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Original Research

Influence of the Geological Origin of the Parent Rock on the Distribution of Total Calcium in Particular Granulometric Fractions

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Abstract

The content of total calcium in particular granulometric fractions is in most cases not correlated with particle size. In soil developed from boulder loam, total Ca content in the analyzed grain sizes increases with depth due to the presence of $CaCO_3$ below 100 cm. In turn, in soil developed from old-alluvial deposits, in which $CaCO_3$ was not noted, Ca content does not reveal any regularity in the particular fractions. The total calcium content in particular fractions depends on the leaching process and the origin and properties of the parent rock.

Keywords: granulometric fraction, total calcium content, boulder loam, old-alluvial deposit.

Introduction

Calcium is the fifth element in relation to its quantity among the main components of the Earth's crust [1] and reaches an average of 35.4 g/kg. Its content, however, is extremely variable in soils. This results from the petrographic and mineralogical variability of the surface deposits from which soils developed [2-11].

Minerals containing calcium are rather unstable in the soil environment and easily undergo weathering processes. Therefore, this element is one of the most labile components of the soil environment. In the climatic conditions of Poland it shifts beyond the soil profile by an average of 200-300 kg per year per surface of 1 ha.

In Polish literature there is only one paper published where the chemical composition of all granulometric fractions isolated from soil developed from sands are described [10]. Numerous analyses were carried out in turn to observe the content of calcium in colloidal clay [12-18].

The purpose of the present study was to investigate total content of calcium in granulometric fractions of two soils characterized by the same pedogenetic process but developed from different parent rock materials. The first profile is represented by leached brown soil developed from boulder loam of the Middle Polish Glaciations (Wartanian Stadial — Gąbin) and the second, leached brown soil developed from old-alluvial deposits of the Vistulian valley (Kazuń Polski).

Material and Methods

The humus content was determined using Tiurin' s method, hydrolytic acidity using Kappen' s method, exchangeable alkaline cations were extracted in 1M CH_3COONH_4 and determined using Atomic Absorption Spectrometry (AAS).

The granulometric fractions were separated using the Attenberg method without using chemical compounds in peptization. Peptization was carried out using the thermal-

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mechanical method, boiling soil and mixing it with a rotor stirrer. The process of boiling and mixing was repeated until the fraction <0.002 mm was completely separated; this was further evaporated to a dry state in a water bath. During separation of the remaining fractions (>0.002mm), water was removed from above the deposited fraction by decantation and used for further separation, whereas the fractions were dried in a water bath. Sand fraction (1-0.1 mm) after drying was isolated on sieves. The granulometric composition of the analyzed soils was calculated from the content of the isolated fractions.

The isolated fractions were melted with Na_2CO_3, and after precipitation and removing SiO_2 using the Giedroic method in solutions, Ca was determined using AAS.

The bulk density of the fractions indispensable in calculating the Ca balance in the profile was determined by the fill method using a cylinder of 100 ml volium. The determination was repeated 3-5 times for accuracy.

General Characteristics of Soils

The soil from Gąbin is developed from heavy boulder loam, with admixture sand down to 50 cm attained during periglacial processes. Therefore, its surface horizons A and Bbr show a grain size typical of light loam (Table 1). All horizons of this soil reveal a large admixture of the silt fraction (0.1-0.02 mm) and in some horizons siltiness is observed. The content of coarse and medium sand fraction in horizons of heavy loam (below 50 cm depth) is low, and the sand content (1-0.1 mm) decreases with depth. The dominating fraction in this soil is colloidal clay <0.002 mm, with the exception of surface soil horizons to 50 cm of depth.

The granulometric composition of the old-alluvial soil is strongly variable in particular genetic horizons and layers (Kazuń Polski) (Table 1). Until 150 cm of depth siltiness, with intercalations of typical silt at 70-90 cm is observed. The remaining horizons down to 150 cm are silty light loams. Below 150 cm occurs loamy sand, underlain below 175 cm by slightly loamy sand. Loam and silt layers contain very low quantities of coarse sand (1-0.5 mm) as well as small amounts of medium sand (0.5-0.25 mm). The entire profile is dominated by the fine sand fraction (0.25-0.1 mm).

The analyzed soils indicate a low content of C-org., which decreases gradually with the depth of profile (Table 2). The acidic or low-acidic reaction in the surface horizons of both analyzed soils passes gradually with the depth of profile into a neutral reaction. Similarly, in both soils, the saturation of the soil sorption complex by alkaline cations (Vs) with the prevalence of Ca and Mg increases with depth (Table 2). Thus, both soils were classified as leached brown soils. The sorption capacity is distinctly variable in the particular horizons and layers of both soils.

Results and Discussion

Total Calcium in Particular Granulometric Fractions

The distribution of calcium in the isolated granulometric fractions does not show any regularity (Table 3). There is no distinct correlation between the diameter of the soil particles and total calcium content. Within the solid phase of the soil, only a slight increase of the calcium content with decrease of grain size is observed. Thus,

Table 1. Texture of soils.

Locality	Horizon	Depth [cm]	% Content fractions of diameter in [mm]									
			1-0.5	0.5-0.25	0.25-0.1	0.1-0.05	0.05-0.02	0.02-0.01	0.01-0.005	0.005-0.002	<0.002	<0.02
Leached brown soil developed from boulder loam												
Gąbin County Gostynin	A	0-25	5.7	14.7	35.6	15.4	8.6	4.3	4.3	4.2	7.2	20.0
	Bbr(t.fe)	25-50	4.4	11.8	29.6	18.5	7.5	5.6	5.5	6.2	10.5	27.8
	Bbr	50-75	1.5	2.7	19.2	14.8	6.7	5.5	7.3	9.4	32.9	55.1
	BbrC	75-100	1.3	4.6	16.8	13.7	6.0	7.0	7.7	9.1	33.8	57.6
	Cca	100-125	1.6	4.8	9.5	21.8	3.6	6.4	8.3	10.8	33.2	58.7
	Cca	125-150	1.8	5.2	14.6	13.3	6.9	8.8	8.6	8.0	32.8	58.2
	Average		2.7	7.3	20.9	16.3	6.6	6.3	7.0	8.0	25.0	49.2
Leached brown soil developed from old-alluvial sediment												
Kazuń Polski County Nowy Dwór Mazowiecki	A	0-25	1.1	7.1	33.2	13.2	17.9	6.7	4.3	3.5	13.0	27.5
	ABbr	25-50	1.2	6.3	34.9	13.3	18.9	6.5	3.0	3.5	12.4	25.4
	Bbr(t.fe)	50-70	0.4	3.8	27.7	13.0	15.6	6.2	3.4	4.1	25.8	39.5
	BbrC	70-90	0.2	1.0	30.6	34.8	11.6	2.1	2.3	1.6	15.8	21.8
	C	90-120	0.1	2.7	48.6	14.6	14.5	2.7	1.7	1.4	13.6	19.4
	C	120-150	0.4	5.0	39.9	16.3	18.4	3.0	1.9	2.4	12.7	20.0
	IIC	150-175	0.3	20.2	46.4	11.0	6.7	10.0	0.6	1.0	3.8	15.4
	IIC	175-200	0.2	26.1	52.7	10.2	4.6	0.8	0.4	0.6	4.4	6.2
	Average		0.5	9.0	39.3	15.8	13.5	4.8	2.2	2.3	12.7	21.7

Table 2. Some physicochemical properties of soils.

Locality	Horizon	Depth [cm]	pH		cmol(+)/kg of soil							BS	C	$CaCO_3$
			H_2O	KCl	Ca^{+2}	Mg^{+2}	K^+	Na^+	TEB	H	CEC	%		
Leached brown soil developed from boulder loam														
Gąbin County Gostynin	A	0-25	5.6	5.3	2.40	0.16	0.58	0.06	3.20	2.50	5.70	56.1	1.06	0.00
	Bbr(t.fe)	25-50	5.7	5.0	2.17	0.20	0.20	0.09	2.66	2.74	5.40	49.2	0.24	0.00
	Bbr	50-75	5.4	4.3	8.50	1.02	0.26	0.22	10.00	3.00	13.00	76.9	0.27	0.00
	BbrC	75-100	6.1	4.9	9.20	1.03	0.30	0.26	10.79	2.10	12.74	84.1	0.19	0.00
	Cca	100-125	7.3	6.5	21.25	1.45	0.31	0.45	23.46	1.10	24.56	95.5	0.20	1.27
	Cca	125-150	7.6	6.7	25.30	1.15	0.26	0.48	27.19	1.00	28.20	96.5	0.14	3.82
Leached brown soil developed from old-alluvial sediment														
Kazuń Polski County Nowy Dwór Mazowiecki	A	0-25	5.0	4.0	2.17	0.78	0.10	0.14	3.19	2.84	6.03	52.9	0.70	0.00
	ABbr	25-50	5.4	4.1	3.60	1.47	0.11	0.23	5.41	2.47	7.88	68.6	0.19	0.00
	Bbr(t.fe)	50-70	5.6	4.1	6.30	2.13	0.14	0.30	8.87	2.28	11.15	79.5	0.18	0.00
	BbrC	70-90	5.7	4.2	7.80	2.37	0.17	0.47	10.81	2.81	13.62	79.4	0.17	0.00
	C	90-120	5.7	4.2	4.82	1.00	0.11	0.63	6.56	1.62	8.18	80.2	0.05	0.00
	C	120-150	5.5	4.1	6.15	1.08	0.14	0.63	8.00	1.50	9.50	84.2	0.07	0.00
	IIC	150-175	6.4	5.5	4.83	1.00	0.10	0.45	6.37	0.82	7.20	88.6	0.02	0.00
	IIC	175-200	6.9	6.1	2.87	0.40	0.07	0.09	3.43	0.50	3.93	87.3	0.01	0.00

Table 3. Content of total calcium in granulometric fractions.

Locality	Horizon	Depth [cm]	Content of Ca [g/kg] in fractions of diameter in [mm]									
			1-0.5	0.5-0.25	0.25-0.1	0.1-0.05	0.05-0.02	0.02-0.01	0.01-0.005	0.005-0.002	<0.002	in whole soil mass
Leached brown soil developed from boulder loam												
Gąbin County Gostynin	A	0-25	0.18	0.15	0.24	0.34	0.45	0.52	0.60	0.66	2.00	0.53
	Bbr(t.fe)	25-50	0.14	0.21	0.16	0.28	0.36	0.37	0.43	0.50	1.78	0.67
	Bbr	50-75	0.43	0.36	0.43	0.50	1.00	1.07	1.00	2.00	6.67	2.75
	BbrC	75-100	4.05	2.48	2.20	2.77	2.48	4.97	3.98	8.45	8.45	6.46
	Cca	100-125	8.45	2.77	1.07	2.00	4.05	6.18	5.18	17.04	8.95	7.67
	Cca	125-150	30.03	8.45	9.86	12.57	27.34	39.05	20.09	18.46	11.15	18.86
Average		0-150	7.21	2.40	2.33	3.08	5.95	8.69	5.21	7.85	6.50	6.16
Leached brown soil developed from old-alluvial sediment												
Kazuń Polski County Nowy Dwór Mazowiecki	A	0-25	0.24	0.78	0.81	1.30	2.30	2.07	3.00	5.00	5.42	2.12
	ABbr	25-50	0.32	2.91	2.51	2.85	1.28	3.52	4.21	4.27	5.30	2.86
	Bbr(t.fe)	50-70	2.72	6.72	3.02	1.20	1.00	3.31	3.07	3.82	4.00	3.11
	BbrC	70-90	1.48	2.54	1.21	2.00	5.70	5.00	5.65	3.86	2.31	2.47
	C	90-120	1.36	2.52	1.50	1.92	2.41	1.92	4.52	4.00	5.35	2.18
	C	120-150	0.84	0.75	1.00	1.00	2.46	2.11	9.40	5.04	1.35	1.62
	IIC	150-175	1.00	1.04	1.82	1.81	4.02	3.00	2.72	4.48	3.53	2.30
	IIC	175-200	0.96	1.03	1.18	1.78	1.27	3.71	5.03	5.23	5.21	1.48
Average		0-200	1.11	2.29	1.63	1.73	2.55	3.08	4.70	4.46	4.06	2.27

Table 3a. Variation coefficients of total Ca content in granulometric fractions of genetic horizons.

Horizons	fractions of diameter in [mm]								
	1-0.5	0.5-0.25	0.25-0.1	0.1-0.05	0.05-0.02	0.02-0.01	0.01-0.005	0.005-0.002	<0.002
Leached brown soil developed from boulder loam									
A + Bbr + BbrC – without $CaCO_3$	51.6	10.8	39.1	25.6	47.1	46.1	35.6	64.0	64.8
Cca + Cca – with $CaCO_3$	78.7	58.4	89.3	79.3	100.7	94.2	75.1	30.2	12.3
Leached brown soil developed from old-alluvial sediment									
A + C + IIC - without $CaCO_3$	64.8	81.9	52.1	9.6	58.4	31.5	43.0	11.8	35.9

it can be stated that the distribution of this element in particular fractions is rather chaotic. This results from its high lability in the soil environment. Calcium forms concretions of different diameter in the carbonate horizons. Often, grains of the sand fraction are composed of $CaCO_3$ and not of quartz [19], therefore its content in the particular fractions is unpredictable and random.

In soil developed from boulder loam (Gąbin) increase of total Ca content is observed in particular fractions of the soil profile. This results from leaching processes and translocation of $CaCO_3$ to deeper horizons. This regularity is not noted in the case of the old-alluvial soil in Kazuń due to its layered structure and lack of $CaCO_3$, which was probably dissolved in the soil material during water transport on large distances from the source area.

Sand fraction (1-0.1 mm) occurring in non-calcareous horizons in soil developed from boulder loam shows a similar content of total Ca regardless of grain size. In turn, fractions isolated from the calcareous horizons lying below 100 cm in the soil profile are strongly variable with regard to total Ca content. This variability occurs in the profile cross-section and in the particular fractions (Tables 3 and 3a). Most probably, the process of $CaCO_3$ leaching from the surface horizons to the deeper part of the profile causes its precipitation and cementation of smaller grains into conglomerates and created sand particle size. This was confirmed by SEM-analysis of the grains-conglomerates [5, 19]. Therefore, Ca and $CaCO_3$ prevail in the coarse sand fraction (1-0.5 mm) in this soil.

Sand fractions in the old-alluvial soil (Kazuń) do not display homogeneity with regard to total Ca content. In each horizon and layer the same fraction can often display totally different contents of this element. This might result from the origin and sources of material, from which each layer developed (Table 3). The medium sand fraction (0.5-0.25 mm) compares to the fine and coarse sand fractions is richest in total calcium. This variability coefficient of total calcium content among sand fractions in different soil horizons of this soil is relatively high and amounts from 52.1 to 81.9% in fine sand (Table 3a). The situation is different in the calcareous horizons of soil developed from boulder loam (Gąbin). The largest variability is observed within the sand separated from calcareous horizons than from surface ones (Table 3a). The sand fraction of the analyzed soils accumulates from 10.8% of total calcium in boulder non-calcareous material to 24.4% in the calcareous horizons. In the old-alluvial soil the sand fraction accumulates at an average of 19.0 % of this element (Fig. 1).

Silt fraction (0.1-0.02 mm) in soil developed from boulder loam indicates a slight enrichment in total Ca in the non-calcareous horizons. In turn, in the calcareous horizons only the fine silt fraction (0.05-0.02 mm) in the deepest horizon (125-150 cm) indicates a similar total Ca content as the coarse sand fraction (Table 3).

In soil developed from the old-alluvial deposit the coarse silt fraction (0.1-0.05 mm) does not vary visibly in total Ca content from the sand fraction. The fine silt fraction (0.05-0.02 mm) shows enrichment in total Ca (Table 3). The variability coefficient in particular horizons with regard to total Ca content in this fraction is very high in soil developed from boulder loam, particularly in the calcareous horizons lying below 100 cm (Table 3a).

This fraction accumulate similar amounts of total Ca in the analyzed soils as the sand fraction (Fig. 1).

Silty clay fractions (0.02-0.002 mm) are richer in total Ca in both analyzed soils in comparison to the coarser fractions (Table 3).

Similar to grains of sand and silt in the non-calcareous horizons of the boulder loam, these fractions contain also lower amounts of total Ca. In turn, deeper horizons contain higher amounts of Ca, particularly the 0.02-0.01 mm and 0.005-0.002 mm fractions. The analyzed fractions in the old-alluvial deposit display a similar content of Ca regardless of grain size and this feature is rather stable in the profile cross-section (Table 3).

These fractions accumulate the highest quantities of total Ca despite their low amounts in the analyzed soils (Tables 1, 3 and Fig. 1). They accumulate an average of 31.9% Ca in the non-carbonate horizons of the boulder loam and up to 45.8% Ca in the calcareous horizons. In the case of these fractions in soil developed from old-alluvial deposits, they accumulate an average of 48% of total calcium in the entire profile, down to 200 cm (Fig. 1).

The variation coefficients of total Ca content in these fractions in different genetic horizons of the analysed soils are rather high (Table 3a).

Colloidal clay fraction (<0.002 mm) is slightly poorer in total Ca in both analyzed soils in comparison to the coarser fractions, except the surface horizons modified in peri-glacial processes in soil developed from boulder loam, in which this fraction contains triple the amount of this element than the 0.005-0.002 mm fraction (Table 3). In turn, this fraction contains much less total Ca in the old-alluvial soil (twice less) in comparison to the 0.01-0.002 mm fraction. Similarly, the presence of Ca in this fraction in the calcareous horizons of soil developed from boulder loam is much lower than in the 0.02-0.002 mm and coarse sand fractions.

In the lessivé soils of the Saskatchewan Province in Canada [20] and in fractions isolated from soils developed from sands in Poland [10], there are similar Ca contents in all analyzed fractions. But content of total Ca obtained in fraction <0.002mm by many authors in soils of Poland characterized by different types of soils and rocks of different origin in most cases are much richer in Ca than those indicated by our results introduced in this paper [12, 6, 13, 7, 14, 8, 15, 16, 17, 11]. In turn, results obtained from this fraction in the Canadian soils [20] and in soils developed from sands [10] correspond to the obtained results. It is difficult to explain such differences of calcium content in colloidal fractions (<0.002mm).

However, the obtained results do not allow a precise determination of the mineral composition of this fraction, particularly in the non-calcareous horizons. Primary minerals containing calcium are rather not present in investigated soils, and the clay minerals mainly bind exchangeable Ca. Earlier X-Ray [2, 4] and SEM-investigations do not point to the occurrence of primary minerals in this fraction [5, 19, 21, 22], but only low quantities of zeolites from the group of philipsite and chabazite in the old-alluvial soil was stated [22].

The colloidal clay fraction in the analyzed soils accumulates up to 43.5% Ca in the non-calcareous horizons, but only up to 16.2% of total calcium in the calcareous horizons of soil developed from boulder loam (Fig. 1). The variability coefficients of the total Ca content in this fraction are rather high in the analyzed soils (Table 3a).

Balance of Total Ca Content in Soils

Concluding the calculated balance (Table 4) between the content of the particular fractions and the Ca content in a volume of 1.5 m^3 (1 m^2 down to 1.5 m) indicates resources of this element in the genetic horizons and layers of the analyzed soils. The values distinctly point to a lack of direct connection between content of a particular fraction in a soil horizon and total Ca content. In soil developed from boulder loam, the largest amounts of Ca are accumulated by the silty clays fraction (0.02-0.002 mm), despite their lower content in comparison to the colloidal clay fraction. Processes of Ca leaching from top to deeper horizons can be observed in this soil. The leaching process is noted in all analyzed fractions, regardless of size. However, it is most distinct in the <0.002 mm fraction. This fraction underwent leaching in two surface horizons down to 50 cm, whereas the larger fractions underwent leaching in the three surface horizons, down to 75 cm (Table 4).

In the old-alluvial soil profile characterized by a layered texture, the vertical variability of the total Ca content resulting from leaching is not observed. The poorly marked leaching process is noted in the case of

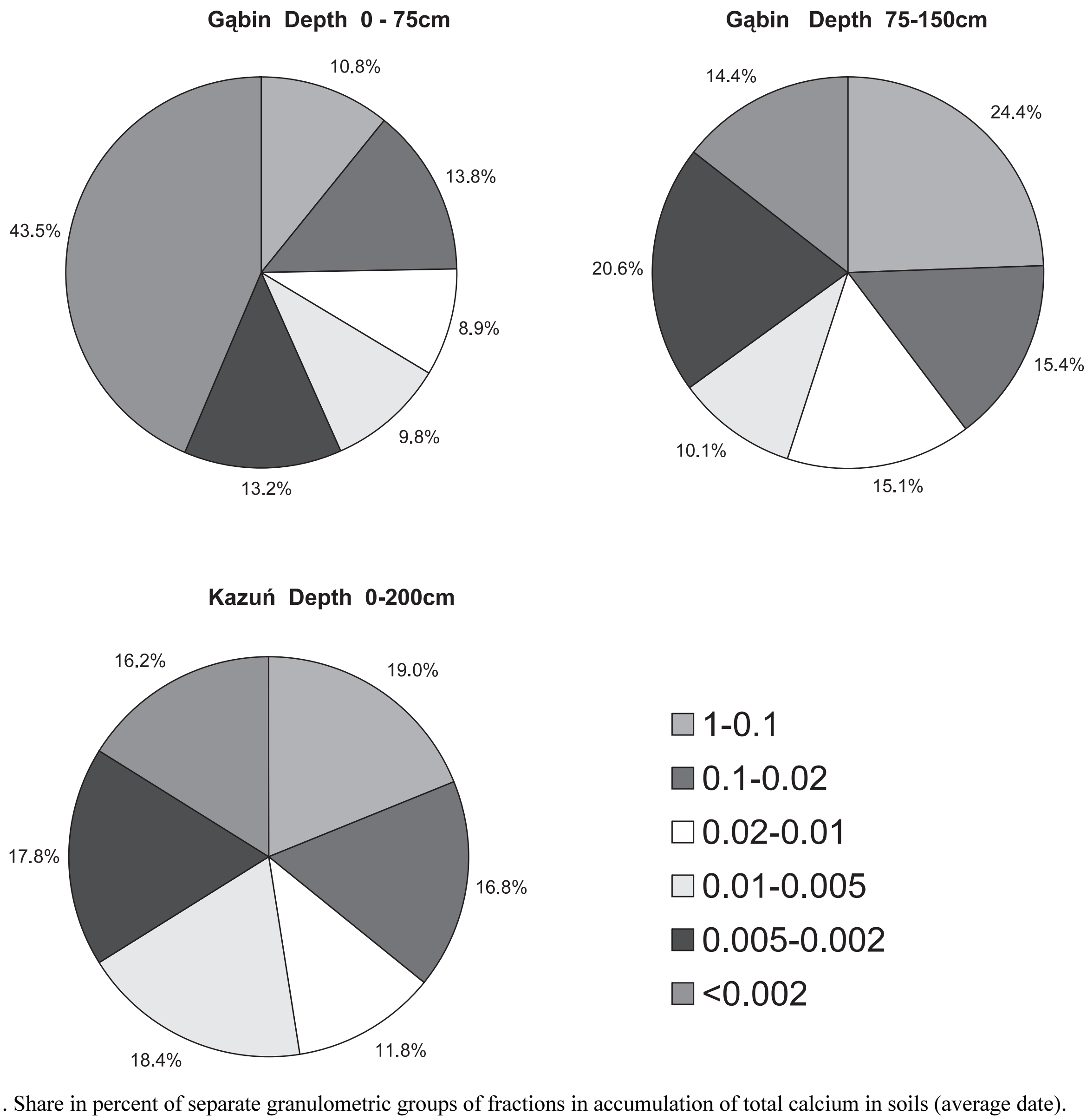

Fig. 1. Share in percent of separate granulometric groups of fractions in accumulation of total calcium in soils (average date).

Table 4. Balance of total Ca and granulometric fractions in genetic horizons of profiles per 1 m2 to 150 cm depth.

Locality	Horizon	Depth [cm]	fractions of diameter in [mm]								Sum		Ca [t/ha]
			1-0.1		0.1-0.02		0.02-0.002		<0.002				
			Fraction [kg]	Ca [g]	Fraction [kg]	Ca [g]	Fraction [kg]	Ca [g]	Fraction [kg]	Ca [g]	Fractions [kg]	Ca [g]	
Leached brown soil developed from boulder loam													
Gąbin County Gostynin	A	0-25	220	46.4	85	30.0	33	19.6	18	36.0	356	132.0	1.32
	Bbr(t.fe)	25-50	184	31.5	94	28.5	47	20.6	26	46.3	351	126.9	1.27
	Bbr	50-75	96	40.5	77	50.5	61	87.9	91	607.0	325	785.9	7.86
	BbrC	75-100	92	226.1	73	195.8	68	406.7	94	794.3	327	1622.9	16.23
	Cca	100-125	64	152.1	104	238.2	78	815.4	95	850.3	341	2056.0	20.56
	Cca	125-150	86	973.7	75	1321.2	78	2039.5	91	1014.7	330	5344.1	53.49
Sum		0-150	743	1470.3	508	1864.2	365	3389.7	415	3348.6	2004	10072.8	100.73
Leached brown soil developed from old-alluvial sediment													
Kazuń Polski County Nowy Dwór Mazowiecki	A	0-25	164	129.5	110	206.3	39	119.1	31	168.0	344	622.9	6.23
	ABbr	25-50	168	421.3	116	223.7	35	135.8	35	185.5	355	966.3	9.66
	Bbr(t.fe)	50-70	98	338.7	81	88.4	30	101.8	66	264.0	275	792.9	7.93
	BbrC	70-90	96	120.3	137	400.7	14	69.3	45	104.0	292	694.3	6.44
	C	90-120	246	382.1	122	263.9	19	60.1	51	272.9	438	979.0	9.79
	C	120-150	217	210.7	150	266.1	84 ?	119.3	50	67.5	441	663.6	6.64
Sum		0-150	994	1602.6	718	1449.1	162	605.4	278	1061.9	2148	4719.0	47.19

* — mass of fractions rounded to 1kg

the exchangeable form of Ca in this profile (Table 2). It should be noted that the distribution of total Ca in the old-alluvial soil is rather even in the entire profile and varies from 6.23 to 9.76 t/ha (Table 4), whereas in soil developed from boulder loam, with a higher degree of leaching, total Ca content in the genetic horizons varies from 1.27 t/ha in the Bbr (t, fe) horizon to 53.5 t/ha in the horizon lying at 125-150 cm. Total Ca content in the analyzed profiles on an area of 1 ha down to 150 cm is distinctly different. In soil developed from boulder loam the content of Ca reaches 100.7 t/ha and in the old-alluvial soil without $CaCO_3$ content only 47.2 t/ha.

Conclusions

1. The distribution of total Ca in the particular granulometric fractions separated from different genetic horizons of soil developed from boulder loam (Gąbin) depends on the leaching process in the upper part of the profile and accumulation of $CaCO_3$ in its lower part below 100 cm.
2. In soil developed from an old-alluvial deposit (Kazuń Polski) the distinct influence of the alluvial process on the quantitative distribution of total Ca in particular granulometric fractions isolated from different horizons of the profile can be observed.
3. Total Ca content in particular granulometric fractions depends on the pedogenetic process of leaching and the origin of the parent rocks from which the soils developed.

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