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Inter-relationships between soil texture and soil organic matter content in eroded *Eutric Albeluvisols* in Lithuania

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There are several methods to determine both soil organic matter (SOM) and soil texture. Furthermore, there are also numerous national soil texture classification systems, often with different particle size interval boundaries. This gives rise to problems of international data comparison, especially when analysing the kinship between SOM and soil texture, as this complicates other data applications, such as carbon sequestration estimates. This paper reports SOM and soil texture data for 92 soil (46 topsoil and 46 subsoil) samples of *Eutric Albeluvisols*, collected from 46 long-term experimental field plots of the Kaltinėnai Research Station of the Lithuanian Institute of Agriculture. Investigations show strong correlation and paired regression relationships between data obtained using all investigated SOM (loss-on-ignition, Walkley–Black, Tyurin titrimetric) and soil texture (Soil Survey of England and Wales, USDA, Kachinskiy) analytical methods. However, results indicate important technical issues and problems of international comparison, because notable differences exist between SOM and soil texture analytical techniques and between national texture classification systems. The concomitant effect is that correlation coefficients between these data can produce contrasting trends. This highlights the difficulty of international comparison, especially where non-identical methodologies are used and, in the case of Kachinskiy data, its comparative unreliability for determining SOM and texture linkages. Therefore, it is proposed that calibration protocols may be used as predictive tools for estimating the potential and rate of soil carbon storage.

Key words: Eutric Albeluvisols, soil texture, soil organic matter, carbon sequestration

INTRODUCTION

Soil organic matter (SOM) content is commonly defined as the percent humus held within a soil. Humus is an unidentifiable residue of plant soil micro-organisms and fauna that becomes quite resistant to further decay. SOM in eroded soil decomposes faster than within intact soil. Organic carbon content within the erodible fine surface fraction is usually ~1–2% [5].

Soil organic matter is a vital indicator of soil quality and productivity. It consists of a complex and varied mixture of organic substances. Stable SOM can become a potential source of 'greenhouse gases' through a series of biochemical transformations initiated by the physical process of erosion [5]. Typically, erosion enhances SOM decomposition at two locations: the eroded land surface and the eroded 'in transit' soil / sediment. Moreover, erosion produces a new pool of mineralizable organic matter, which is different from the remaining stable organic matter. This transported soil organic fraction is no longer under the same physical and environmental conditions that allowed the organic matter to initially stabilize [19].

Agricultural management of soil carbon is a recognized means of improving soil fertility, reducing soil erosion rates, enhancing soil structural stability and assisting carbon sequestration [7, 29, 30–32, 37]. SOM influences many soil properties, such as water retention capacity, extractable bases, capacity to supply macro- and micronutrients, aggregate stability and aeration [28]. Organic carbon is the major component of microorganism cells, plant and animal residues, stable 'humus' synthesized from residues and nearly inert and highly carbonized compounds [23, 28].

Conversion of natural vegetation to agricultural land-uses can decrease SOM and, conversely, reversion of cultivated land to natural vegetation can reliably replenish SOM and return lost soil carbon via increased soil carbon storage [8–10, 32]. The impacts of SOM enrichment on soil carbon dynamics are well documented [12, 21, 35]. However, differences between international soil texture classification systems and SOM analytical methodologies [38] can lead to different interpretations or data redundancy and, thus, impede evaluation of soil carbon sequestration potential. Therefore, it is proposed, successful conversion of Kachinskiy generated East European data to laser diffraction US Department of Agriculture (USDA) and Soil Survey of England and Wales (SSEW) data provides the possibility to both adapt contemporary textural data sets and to harmonize the archives of Kachinskiy textural data with those of Western classification systems [3]. Moreover, a possibility exists to transfer SOM data from methods widely used in Eastern Europe to other protocols, using either simple linear regression equations or even conversion coefficients. Paired regression equations and curves indicate the data sets to be comparable and appropriate for recalculation. Therefore, employment of this approach assists the harmonization of international SOM data and appraisal of long-term global trends in soil carbon storage [4, 16–18].

Underestimation of clay by the laser-diffraction method has been reported [25, 27]. Generally, this is because laser-diffraction and other classical (sieve and pipette) methods each define particle size in different ways and thus measure different properties of the same material [22]. However, the Kachinskiy method does not offer the same precision as the laser-diffraction methodology because of a greater manual error. Digital systems are far superior and, as such, should not have their results compared with classical methods [33]. However, to include former-Soviet and East European soil texture in international carbon sequestration models and avoid data redundancy, it is necessary to advance methodological comparisons and harmonize international data. It is also probable that routine application of HCl acid in the Kachinskiy protocol may damage the crystal lattice of clay particles and strip them into smaller layers. This would decrease the size of the particles and thus increase the proportion of <1 μm particles. However, the latter explanation promotes further methodological investigations beyond the immediate scope of this work.

Precise information on textural and soil organic matter is important because the colloidal partnership between clays and SOM forms a chemical association of clay–humus complexes and thus largely determines the carbon (C) carrying capacity of soil [13, 26]. Therefore, the purpose of this paper is to demonstrate the significance and comparison of SOM relationships with soil particle size data sets, using the Soil Survey of England and Wales (SSEW) (now the National Soil Resources Institute, NSRI), the United States Department of Agriculture (USDA), and the East European (Kachinskiy) texture classification systems.

MATERIALS AND METHODS

Site description and sample collection

Soils were obtained from the Kaltinėnai Research Station (KRS) of the Lithuanian Institute of Agriculture (LIA) which is located on the southern-central Žemaičiai Uplands (55°34'N, 22°29'E) [15]. A total of 92 *Eutric Albeluvisol* samples were collected: 46 from topsoil (0–20 cm: Ap, $n = 38$; Ah, $n = 8$) and 46 from subsoil (20–40 cm: Bt, $n = 46$) horizons of 46 long-term experimental field plots of the KRS (Fig. 1). Ah horizons were developed from Ap horizons after 8 and 20 years under perennial grass. Soil samples were taken from three (localities 1, 2, 3; Fig. 1) monitoring sites (each containing 10 plots) representative of six land management systems. These sites were on slopes of 7–9, 7–8 and 9–11° with a southern aspect (duration 8 years). Samples were also taken from two (localities 4, 5; Fig. 1) monitoring sites (each containing 8 plots) representative of four management systems, on slopes of 10–14° with a northerly aspect and slopes of 12–16° with a southerly aspect (duration 20 years). Soil was moderately eroded on sites 1–4 and strongly eroded on site 5. Therefore, primary Ap horizons were truncated, and secondary Ap horizons were developed from eluvial (El) or partially from the upper illuvial (Bt) soil horizons. Therefore, subsoil samples were taken from Bt horizons. In doing so, to ensure representative sampling, each soil sample represents a composite of 30 subsamples (thoroughly mixed together) taken from each plot using a spiral gauge auger.

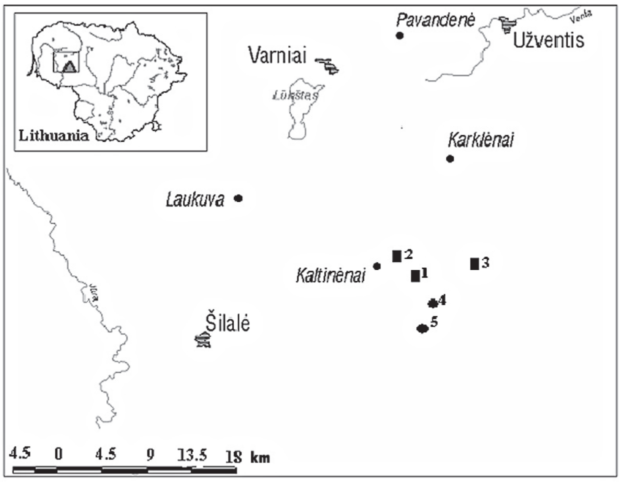

Fig. 1. Location of the Žemaičiai Uplands and the long-term field experiments (1–5) in Lithuania

1–3 are monitoring sites, duration 8 years; 4 and 5 are monitoring sites, duration 20 years

1 pav. Žemaičių aukštumos ir ilgalaikių lauko bandymų vieta (1–5) Lietuvoje.

1–3 – 8-ių metų trukmės lauko bandymai ir 4–5 – 20-ties metų trukmės lauko bandymai

Soil organic matter analyses

For SOM determination, each soil sample was sub-sampled, all visible plant and animal residues were removed and analysed by three separate techniques (performed in the laboratories of the LIA). These were: (a) the traditional U. K. method 'loss-on-ignition' (LoI) at 375 °C for 16 hours [1]; (b) the East European 'Tyurin titrimetric' (Tt) wet combustion method, where humified SOM is oxidized by 0.2 M solution of potassium dichromate with sulphuric acid by heating and excess dichromate is determined by titration with ammonium ferrous sulphate (Mohr's salt solution) [39, 40]; (c) the USDA Walkley–Black method (W–B) which is a wet combustion method similar to the Tyurin techniques, but without external heating [36].

'East European' soil texture analyses

Following the Kachinskiy technique (Kach.) [14, 20], particle size analysis was based on separation of the soil into various size fractions. This included the coarse fraction (>1.0 mm), but the main procedure was applied to the fine-earth fraction (<1.0 mm) only. The analytical procedure included, where appropriate, removal of carbonates using 10% HCl, sample dispersion in 0.5–1 ml NaOH solution, wet sieving using a 0.25 mm sieve and pipetting for fractions ≤0.05, ≤0.01, ≤0.005 and ≤0.001 mm according to precise time intervals and depth, depending on soil particle density. This enabled a standard range of textural parameters to be calculated, which included the percentage sand, silt and clay content of the East European size boundaries [6]. These analyses were performed at the Kaltinenai Research Station Laboratory and the Agrochemical Research Centre Laboratory of the LIA.

'Western' soil texture analyses

For laser diffraction, all analyses were based on bulk fine-earth (<2.0 mm) fraction samples and were subjected to the same textural preparation and analysis procedure, using sieving followed by laser-diffraction analysis [33]. Low Angle Laser Light Scattering (LALLS), using a Malvern Mastersizer Long-bed X with a MSX17 automated sample presentation unit, employs a 5 mW CW He–Ne laser with a wavelength of 632.8 nm as a light source. Measurements were taken on two separate lenses whose ranges overlap (45 mm: 0.1–80 µm, 1000 mm: 4–2000 µm and, once blended, enable measurement of particle sizes within the 0.1–2000 µm range [3]. These analyses were performed at the University of Wolverhampton.

The technique is based on the principle that, as a particle passes through a laser beam, light is diffracted and the diffraction angle is inversely proportional to particle size. This apparatus is based on Fourier-optics, and involves a laser light passing through cell windows that receive a constant flow of dilute sediment suspension. As the suspended particles travel through the laser beam, they cause the light to be diffracted, the resulting diffraction pattern being focused onto a series of detectors. The diffraction patterns received by the detectors are then averaged over a fixed time period and computed into particle size values. These values are then arranged into discrete size ranges given by the size of the detector areas. Unfortunately, this approach (using the Fraunhofer theory [2, 24]) assumes all particle sizes scatter with equal efficiencies and, furthermore, all particles are opaque and transmit no light. Since these assumptions are not always correct, the latest Malvern instrumentation and software is designed to compensate for these influences and (using Mie theory [2, 24]) allows the refractive index of the materials to be taken into account when calculating particle size values. In this case, soils usually are of mixed mineralogies and therefore have mixed refractive indices. The software routine used for the analytical presentation setting (2OHD) was advised by Malvern personnel as being the most appropriate settings for analysing samples consisting of mixtures with optically dissimilar materials [3].

Removal of organic matter preceded textural analyses and was adapted from Gale and Hoare [11]. Macroscopic traces of organic matter were physically removed from representative sub-samples before being treated with hydrogen peroxide (H_2O_2) until frothing ceased. The soil and H_2O_2 mixture was then allowed to evaporate to a thin, moist paste, before being wetted by a dropwise addition of a standard chemical dispersion solution (40 g of sodium hexa-metaphosphate ($(NaPO_3)_6$) per litre of distilled water) to help disaggregate particles. To ensure complete disaggregation, each soil slurry was then subjected to ultrasonic dispersion in the Malvern MSX17 automated sample presentation unit. For greater precision, the mean of five replicate analyses was measured with a mixed refractive indices presentation setting. Comparison of a standard range of textural parameters at the SSEW, USDA and East European size boundaries (the percentage sand, silt and clay content) is indicated in Table 1.

Table 1. **Particle size interval classes of the SSEW, USDA and Kachinskiy soil texture classification systems**

1 lentelė. **SSEW, USDA ir Kačinskio klasifikacinių sistemų dirvožemio granuliometrinės sudėties frakcijų intervalai**

Particle Size *Frakcijos*	SSEW (µm)	USDA (µm)	Kach. (µm)
Sand	60–2000	50–2000	50–1000
Silt	2–60	2–50	1–50
Clay	<2	<2	<1

Particle size analysis by the USDA method was based on separation of soil into various size fractions including gravel and coarser material, but the main procedure was applied to the fine-earth fraction (<2 mm) only. The procedure involves oxidation of OM by hydrogen peroxide (H_2O_2) 30%, removal of carbonates using hydrochloric acid (HCl) 1 M (if required), dispersion, separation of fractions, determination of sand fractions by dry sieving and determination of silt and clay fractions by pipette analysis. The procedures for oxidation of OM and carbonate removal were not used because of the low concentrations of SOM and calcium carbonate in these soil samples. Analyses were performed at the Laboratory of the Agrochemical Research Centre of the Lithuanian Institute of Agriculture (LIA), using the particle-size analysis method of ISRIC FAO [14].

Linear correlation and regression and paired regression between the data sets were calculated using STAT-ENG for EXCEL program version 1.55 [34].

RESULTS AND DISCUSSION

The particle size analysis results of the three investigated textural systems (SSEW, USDA and Kach.) were summarized comprehensively in 'Agricultural Sciences' by Booth et al. [3]. On the basis of the mean properties, for both the laboratory methods and the size classification systems, results show that the Kachinskiy technique underestimates percentage silt and overestimates percentage sand and clay, compared to the laser-diffraction technique and/or the USDA and SSEW textural schemes. However, the successful conversion of Kachinskiy generated East European data to laser-diffraction generated USDA and SSEW data by the *BOOTiFUL* protocol provides an opportunity to both adapt contemporary texture data sets and to harmonize the archive of Kachinskiy textural data with those of western classification systems [3].

Results show different soil particle size distributions among the experiments and between the upper (0–20 cm) and deeper (20–40 cm) soil layers in some trials (Table 2). Soil trials 2, 4 and 5 were sandy loams (according to the USDA classification [36]). In spite of the identical classifications for each trial, trial 2 soils contain only 5.9–7.3% clay, while soils of trials 4 and 5 contain 15.3–18.0% and 18.4–18.6% clay, respectively.

Some trial 2 soils are coarse loamy, while trial 5 soils are fine loamy [39]. Soils of trial 1 (both horizons) and trial 3 (only the top 0–20 cm horizon) were silty clay loams, whereas soils at 20–40 cm from trial 5 were silty clays [36]. These textural differences are particularly useful for evaluation of SOM content by various methods, as SOM content depends on climatic conditions, land use and soil texture. As mentioned in Introduction, clays and SOM are strongly associated due to their mutual attraction by surface charges, and the colloidal partnership between clays and SOM forms the chemical association of 'clay–humus complexes' and thus largely determines the soil C-carrying capacity [13, 26].

SOM data show significant differences also between the SOM analytical results (Table 3), but it is noteworthy that highly significant correlation coefficients exist among all investigated methods. Consequently, the possibility exists to generate transfer protocols from methods widely used in Eastern Europe to other protocols [16, 17]. Comparatively, both the loss-on-ignition and Walkley–Black techniques generate greater mean SOM estimates than both of the Tyurin titrimetric techniques. The textural and SOM data highlight an important technical issue and the problem of international comparison. This is because the strength and significance of any subsequent correlation or regression analyses will contrast, depending on the techniques (textural and organic) and textural classification systems used.

Soil texture data are of global importance, as they fundamentally affect the dynamic processes of SOM accumulation and interactions to form complexes and microaggregates. The awareness of differences between East European and Western textural analysis techniques is technically important for comparative studies, as this aids our understanding of C-sequestration, nutrient cycling and the biophysical attributes of land management systems. Therefore, depending on the way it is viewed, the sizeable underestimation by laser-diffraction method or overestimation by the Kachinskiy method of percentage sand, silt and clay content is extremely important for quantifying the C-sequestration potential of former-Soviet and East European soils.

Many correlation and regression analyses are possible while comparing results of different soil particle size fractions (sand, silt, clay) generated by different methods (SSEW, USDA, Kach) with SOM content analysed by different methods (W–B, LoI, Tt). Coefficients of linear correlation between all SOM data by each of the textural techniques and each of the particle size fractions (sand, silt and clay) were highly significant ($p < 0.001$; Table 3). However, variations existed in the strength of associations. For instance, SOM (LoI_K data) with each of the textural techniques showed the strongest correlation ($r = 0.877$–0.762), whereas the weakest were between SOM W–B data ($r = 0.645$–0.408), and only a slightly stronger correlation was obtained using SOM Tt data ($r = 0.674$–0.467). Moreover the correlation coefficients were notably lower between SOM by W–B and Tt with the clay fraction by Kachinskiy and USDA, compared with sand and silt fractions.

Both cited references [13, 26] and our data suggest the need to pay closer attention to analysing the relationships between SOM and clay content. Table 4 shows modified power paired regression parameters between SOM (X) content and clay fraction (Y). Separate analyses of topsoil (0–0.2 m) and subsoil (0.2–0.4 m) data illustrate high probability values (Fisher's test

Table 2. **Particle size distribution of study *Eutric Albeluvisols* determined by the USDA method**

2 lentelė. **Tyrinėtų pasotintųjų balkšvažemių granuliometrinės sudėties frakcijų pasiskirstymas analizavus USDA metodu**

Site number and depth (m) ***Bandymo nr. ir gylis (m)***	**n**	**Particle size / *Frakcijų dydžiai* (mm)**					
		Sand / *Smėlis* (2.0–0.5)		**Silt / *Dulkės* (0.50–0.002)**		**Clay / *Molis* (<0.002)**	
		Mean / *Vidurkis* %	**SD**	**Mean / *Vidurkis* %**	**SD**	**Mean / *Vidurkis* %**	**SD**
1. 0–0.2	10	17.7	4.61	52.9	3.09	29.4	2.47
1. 0.2–0.4	10	15.4	7.07	49.5	5.54	35.1	4.65
2. 0–0.2	10	65.6	1.94	28.5	1.90	5.9	0.50
2. 0.2–0.4	10	62.7	5.01	30.0	3.59	7.3	1.82
3. 0–0.2	10	18.3	1.96	46.0	1.60	35.7	3.08
3. 0.2–0.4	10	11.3	3.38	45.6	3.89	43.1	5.79
4. 0–0.2	8	57.9	2.56	26.8	1.29	15.3	2.51
4. 0.2–0.4	8	56.2	3.44	25.8	2.06	18.0	1.96
5. 0–0.2	8	54.2	2.58	27.4	1.04	18.4	2.70
5. 0.2–0.4	8	54.1	2.28	27.3	1.31	18.6	2.09
1–5. 0–0.2	46	41.6	21.19	37.1	11.22	21.3	11.13
1–5. 0.2–0.4	46	38.6	22.82	36.4	10.54	25.0	13.78

*SD = standard deviation / *Standartinis nuokrypis*.

Table 3. **Coefficients (*r*) of linear correlation between analytical results of SOM and the textural classification systems of the Kachinskiy, SSEW and USDA approaches ($n = 92$)**

3 lentelė. **Linijinės koreliacijos tarp dirvožemio organinės medžiagos ir dirvožemio granuliometrinės sudėties duomenų, gautų Kačinskio, SEEW ir USDA metodais koeficientai (*r*) ($n = 92$)**

Analytical technique and soil property *Analizavimo metodai ir frakcijos*		**Linear correlation** *Linijinė koreliacija*		**Mean** *Vidurkiai*	**SD**	**CV**
X	**Y**	**r**	**Sr. t_{05}**	**X ± m**		**%**
LoI$_K$	Kach. Sand	–0.859***	± 0.054	2.93 ± 0.105	1.01	34.40
LoI$_K$	Kach. Silt	0.848***	± 0.056			
LoI$_K$	Kach. Clay	0.762***	± 0.068			
LoI$_K$	SSEW Sand	–0.877***	± 0.051			
LoI$_K$	SSEW Silt	0.840***	± 0.057			
LoI$_K$	SSEW Clay	0.872***	± 0.052			
LoI$_K$	USDA Sand	–0.838***	± 0.057			
LoI$_K$	USDA Silt	0.810***	± 0.062			
LoI$_K$	USDA Clay	0.764***	± 0.068			
W–B	Kach. Sand	–0.521***	± 0.09	2.144 ± 0.077	0.74	34.49
W–B	Kach. Silt	0.531***	± 0.089			
W–B	Kach. Clay	0.438***	± 0.095			
W–B	SSEW Sand	–0.590***	± 0.085			
W–B	SSEW Silt	0.540***	± 0.089			
W–B	SSEW Clay	0.645***	± 0.081			
W–B	USDA Sand	–0.487***	± 0.092			
W–B	USDA Silt	0.512***	± 0.091			
W–B	USDA Clay	0.408***	± 0.096			
Tt.	Kach. Sand	–0.611***	± 0.083	1.838 ± 0.071	0.68	36.82
Tt.	Kach. Silt	0.655***	± 0.080			
Tt.	Kach. Clay	0.468***	± 0.093			
Tt.	SSEW Sand	–0.655***	± 0.080			
Tt.	SSEW Silt	0.618***	± 0.083			
Tt.	SSEW Clay	0.674***	± 0.078			
Tt.	USDA Sand	–0.573***	± 0.086			
Tt.	USDA Silt	0.618***	± 0.083			
Tt.	USDA Clay	0.467***	± 0.093			

*** All values have a significance level $P < 0.001$ / *Visų reikšmių patikimumo lygis* $P < 0{,}001$.

$P \le 0.01$, high multiple regression coefficients ($r = 0.67$–0.97), a strong correlation and determination of XY values). SOM results (analysed by loss-on-ignition) show the strongest association between clay fractions (analysed by all soil texture methods studied). Notably higher SOM and clay relationship values were calculated for deeper (0.2–0.4 m) soil layers than for arable topsoil using all presented soil texture and SOM analytical methods. The regression coefficients were lowest for SOM data analysed by Tt and W–B methods and clay fractions analysed by the Kachinskiy method.

Irrespective of whether considering topsoil, subsoil (Table 4) or the entire soil database (Figs. 2 and 3, Table 5), texture and SOM regression coefficients were higher for the data generated by the loss-on-ignition technique than by the other methods. Furthermore, the texture and SOM regression coefficients were higher for subsoil than for topsoil. A plausible explanation is that topsoils contain more plant residues, with few penetrating the subsoil. Thus, the association between texture and humus is stronger in subsoils.

Comparison of results presented in Figs. 2 and 3 demonstrate quite strong, even linear, relationships between SOM data and sand fractions analysed by the SSEW method, when modified power and power regressions show regression coefficients to equal 1.

The parameters of modified power paired regression between all SSEW, USDA and Kachinskiy textural data with SOM data analysed by loss-on-ignition were much higher ($R^2 = 0.74$–0.84; $t = 10.38$–14.67), than that with Tiurin titrimetrical ($R^2 = 0.31$–0.5; $t = 3.05$–5.5) or Walkley-Black ($R^2 = 0.24$–0.4; $t = 2.33$–4.1) techniques (Table 5). Furthermore, there are no differences between sand, silt or clay fractions.

The relevance of these findings to other studies is the weaker correlation coefficients of the Kachinskiy data with SOM than the laser-diffraction SSEW data indicate correlations between East European texture and SOM correlation data are probably, in fact, much stronger than those presented in previous Soviet and East European literature. Furthermore, the Kachinskiy data shows the correlation of clay content with SOM to be much

Table 4. **Paired regression relationship between SOM (X) content and clay fraction (Y) of soil texture (*n* = 46)**

4 lentelė. **Porinės regresijos ryšiai tarp dirvožemio organinės medžiagos kiekio (X) ir dirvožemio granuliometrinės sudėties molio frakcijos procento (Y) (*n* = 46)**

SOM analytical method and depth (m) ***DOM analizavimo metodai ir gylis (m)***	**Paired regression (type)** ***Porinės regresijos tipas***	**R^2**	**Fisher's test** ***Fišerio kriterijus***	**Correlation** ***Koreliacijos*** **XY**	**Determination** ***Determinacijos*** **XY**	**Multiple** ***Daugianarė*** **R**
			Kachinskiy method			
$\mathrm{T_t}$ 0–0.2	M.P.	0.445	35.31**	0.57 ± 0.123	0.33	0.67
$\mathrm{T_t}$ 0.2–0.4	M.P.	0.732	120.41**	0.72 ± 0.104	0.52	0.86
W–B 0–0.2	M.P.	0.514	46.6**	0.66 ± 0.113	0.44	0.72
W–B 0.2–0.4	M.P.	0.571	58.58**	0.64 ± 0.116	0.41	0.76
$\mathrm{LoI_K}$ 0–0.2	M.P.	0.816	195.21**	0.81 ± 0.087	0.66	0.90
$\mathrm{LoI_K}$ 0.2–0.4	M.P.	0.919	497.07**	0.91 ± 0.061	0.83	0.96
			SSEW method			
$\mathrm{T_t}$ 0–0.2	M.P.	0.655	83.62**	0.72 ± 0.105	0.52	0.81
$\mathrm{T_t}$ 0.2–0.4	M.P.	0.769	146.48**	0.79 ± 0.092	0.63	0.88
W–B 0–0.2	M.P.	0.634	76.13**	0.72 ± 0.105	0.52	0.80
W–B 0.2–0.4	M.P.	0.713	109.32**	0.77 ± 0.095	0.60	0.84
$\mathrm{LoI_K}$ 0–0.2	M.P.	0.969	1370.14**	0.89 ± 0.069	0.79	0.98
$\mathrm{LoI_K}$ 0.2–0.4	M.P.	0.897	381.94**	0.91 ± 0.062	0.83	0.95
			USDA method			
$\mathrm{T_t}$ 0–0.2	M.P.	0.658	84.59**	0.64 ± 0.116	0.41	0.81
$\mathrm{T_t}$ 0.2–0.4	M.P.	0.938	6.22**	0.72 ± 0.104	0.52	0.97
W–B 0–0.2	M.P.	0.646	80.34**	0.68 ± 0.111	0.46	0.80
W–B 0.2–0.4	M.P.	0.690	98.05**	0.62 ± 0.118	0.39	0.83
$\mathrm{LoI_K}$ 0–0.2	Linear^a	0.760	139.34**	0.87 ± 0.073	0.76	0.87
$\mathrm{LoI_K}$ 0.2–0.4	Linear^a	0.823	204.42**	0.91 ± 0.063	0.82	0.91

$\mathrm{T_t}$: Tyurin titrimetric / *Tiurino titrimetrinis*; W–B: Walkley–Black; $\mathrm{LoI_K}$: Loss-on-ignition (Kaltinėnai) / *Kaitinimo nuostolių*; MP: modified power / *Parodomoji*; Linear^a, when M. P. R^2 was 1 / *Linijinė, kai M. P. $R^2 = 1$.* ** Significance level / *Patikimumo lygis* $P \leq 0.01$.

Table 5. **Parameters of modified power paired regression between soil texture fractions and different sets of SOM analytical data (*n* = 92)**

5 lentelė. **Parodomosios porinės regresijos tarp dirvožemio granuliometrinės sudėties frakcijų ir skirtingų dirvožemio organinės medžiagos analizavimo metodų rodikliai (*n* = 92)**

Soil textural methods ***Granuliometrinės sudėties metodai***	**Particle size fractions** ***Granuliometrinės sudėties frakcijos*** **(X)**	**SOM methods / *DOM metodai* (Y)**		
		$\mathrm{LoI_K}$	**W–B**	**$\mathrm{T_t}$**
SSEW	Sand	$R^2 = 0.83$; $t = 14.09$	$R^2 = 0.40$; $t = 4.10$	$R^2 = 0.46$; $t = 4.95$
	Silt	$R^2 = 0.76$; $t = 10.99$	$R^2 = 0.34$; $t = 3.48$	$R^2 = 0.42$; $t = 4.40$
USDA	Clay	$R^2 = 0.84$; $t = 14.67$	$R^2 = 0.29$; $t = 2.85$	$R^2 = 0.50$; $t = 5.50$
	Sand	$R^2 = 0.79$; $t = 12.32$	$R^2 = 0.30$; $t = 2.93$	$R^2 = 0.38$; $t = 3.92$
	Silt	$R^2 = 0.78$; $t = 11.63$	$R^2 = 0.31$; $t = 3.07$	$R^2 = 0.40$; $t = 4.19$
Kachinskiy	Clay	$R^2 = 0.74$; $t = 10.38$	$R^2 = 0.24$; $t = 2.33$	$R^2 = 0.31$; $t = 3.05$
	Sand	$R^2 = 0.83$; $t = 14.01$	$R^2 = 0.33$; $t = 3.34$	$R^2 = 0.42$; $t = 4.45$
	Silt	$R^2 = 0.81$; $t = 12.99$	$R^2 = 0.34$; $t = 3.42$	$R^2 = 0.46$; $t = 4.95$
	Clay	$R^2 = 0.76$; $t = 11.09$	$R^2 = 0.27$; $t = 2.67$	$R^2 = 0.32$; $t = 3.18$

All presented relationships have a significance level of / Visų pateiktųjų priklausomybių patikimumo lygis yra $P \leq 0.01$. $\mathrm{LoI_K}$: loss-on-ignition / Kaitinimo nuostolių, Kaltinėnai; W–B: Walkley–Black; $\mathrm{T_t}$: Tyurin titrimetrical / Tiurino titrimetrinis; R^2: regression coefficient / regresijos koeficientas; t: R^2Y/X.

weaker than the correlation of both sand and silt content with SOM. In doing so, this indicates the Kachinskiy technique and / or the East European texture scheme may be less reliable in determining linkages between texture and SOM.

Results indicate important technical issues and problems of international comparison, because notable differences exist between SOM and soil textural analytical techniques and between national texture classification systems. The concomitant effect is that correlation coefficients between these various data can produce contrasting trends. This highlights difficulties of international comparison, especially where non-identical methodologies are used, and, in the case of Kachinskiy data, its comparative unreliability for determining SOM and texture linkages. Therefore, it is proposed, calibration protocols may be used as

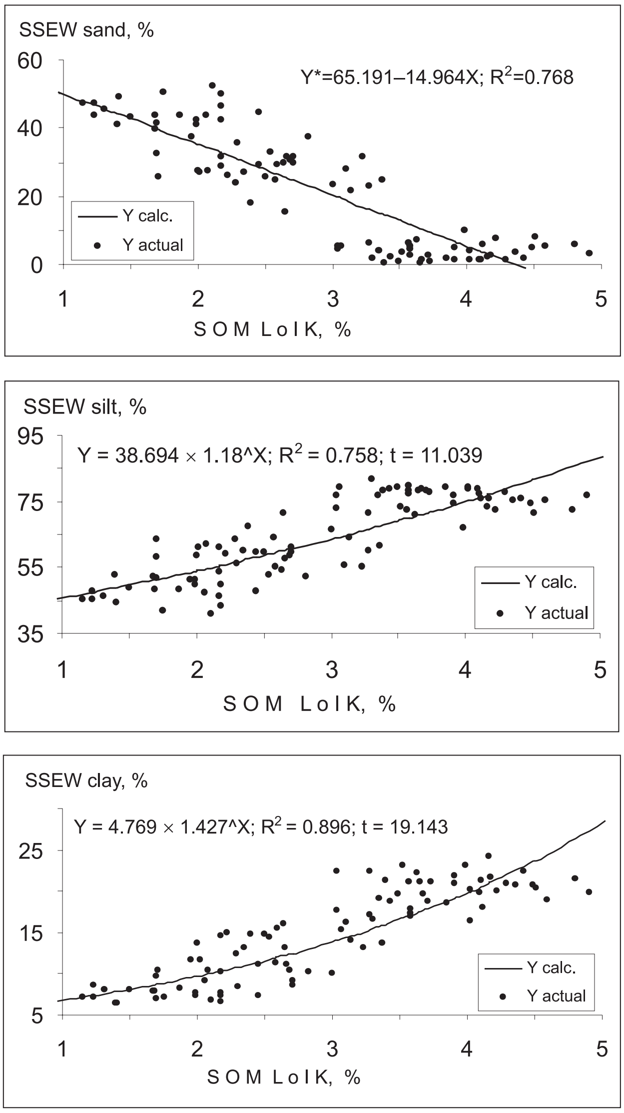

Fig. 2. Association between SOM content and soil textural data (sand, silt and clay) located in increasing order, evaluated by linear* and modified power paired regressions on Eutric Albeluvisol samples. *Linear regression was used because power and modified power regressions showed $R^2 = 1$

2 pav. Linijiniai ir parodomosios porinės regresijos ryšiai tarp pasotintųjų balkšvažemių ($a = 92$) dirvožemio organinės medžiagos kiekio, išdėstyto didėjančia tvarka, ir dirvožemio granuliometrinės sudėties (smėlio, dulkių, molio) frakcijų procento. *Linijinė regresija skaičiuota tuo atveju, kai parodomoji ir laipsninė regresijos rodė $R^2 = 1$

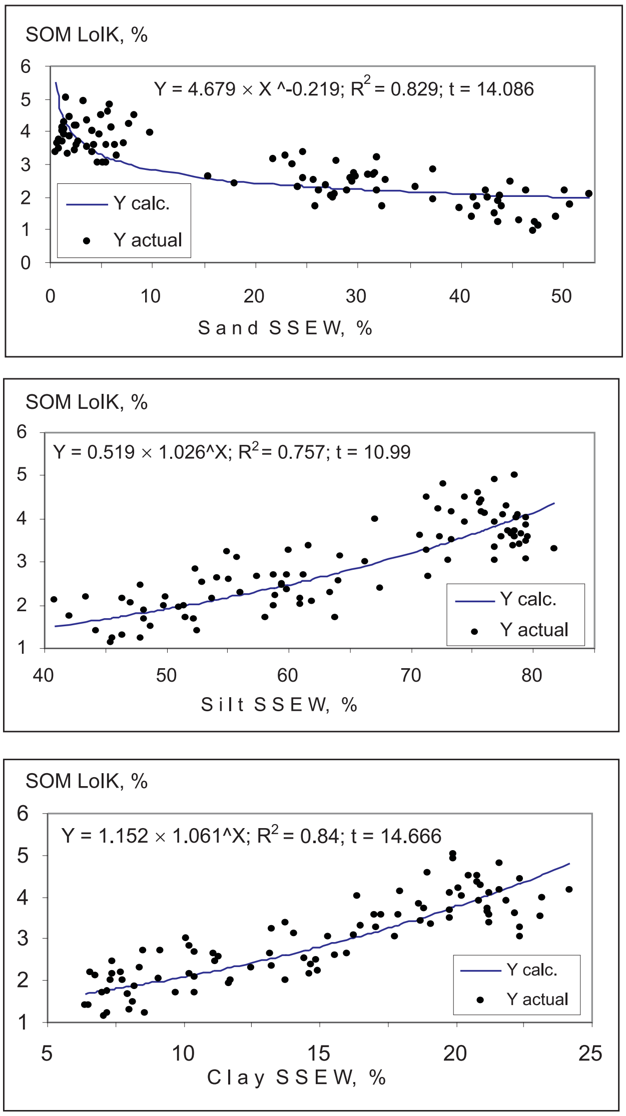

Fig. 3. Association between soil textural data (sand, silt and clay) and SOM content, located in increasing order, evaluated by modified power paired regression on Eutric Albeluvisols ($n = 92$ samples)

3 pav. Parodomosios porinės regresijos ryšiai tarp pasotintųjų balkšvažemių granuliometrinės sudėties (smėlio, dulkių, molio) frakcijų, išdėstytų didėjančia tvarka, procento ir dirvožemio organinės medžiagos kiekio ($n = 92$)

predictive tools for estimating the potential and rate of soil C-storage. The primary calibration protocols for soil texture data and equations for transferring SOM data have been published [3, 17, 18]. Division of the database also highlights the complexity of textural and SOM associations. This promotes concerns about the ability to cross-reference between laboratory databases and also the need to be aware of the differences not only between textural techniques and classification systems, but also the variation between the techniques used to measure SOM. Despite the entire textural analyses being conducted on the same samples, Tables 3, 4 and 5 emphasize the technical problem of international comparison of national soil texture datasets. This highlights the need for an internationally adopted universal soil texture system or to continue the development of soil texture transfer functions between the analytical protocols currently employed by West and East European laboratories.

CONCLUSIONS

1. Notable differences exist between soil texture results and national texture classification systems, which highlight a comparative overestimate of clay content using the Kachinskiy approach.

2. There are notable differences between data obtained by three different techniques of SOM analysis, however, a highly significant correlation and paired regression coefficients exist among all the study methods.

3. The strongest linear correlation associations exist between SOM analysed by the loss-on-ignition method with each of the textural techniques and with each of the particle size fractions

(sand, silt and clay) ($r = 0.877–0.762$), and notably weaker relationships were obtained using SOM Walkley–Black and Tyurin titrimetrical data ($r = 0.674–0.408$; all $n = 92$, $p < 0.001$).

4. The relationships of paired regression among all SSEW, USDA and Kachinskiy textural data with SOM data analysed by the loss-on-ignition technique were much stronger ($R^2 = 0.74–0.84$) than by the Tyurin titrimetrical ($R^2 = 0.31–0.5$) or Walkley–Black ($R^2 = 0.24–0.4$) techniques.

5. Topsoil samples showed lower correlation coefficients between SOM and texture than did subsoil samples. A plausible explanation is that topsoils contain more plant residues in different stages of decomposition, while subsoil SOM consists mostly of specific humic substances.

6. This research highlights the need of an internationally adopted universal soil texture system or of continuing the development of texture transferable functions between the analytical protocols used by West and East European laboratories.

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LIETUVOS ERODUOTŲ PASOTINTŲJŲ BALKŠVAŽEMIŲ GRANULIOMETRINĖS SUDĖTIES IR ORGANINĖS MEDŽIAGOS KIEKIO TARPUSAVIO RYŠIAI

Santrauka

Dirvožemio organinės medžiagos (DOM) kiekiui ir granuliometrinei sudėčiai įvertinti taikomi įvairūs metodai. Be to, egzistuoja kelios nacionalinės dirvožemio granuliometrinės sudėties klasifikavimo sistemos su skirtingais dalelių dydžių intervalais. Dėl to kyla tarptautinio duomenų palyginamumo problemų, ypač įvertinant artimų granuliometrinės sudėties frakcijų vaidmenį dirvožemio anglies sekvestravimui. Straipsnyje pateikiami dirvožemio organinės medžiagos ir jo granuliometrinės sudėties duomenys, gauti išanalizavus 92 pasotintojo balkšvažemio (*Eutric Albeluvisols*) mėginius (46 iš viršutinio ir tiek pat iš apatinio dirvožemio sluoksnių), kurie paimti iš 46-ių Lietuvos žemdirbystės instituto Kaltinėnų bandymų stoties ilgalaikių lauko bandymų laukelių. Tyrimų duomenys parodė glaudžią patikimą koreliacijos ir porinės regresijos priklausomybę tarp duomenų, gautų analizuojant DOM Tiurino titrimetriniu, kaitinimo (LOI) ir Walkley–Black metodais, o granuliometrinę sudėtį Didžiosios Britanijos (SSEW), JAV (USDA) ir Rytų Europos (Kačinskio) metodais. Rezultatai atskleidė tarptautinio masto duomenų palyginamumo technines problemas, kylančias dėl ženklių skirtumų tarp analizavimo metodų ir nacionalinių dirvožemio granuliometrinės sudėties klasifikavimo sistemų. Tai sąlygoja kontrastiškas koreliacijos koeficientų kaitos tendencijas tarp įvairių duomenų ir atskleidžia sunkumus nustatant organinės medžiagos ir granuliometrinės sudėties sąsajas, kai naudojamos netapačios metodikos, ypač Kačinskio metodo taikymo atveju. Nustatytieji priklausomybės ryšiai gali būti panaudoti dirvožemio anglies kaupimo (pagal tarptautinę terminologiją – „sekvestravimo“) galimybių prognozavimui.

Raktažodžiai: pasotintieji balkšvažemiai (*Eutric Albeluvisols*), dirvožemio granuliometrinė sudėtis; dirvožemio organinė medžiaga, anglies kaupimas (sekvestravimas)

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ВЗАИМООТНОШЕНИЯ МЕЖДУ ГРАНУЛОМЕТРИЧЕСКИМ СОСТАВОМ И СОДЕРЖАНИЕМ ОРГАНИЧЕСКОГО ВЕЩЕСТВА В ЭРОДИРОВАННЫХ ПОДЗОЛИСТЫХ ПОЧВАХ ЛИТВЫ

Резюме

Содержание органического вещества почвы (ОВП) и ее гранулометрический состав определяются несколькими методами. Кроме того, на национальном уровне существуют различия интервалов частиц в классификационных системах гранулометрического состава почв. Это осложняет международное сопоставление данных, особенно при анализе близких связей между ОВП и гранулометрическим составом почвы, и затрудняет использование этих данных для других целей, например, при оценке секвестрации углерода в почве.

В статье представлены данные гранулометрического состава и количества ОВП 92 образцов дерново-подзолистой почвы (*Eutric Albeluvisols*) (46 из пахотного слоя и 46 из подпахотного), собранных с 46 делянок многолетних полевых опытов на Кальтиненской опытной станции Литовского института земледелия. Результаты показывают достоверную корреляцию и регрессию парных связей между данными полученными разными методами определения ОВП (титриметрический Тюрина, метод накаливания (LOI) и Валклеи–Бляк) и гранулометрического состава почвы (Служба почв Англии и Уэльса (SSEW), USDA и Качинского). Однако результаты свидетельствуют о существовании важных технических вопросов и проблем международных сопоставлений из-за методических различий в определении ОВП и гранулометрического состава почвы. Сопутствующий эффект состоит в том, что коэффициенты корреляции между этими различными данными могут привести к контрастным тенденциям. Это подчеркивает сложность международных сопоставлений, особенно при использовании неидентичных методологий и в случае данных, полученных по методу Качинского. Установленные связи могут быть использованы в качестве средств прогнозирования потенциала и темпов секвестрации углерода.

Ключевые слова: дерново-подзолистые почвы (*Eutric Albeluvisols*), гранулометрический состав почв, органическое вещество почв, секвестрация углерода