolved if suitable explanations are provided, which help explain local characteristics to international readers.

Humus status and dynamics

Soil humus status is one of the most important indicators of soil quality (Post and Kwon, 2000; Carter, 2002; Guo and Gifford, 2002). For comparative analysis of soil humus status in the three EAs the data of Estagriproject (Kokk and Rooma, 1974, 1978), from our database 'Pedon' and the digital soil map data (Land Board, 2001) are presented (Table XII). The thickness of humus horizons is substantially greater in all three EAs compared with model-soils. Deeper A-horizons was probably caused by deep ploughing of arable land during the period 1960-1980. At the same time, the humus concentration of EAs soils is generally lower than concentrations in model-soils and specified by the 'Pedon' database. Low humus content of ABst indicates humus deficits. This may have been caused by mixing of A-horizons with humus-deficient deeper horizons. This statement is supported by analysis of humus stocks, which are similar to other soils of the same species. Relatively large humus stocks on KEA CMha soils and modest stocks on GLmo are caused by regional soil characteristics. The low humus stock of GLmo is caused by soil drainage, which promotes intensive SOM mineralization and depletion (Balesdent *et al.,* 2000; Post and Kwon, 2000; Garcia-Oliva and Masera, 2004; Rousevell *et al.,* 2005).

The environmental protection value of soils

Data on EA soil cover composition (species, varieties) and distribution enable several conclusions on suitable soil management techniques and issues relating to the health of environments, including pedoenvironments. Inappropriate land use leads to inefficient exploitation of natural resources, destruction of land resources, poverty and related social problems (Rossiter, 1996).

In terms of soil cover composition and properties, the soils of all studied EAs are adequate for regional ecological conditions and are therefore suitable for the establishment of field experiments for various purposes. The use of the very heterogeneous soil cover of KEA for agricultural experiments is justified. By forming smaller land use units, it is possible to incorporate more homogeneous fields into agricultural experiments. Furthermore, it is possible to design experiments with considerable differences in soil cover quality within fields.

The role of soils in sustaining the environment has received much research attention (Pierzynski *et al.,* 2000; Blum, 2002; Environment Agency, 2006). We have analysed the influence of soil cover on overall environmental status by investigating soil functions (Kõlli *et al*., 2004). Using these functions it is possible to characterize different aspects of the EPV of soils (Table XI).

The biological aspect of the EPV of soils depends on soil productivity and the longevity of periods suitable for the activity of soil organisms. Therefore, all means which increase soil productivity also increase its EPV value. These means include optimal fertilization. The physical properties of the EPV of soils may be regulated by ameliorating soil humus status. Intensive tillage and artificial drainage may diminish soil EPV, but these practises may be compensated by greater biological EPV.

The most suitable soil climate for soil organisms is sufficiently warm and aerated and with sufficient water. The highest EPV vales are in JEA on well-structured, well-drained loamy soils. In KEA, the hydro-ameliorative system used on gley soils promotes soil aeration by elimination of excess water, which also improves the soil redox regime. Better soil aeration favours oxidation processes, including SOM decomposition, and impedes paludification. Favourable moisture regimes can be attained relatively quickly in drained soils. Soil properties may be impaired in drained soils compared with soils formed in permanently well-aerated conditions, due to injurious redox processes.

Soil cover substratum in Quaternary deposits with mobile water may render contaminants harmless or sequester pollutants for prolonged periods. The relatively low EPV of KEA is mainly related to the thin and skeletal layer of Quaternary sediments. The drainage of arable lands has considerably increased the EPV of arable lands within KEA.

CONCLUSIONS

1. To receive suitable and applicable results from field experiments, the composition of the soil cover of an experimental area should be typical for the specific region.
2. To promote international collaboration, the keys and rules for comparing international and local soil classifications should be as clear and detailed as possible.
3. For more precise characterization of regional soil cover, dominant soil varieties, associated soil varieties and soil associations should be specified and studied.
4. Linkages between biodiversity and pedodiversity should be fully explored.

5. Inter-relationships between surveys of arable soils, field experiments and the environmental protection value (EPV) of soils should be explicitly investigated.

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Table VI. Characterization of soil covers of experimental areas by means of WRB qualifiers

No	Reference qualifiers			Prefix qualifiers			Suffix qualifiers		
	JEA	KEA	OEA	JEA	KEA	OEA	JEA	KEA	OEA
1	**luvic**[a)]	**epigleyic**	**albeluvic**	**cutanic**	**mollic**	**stagnic**	**endoeutric**	**calcaric**	**abruptic**
2	**argic**	**reductic**	**glossalbic**	**mollic**	**calcic**	**fragic**	**anthric**	**eutric**	**endoeutric**
3	**cambic**	**cambic**	**argic**	gleyic	**cutanic**	umbric	**calcaric**	**drainic**	endoarenic
4	albeluvic	**luvic**	spodic	stagnic	**endogleyic**	endogleyic	endoarenic	**arenic**	anthric
5	glossalbic	**argic**	epigleyic	fragic	**rendzic**	mollic	drainic	anthric	drainic
6	epigleyic	leptic	reductic	rendzic	**endoleptic**	cutanic	abruptic	abruptic	calcaric
7	reductic	lithic	luvic	endoleptic	**endoskeletic**				
8		skeletic		endoskeletic	saprihistic				
9		albeluvic			umbric				
10		glossalbic			stagnic				
11					fragic				
	7(3)[b)]	10(5)	7(3)	8(2)	11(7)	6(2)	6(3)	6(4)	6(2)

a) The dominant qualifiers of soils are given in bold text.

b) Total number of soil qualifiers (in brackets number of dominant qualifiers).

Table VII. Pedodiversity of soil cover and soil contrast on the three experimental areas

Experimental area	JEA[d]				KEA[d]				OEA
Land parcel	I	II	III	I-III	I	II	III	I-III	
Number of species	7	6	5	10	8	2	8	14	5
Number of varieties	15	12	8	28	19	2	16	36	6
Number of textures	7	6	4	10	9	2	11	19	4
Varieties per one species	2.1	2.0	1.6	2.8	2.4	1.0	2.0	2.6	1.2
Contours per 10 ha	1.6	1.7	4.1	1.8	5.6	4.6	2.8	3.7	1.4
Mean area of contours (ha)	6.2	6.0	2.4	5.6	1.8	2.2	3.6	2.7	7.0
Cntr-100[a)], formula[b)]	2.8/3/2.2	2.8/2.2/1	2/2/1.6	2.8/3/2.2	3/4/2.5	1/0/0.5	4/2/3.6	5/4/6	2.8/3.2/3
Cntr-100, total[c)]	8	6	5.6	8	9.5	1.5	9.6	15	9
Cntr-90[a)], formula[b)]	2/1/0.1	2/1/0.5	0/1/0	2/1/0	2/1/2	1/0/0.5	2/1.2/3	4/2/4	1/1/1.2
Cntr-90, total[c)]	3.1	3.5	1	3	5	1.5	6.2	10	3.2

a) Cntr: soil contrast 100 (all soils were taken into account) and 90 (only 90% of soil area taken into account).
b) Formula of soil contrast: moisture/genesis/texture.
c) Total soil contrast.
d) Numbers are less than the sum of I, II and III, as the same soil categories (species, varieties and textures) recur in several land parcels.

Table XII. Comparative analysis of the humus status[a)] of the dominant soils of the three experimental areas

Characteristics	JEA		KEA					OEA
Soil	LVct	CMha	GLmo	CMha	LVgln	CMrz	LPrz	ABst
Texture	L/SCL/L	L	FS, LS	L	LS/FS	L/L, SL	SL/r	SL/SCL
Proportion (%)	54	30	43	13	12	8	6	86
A-horizon thickness (cm)								
Transect	31.6−32.8	29.0−29.0	37.1−38.9	27.6−30.4	−	25.9−27.1	−	35.0−37.0
Model soil	24.9−25.3	25.2−25.6	23.1−24.5	25.2−25.6	25.7−27.1	23.8−24.0	17.2−18.0	22.7−23.3
DB Pedon[b)]	25.2−27.8	25.6−28.2	22.8−25.2	25.6−28.2	25.6−28.4	25.2−27.8	18.3−20.3	24.9−27.5
Digital soil map	24−30	23−30	20−29	23−26	22−30	20−30	18−23	28−30
Humus content (g kg^{-1})								
Transect	23.0−25.0	23.6−24.4	40.7−43.3	32.5−33.5	−	36.4−40.0	−	14.4−15.4
Model soil	28.1−28.9	29.7−30.5	69.1−87.5	29.7−30.5	29.4−33.0	32.2−33.0	36.8−40.3	18.8−19.4
DB Pedon[b)]	26.6−29.4	27.6−30.4	70.3−77.7	27.6−30.4	32.3−35.7	31.4−34.6	38.0−42.0	20.9−23.1
Humus stock of A-horizon (Mg ha^{-1})								
Transect	107−121	98−102	124−138	119−134	−	111−128	−	72−82
Model soil	104−108	106−110	179−240	106−110	110−130	94−97	65−74	64−68
DB Pedon[c)]	101−123	100−121	168−206	100−121	116−142	97−119	70−88	78−95

a) Mean ± (SE) standard error.

b) DB: database 'Pedon', mean ±5%.

c) Corrected to account for pebble content.