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SOIL CHEMISTRY

Regional Specifics of the Carbon Storage Formation in the Haplic Cambisols in the South of the Primorskii Krai

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Abstract—The stocks of total and organic carbon in the soils of two types of natural forest biogeocenoses (Korean pine and broadleaved stands) are determined based on the study of physical and chemical properties, including the content and distribution of carbon and nitrogen in the profiles of Haplic Cambisols in the south of the Primorskii krai (Russia). These are slightly acidic soils (pH_{H_2O} 5.8–6.6) with a low content of carbonates (0.048–0.066%), contrasting increase in density (0.68–2.23 g/cm^3), and a decrease in the content of fine earth (92.5–8.2%) downward the profile. The carbon and nitrogen contents in forest litter vary in the range of 32.4–48.3% (C) and 1.5–3.6% (N) in the OL subhorizon and 20.6–34.6% (C) and 1.1–2.0% (N) in the OFH subhorizon. Intensive mineralization of abundant plant litter contributes to an active input of carbon and nitrogen into the AY horizon (5.6–14.3 and 0.5–1.0%, respectively); the content of the elements sharply decreases with depth. The highest potential for carbon accumulation and stabilization in the soil profile is typical of Haplic Cambisols under Korean pine stands with maximum stocks of both C_{tot} (169.6 t/ha) and C_{org} (169.4 t/ha) in the profile. A comparison of the intensities of forest litter decomposition and the input of C-containing compounds to the underlying horizons of Haplic Cambisols under elementary biogeoareas (EBGAs) in Korean pine stands suggests more intensive processes in the Haplic Cambisols under linden mixed-shrub EBGA than under Korean pine EBGA without vegetation in the ground cover. The C_{tot} and C_{org} stocks in the Haplic Cambisol profile under broadleaved forest match the worldwide average carbon stocks in the soils under deciduous forests of temperate latitudes and amount to 138.8 and 138.6 t/ha, respectively.

Keywords: carbon, nitrogen, Haplic Cambisols, forest soils

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INTRODUCTION

A system of positive and negative feedbacks formed in biogeocenoses (BGCs) drives the input, transformation, accumulation, and removal of carbon-containing compounds from a multiple-phase open soil system [6, 35]. A multiple-component soil structure creates the conditions for concurrent differently directed biochemical and physicochemical processes enhancing carbon (hereinafter, C) accumulation and the formation of its stock. The soils of natural forest massifs are the most important reservoir of stable C in the biosphere and contain over 40% of the organic C volume in terrestrial ecosystems [44, 46]. Over 50% of the organic C stock (approximately 170 Gt C) are harbored in the soils under forest vegetation in Russia [25].

Soil capacity to stabilize and accumulate C reflects the procedural character of the components of the biological cycle in BGCs and depends on the factors that determine the direction of the main soil-forming process and soil properties [1, 14, 19, 25, 26, 35, 41, 46]. Most studies regard the quantitative composition and weight of plant litter, intensity of its decomposition, hydrothermal conditions, mineralogical composition of parent rock, content of physical clay fraction, cation exchange capacity, content of exchangeable bases, and soil pH as the key factors determining the C stock in the soils of forest biocenoses [8, 14, 19, 26, 35].

The specificity of natural factors involved in soil formation at the continent–ocean interface undoubtedly influences the general patterns of the C accumulation in soils. Available data on the C content, formation of its stock, and its cycling in soils of the transitional area from southern Eurasia to the Pacific Ocean (Primorskii krai, Russian Federation) suggest the presence of factors and the development of conditions enhancing both the accumulation/stabilization of C-containing compounds (abundant input of plant litter, long period of its transformation and formation of newly synthesized C-containing compounds followed by their conservation in the soil profile upon sharp seasonal changes in hydrothermal conditions) and intensification of the C removal from the soil profiles to adjacent media (hilly topography, heavy rainfall, fragmented soil cover patterns) [8, 10, 11, 16, 28, 30, 31, 34]. The south of the Primorskii krai is part of the eastern Haplic Cambisol (brown forest soils) region [11, 20, 27]. In general, these soils have a high content of C in the humus horizon (average thickness, 10 cm) [11, 26, 27, 33, 34]. The range of variation of the C content in the upper horizon of Haplic Cambisols (4.8–17.6%) reflects the effect of the species composition of forest stands on the input and accumulation of C-containing compounds in the soil profile [8, 18, 30]. However, data on the C content and stock in the soils of unique broadleaved forests of the Primorskii krai are rather fragmentary and require updating in terms of the observed climate changes, which are rather contrasting in the examined area. New information about the content and profile differentiation of C accumulation is also relevant because of the need to take into account the local specificity in the formation of soil C stock when assessing the effect of predicted climate change on the parameters of carbon cycling [32, 48]. When studying the specific regional features in the C stock formation and its further assessment in the soils of different bioclimatic zones in Russia, the development of a unified methodology for field work and laboratory analyses of soil properties associated with C stock are of great importance. The development, adaptation, and evaluation of the unified methodology within the currently implemented most important innovative project of national significance (MIIP NS)"*Development of a System for Ground-Based and Remote Monitoring of Carbon Pools and Greenhouse Gas Fluxes in the Territory of the Russian Federation Ensuring the Creation of Data Recording Systems on the Fluxes of Climate-Active Substances and the Carbon Budget in Forests and Other Terrestrial Ecological Systems*" implies an improvement in the assessment of C stocks in soils of a vast territory of the Russian Federation and its detailing based on the reproducible and reliable results.

The aim of this work was to study the physical and chemical parameters of soils that determine the formation of C stock, levels of C and N contents, and the C stock in Haplic Cambisols under typical coniferous–broadleaved forests in the south of the Primorskii krai based on evaluation of a set of methods recommended by the above mentioned project.

OBJECTS AND METHODS

In this study, we have analyzed samples (forest litters, humus horizons, and mineral horizons) of the soils that correspond to slightly unsaturated brown forest soils (burozems) [13], typical burozems [12], and Haplic Cambisols [47] (according to the diagnostic criteria of corresponding soil classification systems); in further discussion, these soils are collectively referred to as Haplic Cambisols.

The examined Haplic Cambisols were formed in two types of forest BGCs (BGC 1, 44°02′15″–44°04′01″ N, 134°12′16″–134°20′78″ E and BGC 2, 43°70′23″–43°70′73″ N, 132°15′82″–132°16′11″ E) typical of the natural mixed coniferous–broadleaved forests on the slopes of the Sikhote-Alin Range (south of the Russian Far East) undisturbed by direct technogenic impacts. The examined territory belongs to the temperate zone of the Pacific climatic province with the cold and dry winter poor in snow and wet (humid tropical) weather in summer (with daily air temperature >22°C and air moisture content >80%) [9, 11]. Table 1 briefly characterizes the soil-forming conditions,

Under these conditions, weakly decomposed plant residues retaining their morphological structure form a thin subhorizon of forest litter OL (1–2 cm) merging into the fermentated and humified OFH subhorizon (1–3 cm) with a considerable degree of plant litter decomposition (over 50 wt % of the layer is represented by plant debris that have lost their cellular structure). The morphological similarity of subhorizons in forest litters of Haplic Cambisols in two examined BGCs is determined by similar hydrothermal conditions of plant litter decomposition in the studied area. The soils have the following horizonation and morphology: (i) gray-humus AY horizon (thickness, 9–17 cm), dark gray, wet, angular blocky to fine granular structure, loose, sandy loamy, densely penetrated by fine roots, with occasional fungal mycelium and macrofauna (earthworms), with a low content of gravelly material, and with a sharp transition to the underlying horizon; smooth of wavy boundary with occasional humus tongues; (ii) structural metamorphic BM horizon (thickness, 20–35 cm), brown, with dark humic lenses and dark-colored humus tongues along frost cracks of different sizes; wet; fine (powdery) structure; compacted, silty clay loamy, with fine plant roots and occasional fungal mycelium and macrofauna (earthworms); gravelly, with coarse stone fragments; gradual wavy boundary; and (iii) C horizon; dark brown with dark humus tongues, wet, with single fine roots, strongly stony; the fine earth content is less than 10% of the volume of the horizon; the fine earth is silty clay loam, with very fine (silty) structure.

In each BGC, sampling was performed on five test plots with a total area of 2500 m^2 at the end of the growing season of 2023 (second half of September, Fig. 1). Each test plot contained one full-depth soil pit (down to 73–97 cm) and two shallow pits to 55–65 cm. The sites for pid digging were selected taking into account the coverage of the most representative elementary biogeoareas (EBGAs) within each BGC type.

Table 1. Conditions of formation of Haplic Cambisols in two biogeocenoses (BGCs)

Factor	Haplic Cambisols of BGC 1	Haplic Cambisols of BGC 2
Parent rock	Colluvium of siltstone	Colluvium of basalts
Climate	Continental with monsoon traits	
Type of forest BGCs and average age of tree stand	Mixed-shrub Korean pine with yellow birch and linden, 200 years old	Mixed-shrub– herb oak–linden–maple, 110 years old
Elementary biogeoareas and the share in BGC	Mixed-shrub Korean pine, 36%	Mixed-shrub oak stand, 53%
	Mixed-shrub linden, 22%	Mixed-shrub linden, 16%
	Hazel mixed-shrub, 14%	Mixed-shrub fern–herb, 16%
	Mixed-shrub, 11%	Mixed-shrub maple, 7%
	Korean pine without living ground cover, 9%	Mixed-shrub black birch, 4%
	Mixed-shrub maple, 8%	Mixed-shrub horsetail–herb, 4%
Relief and slope aspect	Middle part of southwestern slope	Upper part of northeastern slope
Altitude, m	650	260

According to the recommendations by Orlova [22], the names for EBGAs are based on the dominant plant component and correspond to the definition of cenobiotic microgroups.

The forest litters were sampled from 0.25 × 0.25 m plots in the right corner of the front wall of the pits and further divided into subhorizons. The humus and mineral horizons were sampled from the front wall along the overall horizon thickness. All samples were dried to an air-dry state, transported to the laboratory and weighed.

The soil properties were analyzed using routine methods of soil science. The moisture content in samples was determined according to State Standard (GOST) 28268-89; bulk density, with sieved sand replacement method [40]; and the content of fine earth, using a combination of weighing and calculation techniques [37]. Actual soil acidity (pH_{H_2O}) was determined potentiometrically on a S220-Kit (Mettler Toledo, Switzerland) pH-meter according to state standard GOST 26423-85; the content of carbonates in the soil samples with pH_{H_2O} >6.0, with calcimetry in a KOUK calcimeter (TU 25-11-1106-75) according to the manufacturer's protocol [23]. The contents of total carbon (C_{tot}) and nitrogen (N_{tot}) were determined by gas chromatography in a Flash 2000 (Thermo Scientific, United States) elemental analyzer with a CNHS configuration using a standard reference standard (Cystine, certificate no. 134139); temperature of reactor, 900°C; rate of helium and oxygen flows in reactor, 140 and 100 mL/min, respectively; and measurement cycle duration, 380 s. The significance of the measurement data was assessed by analyzing a Soil Standard Peaty OAS (for litter horizons) and Soil Standard Loamy OAS (for humus-accumulative and mineral soil horizons) and reference samples assessed after every 10 measurements of unknown (experimental) samples. The maximum deviation from the certified values in the C and N content did not exceed 0.05% (C) and 0.02% (N) for Soil Standard Peaty OAS and 0.02% (C) and 0.005% (N) for Soil Standard Loamy OAS. Each characteristic was determined in triplicate.

As for the experimental samples with pH >6.0, the organic carbon (C_{org}) content was determined in an indirect manner (by calculation) taking into account the content of carbonates according to state standard GOST ISO 10694-2024. The C_{tot} in the samples with pH_{H_2O} ≤6.0 was assumed to be equal to the C_{org} content. The C_{tot} content in the subhorizons of forest litter was also assumed to be equal to the C_{org} content. In this work, the C_{tot} and C_{org} contents are given per absolutely dry weighed sample taking into account the measured soil moisture content.

The C_{org} stock in the forest litter subhorizons was calculated according to the C_{org} content and litter stock as described in [24].

The C_{tot} and C_{org} stocks in the mineral horizons and in the entire profile of Haplic Cambisols were calculated using the equation by Orlov et al. [21] with additional adjustment factor taking into account the fine earth content in a horizon or the overall profile or according to [42–45]:

$$S_{soil} = Ch\rho k,$$

where S_{soil} is the C_{tot} or C_{org} stock in soil, t/ha; C, content of C_{tot} or C_{org}, %; h, thickness of horizon or overall profile, cm; ρ, bulk density, g/cm^3; and k, adjustment factor taking into account the share of fine earth.

The C_{tot} and C_{org} stocks in the 0–10- and 0–30-cm layers were calculated by summing the proportional contributions of the C_{tot} and C_{org} stocks in individual horizons of the corresponding layer.

To adequately reflect the specificity of C stock formation in two studied BGCs, we calculated the weighted means of C_{tot} and C_{org} stocks in forest litter, individual layers (0–10 and 0–30 cm), and entire pro-

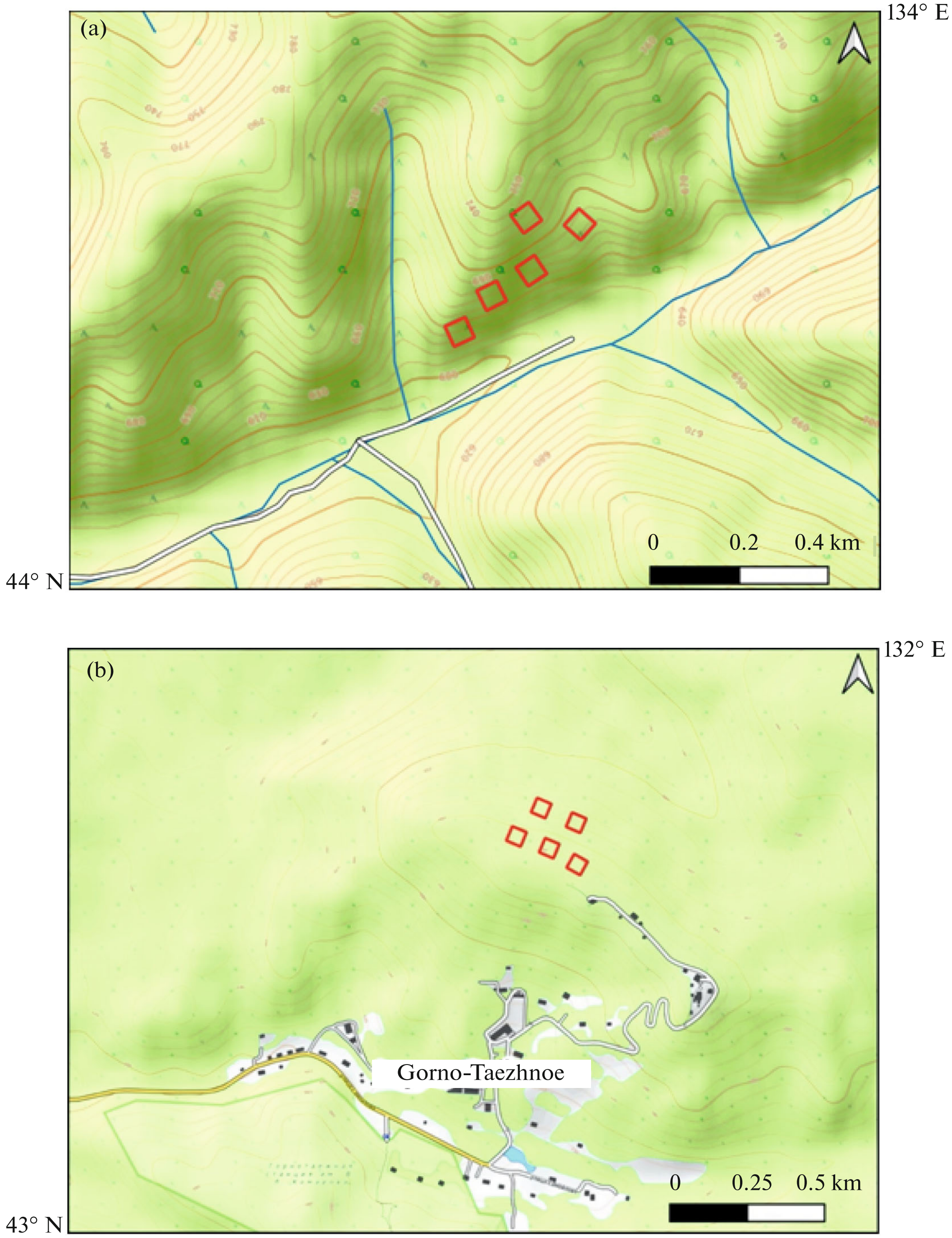

Fig. 1. Arrangement of test plots: (a) BGC 1 (mixed-shrub Korean pine stand with yellow birch and linden) and (b) BGC 2 (mixed-shrub–herb oak–linden–maple forest).

files of Haplic Cambisols taking into account the share occupied by each EBGA in individual BGCs.

The data were statistically processed using descriptive and test statistics by calculating mean arithmetic, standard error of the mean, weighted mean, coefficient of variation (CV), and statistical significance of differences (*t*-test for independent samples) with the help of MS Excel and SPSS software (SPSS Inc., version 13, 2018) at $p \leq 0.05$. The tables, plots, and diagrams show mean arithmetic values and their standard errors; significant differences are denoted with different letters.

State-of-the-art equipment of the core facility “Biotechnology and Genetic Engineering” of the Federal Scientific Center of the East Asia Terrestrial Biodiversity, Far East Branch, Russian Academy of Sciences, was used in the work.

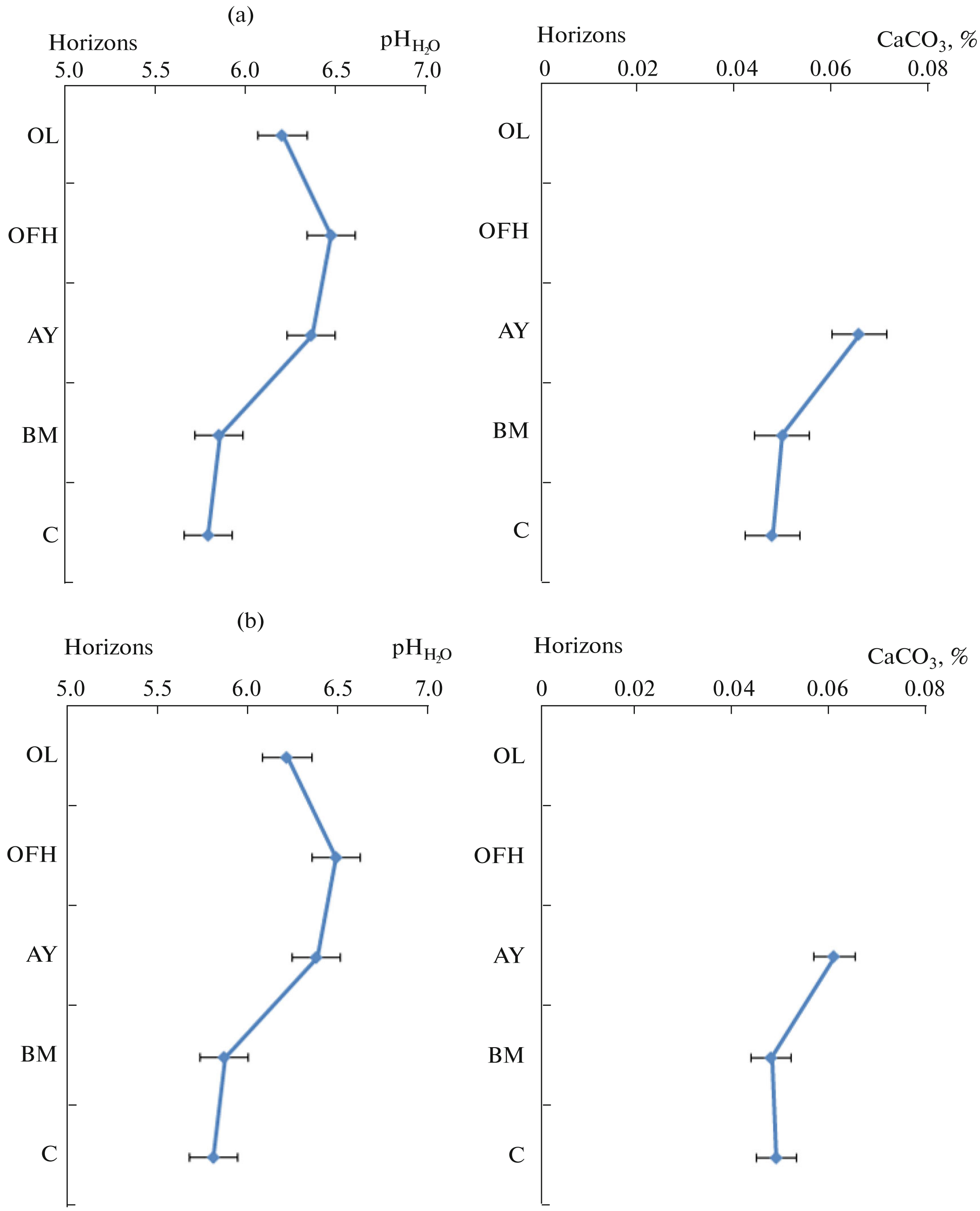

Fig. 2. Vertical differentiation of the actual acidity and carbonate content in the profiles of Haplic Cambisols under two types of forest biocenoses: (a) mixed-shrub Korean pine stand with yellow birch and linden and (b) mixed-shrub–herb oak–linden–maple stand (n = 15).

RESULTS

The content of carbonates in the Haplic Cambisols of the studied BGCs amounts to hundredths of a percent (Fig. 2). In most of the soil profiles, the content of carbonates was determined in the AY (gray-humus) horizon. The highest carbonate content in the humus horizon was recorded in the Haplic Cambisols under mixed-shrub and Korean pine mixed-shrub EBGAs (0.075 and 0.068%, respectively) and the lowest, in the soils under hazel mixed-shrub EBGA (0.014%) in Korean pine stand with yellow birch and linden (hereinafter, Korean pine stand). The maximum carbonate content in the Haplic Cambisols was recorded under the mixed-shrub–herb oak-linden-maple forest (hereinafter, broadleaved forest) is observed in the soils under linden mixed-shrub EBGA (0.091%) and the minimum, under oak mixed-shrub EBGA (0.031%). Differences in the carbonate C content in humus horizons of Haplic Cambisols of different EBGAs are statistically significant.

Acidity. The pH of forest litters in the Haplic Cambisols of the studied BGCs is slightly acid according to Arinushkina [2] (Fig. 2). The pH_{H_2O} value of the water extract is lower in the OL subhorizon as compared with the OFH subhorizon. The pH_{H_2O} further decreases in the AY and BM still remaining in the range of weak acid values. The pH in the middle and lower parts of the Haplic Cambisol profile is more acidic as compared with the upper part. The pH_{H_2O} of the forest litters insignificantly varies in the Haplic Cambisols of individual EBGAs of broadleaved stands; the lowest value is in the litters of mixed-shrub fern–herb EBGA (5.9 in OL and 6.4 in OFH). Despite a slightly acid range of pH_{H_2O} values in the soils of the two examined BGCs, Haplic Cambisols in the broadleaved forest are characterized by a more smooth decrease in pH_{H_2O} from the upper to middle parts of the profile with furether increase in the actual acidity in the C horizon As for the Haplic Cambisols under Korean pine stand, the lowest pH_{H_2O} values (5.6 to 5.9)were recorded in the soils under Korean pine stand without living ground cover and the highest, in the litters and humus horizons of maple mixed-shrub (6.4 in OL, 6.8 in OFH, and 6.7 in AY) and hazel mixed-shrub (6.5 in OL, 6.7 in OFH, and 6.6 in AY) EBGAs. The degree of variation in pH_{H_2O} values in different horizons of the Haplic Cambisol profile in individual EBGAs is insignificant (CV = 5), while the recorded differences are statistically significant.

Content of C and N. The distribution of C_{tot}, C_{org}, and N in the Haplic Cambisols is characterized by a distinct peak in the upper litter subhorizon followed by a gradual decrease in the lower litter subhorizon and humus horizon and a sharp decrease in the structural metamorphic horizon (Tables 2 and 3). The decrease in the content of these elements becomes smoother with depth. The content of C_{tot}, C_{org}, and N and the C/N ratio in the litter and humus horizon of Haplic Cambisols vary in a relatively wide range, which narrows in the lower horizons of the profile. The C_{org} content averages 99.9% of the C_{tot} content in the humus horizons, 99.6% in the structural metamorphic horizons, and 98.7% in the C horizon.

The average C content in the litter subhorizons of Haplic Cambisols under Korean pine stands reaches 41.4% in the OL and 28.9% in the OFH subhorizons. With respect to the C content, litters of different EBGAs form the following sequence: hazel mixed-shrub EBGA > Korean pine EBGA without living ground cover > Korean pine mixed-shrub EBGA > mixed-shrub EBGA > maple mixed-shrub EBGA > linden mixed-shrub EBGA. The average N content in the two litter subhorizons of Haplic Cambisols under Korean pine stands reaches 1.6%, and the C/N ratio is 21. In addition, Haplic Cambisols under Korean pine stand display a higher average C content in the AY horizon (C_{tot} 10.8% and C_{org} 10.5%). The mean C_{tot} and C_{org} contents in the BM horizon amount to 2.4 and 2.1%, respectively; in the C horizon, 0.7 and 0.5%, respectively.

Although the average C content is lower in the litters of broadleaved forests (35.7% in OL and 22.5% in OFH), these litters have a higher content of N (2.3%) and a narrower C/N ratio (13). The highest C content under broadleaved forest is observed in the litter under black birch mixed-shrub and horsetail–herb mixed-shrub EBGAs; the lowest C content is in the lotter of mixed-shrub oak EBGA. The mean C_{tot} and C_{org} contents in the humus and lower mineral horizons of Haplic Cambisols under broadleaved forest are very close differing only at the level of hundredths. As compared with Haplic Cambisols under Korean pine stands, these soils are characterized by a lower C content in the AY horizon (7.8%) and a higher C content in the BM and C horizons (2.7 and 0.9%, respectively).

Litter stocks. The average litter stock in the Haplic Cambisols under Korean pine stands (3.7 kg/m^3) is 2.6-times higher as compared with that in the Haplic Cambisols under broadleaved forest (1.4 kg/m^3). The litter stock in the Haplic Cambisols of different EBGAs of Korean pine stands gains maximum in the EBGA without living ground cover and decreases in the maple, hazel, and mixed-shrub EBGAs to reach the minimum in the linden mixed-shrub and mixed-shrub EBGAs (Fig. 3). As for the litter stock in the Haplic Cambisols under broadleaved stands, it decreases from the mixed-shrub EBGA to black birch mixed-shrub EBGA. Litter stocks of Haplic Cambisols of the linden mixed-shrub, maple mixed-shrub, and fern–herb mixed-shrub EBGAs in broadleaved stands are close and occupy an intermediate position. The noted differences in litter stocks under different EBGAs are statistically significant.

Carbon stocks and soil physical properties. A comparative analysis of the C_{tot} and C_{org} stocks based on the calculation of weighted means in the layers of 0–10 and 0–30 cm and in the entire soil profile (down to a depth of 55–97 cm) indicates that higher stocks are characteristic of EBGAs of Korean pine stands (Fig. 4). On the average, the C_{tot} and C_{org} stocks in the Haplic Cambisols under Korean pine stands are higher than those under broadleaved stands by 26.5% in the layer of 0–10 cm, 9.4% in the layer of 0–30 cm, and 18.2% in the entire soil profile. In addition, the weighted average C stock in litter, humus, and structural metamorphic horizons of Haplic Cambisols under Korean pine are also higher. At the same time, the maximum weighted average C_{tot} and C_{org} stocks in the lower hori-

Table 2. Contents of C and N in Haplic Cambisols of different EBGAs under mixed-shrub Korean pine stand with yellow birch and linden (*n*, sample size)

Horizon	C_{tot}, %	C_{org}, %	N_{tot}, %	C/N
Mixed-shrub Korean pine ($n = 4$)				
OL	40.92 ± 4.56*a*		1.71 ± 0.04*a*	24 ± 3*a*
OFH	28.77 ± 3.2*a*		1.26 ± 0.04*a*	23 ± 3*a*
AY	11.61 ± 1.64*a*	11.60 ± 1.61*a*	0.81 ± 0.03*a*	14 ± 2*a*
BM	2.38 ± 0.43*a*	2.38 ± 0.43*a*	0.19 ± 0.01*a*	13 ± 1*a*
C	0.80 ± 0.08*a*	0.80 ± 0.08*a*	0.07 ± 0.01*a*	12 ± 1*a*
Mixed-shrub linden ($n = 3$)				
OL	36.38 ± 3.82*b*		1.58 ± 0.03*b*	23 ± 1*b*
OFH	29.67 ± 1.75*b*		1.43 ± 0.09*b*	21 ± 1*b*
AY	10.40 ± 1.38*b*	10.40 ± 1.38*b*	0.73 ± 0.01*b*	14 ± 2*a*
BM	2.14 ± 0.29*b*	2.13 ± 0.28*b*	0.18 ± 0.01*a*	12 ± 1*b*
C	0.55 ± 0.03*b*	0.54 ± 0.02*b*	0.05 ± 0.01*b*	12 ± 1*a*
Mixed-shrub hazel ($n = 2$)				
OL	48.35 ± 1.09*c*		1.48 ± 0.02*c*	33 ± 2*c*
OFH	27.81 ± 0.13*c*		1.14 ± 0.03*c*	24 ± 1*c*
AY	14.29 ± 0.40*c*	14.29 ± 0.40*c*	0.99 ± 0.02*c*	14 ± 1*a*
BM	3.16 ± 0.07*c*	3.15 ± 0.06*c*	0.25 ± 0.01*b*	13 ± 1*a*
C	0.52 ± 0.03*b*	0.51 ± 0.02*b*	0.04 ± 0.01*b*	13 ± 1*b*
Mixed-shrub ($n = 2$)				
OL	39.85 ± 0.97*ab*		2.00 ± 0.21*d*	20 ± 2*d*
OFH	26.53 ± 0.81*d*		1.66 ± 0.13*d*	16 ± 1*d*
AY	9.73 ± 1.42*d*	9.72 ± 1.42*d*	0.88 ± 0.07*ac*	11 ± 1*b*
BM	2.27 ± 0.08*a*	2.27 ± 0.08*a*	0.22 ± 0.01*c*	11 ± 1*c*
C	0.71 ± 0.02*c*	0.71 ± 0.02*c*	0.06 ± 0.01*a*	12 ± 1*a*
Korean pine without living ground cover ($n = 2$)				
OL	44.33 ± 1.26*d*		1.82 ± 0.05*a*	24 ± 1*a*
OFH	34.61 ± 0.84*e*		1.49 ± 0.03*b*	23 ± 1*a*
AY	6.88 ± 0.09*e*	6.88 ± 0.09*e*	0.59 ± 0.01*d*	12 ± 1*c*
BM	1.83 ± 0.02*d*	1.83 ± 0.02*d*	0.20 ± 0.01*ac*	9 ± 1*d*
C	0.86 ± 0.01*a*	0.86 ± 0.01*a*	0.08 ± 0.01*c*	10 ± 1*c*
Mixed-shrub maple ($n = 2$)				
OL	38.35 ± 1.00*ab*		2.09 ± 0.06*d*	18 ± 1*e*
OFH	26.12 ± 0.72*d*		1.34 ± 0.02*ab*	19 ± 1*bd*
AY	12.07 ± 0.38*ac*	12.06 ± 0.38*ac*	0.76 ± 0.01*ab*	16 ± 1*d*
BM	2.75 ± 0.05*ac*	2.74 ± 0.05*ac*	0.22 ± 0.01*c*	13 ± 1*a*
C	0.51 ± 0.01*b*	0.51 ± 0.01*b*	0.05 ± 0.01*ab*	11 ± 1*ac*

zons are in the soils under broadleaved foresta. The weighted average C_{tot} and C_{org} stocks in the AY horizon of the two examined BGCs differ insignificantly (on the average, by 2.4%), while the difference considerably increased in the BM and C horizons (by 39.7 and 48.6%, respectively).

Haplic Cambisols under Korean pine and broadleaved forests have similar thicknesses of their AY (14 and 17 cm, respectively) and C (19 and 23 cm, respectively) horizons. The structural metamorphic horizon in the Haplic Cambisols under Korean pine stand is thicker (on the average, 33 cm) as compared with the Haplic Cambisols under broadleaved forest (on the average, 22 cm). The degree of variation in the mean thickness of the AY and BM horizons is moderate (CV = 16–19) and of the C horizon, very high (CV = 51).

Table 3. Contents of C and N content ine Haplic Cambisols of different EBGAs under mixed-shrub–herb oak–linden–maple stand (*n*, sample size)

Horizon	C_{tot}, %	C_{org}, %	N_{tot}, %	C/N
Mixed-shrub oak (*n* = 2)				
OL	32.36 ± 0.93*a*		2.04 ± 0.21*a*	16 ± 2*a*
OFH	21.05 ± 1.72*a*		1.50 ± 0.13*a*	14 ± 1*a*
AY	5.62 ± 0.32*a*	5.62 ± 0.32*a*	0.47 ± 0.05*a*	12 ± 1*a*
BM	2.50 ± 0.27*a*	2.50 ± 0.27*a*	0.19 ± 0.01*a*	13 ± 1*a*
C	0.92 ± 0.16*a*	0.92 ± 0.16*a*	0.07 ± 0.01*a*	13 ± 1*a*
Mixed-shrub linden (*n* = 3)				
OL	37.12 ± 2.46*b*		3.15 ± 0.45*b*	14 ± 3*b*
OFH	24.15 ± 2.09*b*		1.94 ± 0.69*b*	13 ± 1*b*
AY	6.94 ± 0.54*b*	6.92 ± 0.54*b*	0.60 ± 0.01*b*	12 ± 1*a*
BM	2.46 ± 0.15*a*	2.45 ± 0.15*a*	0.24 ± 0.01*b*	10 ± 1*b*
C	0.95 ± 0.11*a*	0.94 ± 0.11*a*	0.10 ± 0.02*b*	11 ± 2*b*
Mixed-shrub fern–herb (*n* = 3)				
OL	34.53 ± 1.54*ab*		2.32 ± 0.21*c*	16 ± 3*a*
OFH	20.55 ± 1.85*c*		1.88 ± 0.18*b*	12 ± 3*c*
AY	7.93 ± 0.83*c*	7.92 ± 0.83*c*	0.62 ± 0.08*b*	13 ± 2*b*
BM	2.88 ± 0.34*b*	2.87 ± 0.34*b*	0.29 ± 0.02*c*	10 ± 2*b*
C	0.79 ± 0.05*b*	0.79 ± 0.05*b*	0.07 ± 0.01*a*	11 ± 1*b*
Mixed-shrub maple (*n* = 3)				
OL	33.28 ± 2.08*a*		3.11 ± 0.34*b*	11 ± 1*c*
OFH	22.38 ± 0.52*ab*		1.69 ± 0.08*ab*	13 ± 1*b*
AY	9.47 ± 0.92*d*	9.47 ± 0.92*d*	0.77 ± 0.10*c*	12 ± 1*a*
BM	3.91 ± 0.44*c*	3.90 ± 0.44*c*	0.33 ± 0.03*d*	12 ± 1*c*
C	1.36 ± 0.15*c*	1.35 ± 0.15*c*	0.12 ± 0.02*b*	11 ± 1*b*
Mixed-shrub black birch (*n* = 2)				
OL	41.00 ± 3.33*c*		3.57 ± 0.04*d*	11 ± 1*c*
OFH	22.83 ± 0.29*ab*		1.80 ± 0.02*b*	13 ± 1*b*
AY	9.40 ± 0.29*e*	9.39 ± 0.29*e*	0.77 ± 0.01*c*	12 ± 1*a*
BM	2.56 ± 0.04*ab*	2.55 ± 0.04*ab*	0.23 ± 0.01*b*	11 ± 1*bc*
C	0.96 ± 0.01*a*	0.95 ± 0.01*a*	0.08 ± 0.01*ab*	13 ± 1*a*
Mixed-shrub horsetail–herb (*n* = 2)				
OL	38.85 ± 3.16*bc*		3.39 ± 0.16*bd*	11 ± 1*c*
OFH	24.23 ± 0.43*b*		1.58 ± 0.03*a*	15 ± 1*d*
AY	7.60 ± 0.80*bc*	7.60 ± 0.88*bc*	0.66 ± 0.04*bc*	11 ± 1*c*
BM	2.08 ± 0.37*d*	2.08 ± 0.37*d*	0.20 ± 0.02*a*	10 ± 1*b*
C	0.61 ± 0.01*d*	0.61 ± 0.01*d*	0.05 ± 0.01*c*	13 ± 1*a*

Soil bulk density increases with depth (Tables 4 and 5) being on the average higher under broadleaved forests: 0.9 g/cm^3 in the AY horizon and 2.2 g/cm^3 in the C horizon. The fine earth content decreases down the soil profiles with a sharp increase in the content of gravels and stones in the middle-profile and lower horizons, which is evident from the morphological descriptions of soil profiles. The fine earth contents in the upper (90.9–92.5%) and lower (8.1–10.7%) horizons of Haplic Cambisols under Korean pine and broadleaved forests are similar; as for the middle-profile BM horizon, the fine earth content under broadleaved forest is lower than that under Korean pine forest (53.1 vs 84.4%, respectively). The BM horizon of Haplic Cambisols under broadleaved forest is also characterized by the high variability (CV = 44%) of the fine content.

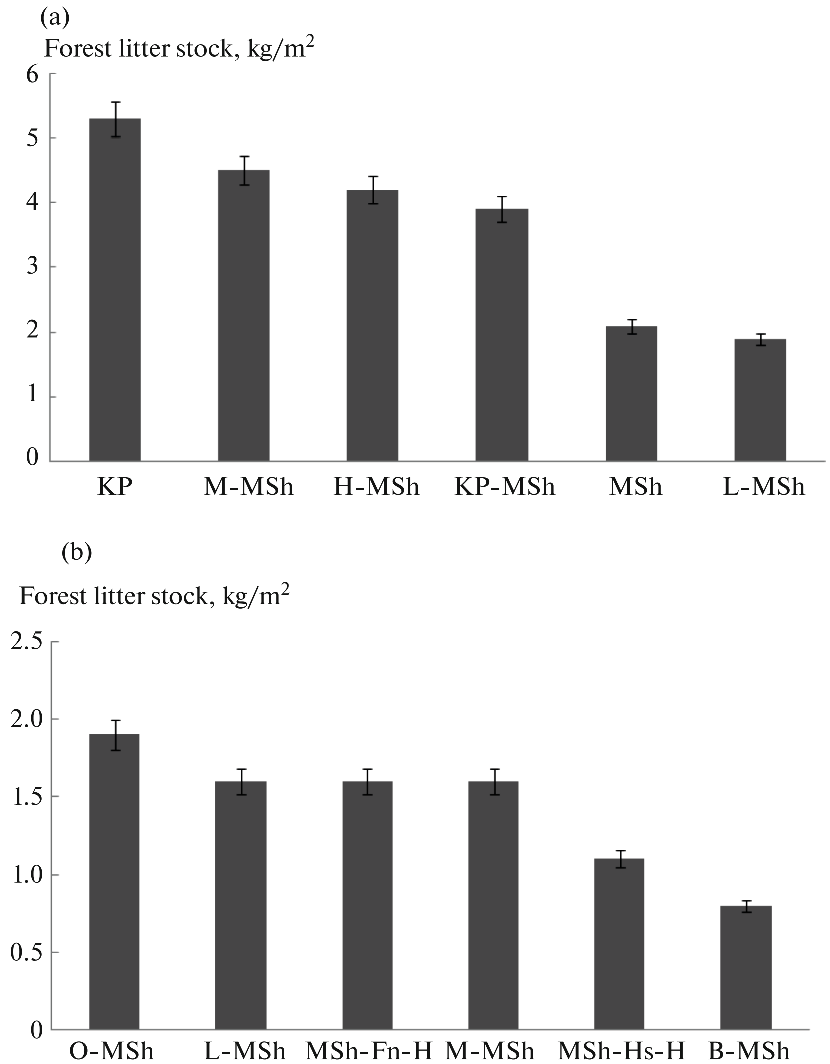

Fig. 3. Forest litter stocks in Haplic Cambisols of two types of forest biogeocenoses: (a) mixed-shrub Korean pine stand with yellow birch and linden (KP, Korean pine without ground cover; M-MSh, mixed-shrub maple; Haz-MSh, mixed-shrub hazel; KP-MSh, mixed-shrub Korean pine; MSh, mixed-shrub; and L-MSh, mixed-shrub linden) and (b) mixed-shrub–herb oak–linden–maple forest (O-MSh, mixed-shrub oak; L-MSh, mixed-shrub linden; MSh-Fn-H, mixed-shrub fern–herb; M-MSh, mixed-shrub maple; MSh-Hs-H, mixed-shrub horsetail–herb; and B-MSh, mixed-shrub black birch).

The C_{tot} and C_{org} stocks in the AY horizon of Haplic Cambisol of the two BGCs calculated with due account for the fine earth content constitute 82.9–97.9% of corresponding stocks without the adjustment factor; in the BM horizon, this calculation gives us the range from 8.6 to 96.1%; in the C horizon, from 3.5 to 22.45%.

The maximum C stock in the litters of different EBGAs has been found for Korean pine EBGA without living ground cover. Note that C_{tot} and C_{org} stocks in the AY horizon of this EBGA are minimal among all Haplic Cambisols under Korean pine stands. The C stock in the litter of Korean pine mixed-shrub EBGA is less than that in the litter of Korean pine EBGA without living ground cover, whereas the C_{tot} and C_{org} stocks in the AY horizon gain their maximum. The lowest C stocks in the litters of Korean pine stand are under mixed-shrub and linden mixed-shrub EBGAs. However, the humus (AY) horizon of the latter EBGA is characterized by rather high C_{tot} and C_{org} stocks because of a great thickness of this horizon (13 to 17 cm) as compared with that under mixed-shrub EBGA (9 to 12 cm). Carbon stocks in the litters under hazel mixed-shrub and maple mixed-shrub EBGAs are as similar. However, C stock in the AY horizon under the hazel mixed-shrub EBGA is 47.3% higher than that under the maple mixed-shrub EBGA, which is determined by a lower density of the horizon in the maple mixed-shrub EBGA.

In the broadleaved stands, maximum C stocks in the litters are observed under linden and oak mixed-shrub EBGAs; at the same time, these EBGAs are

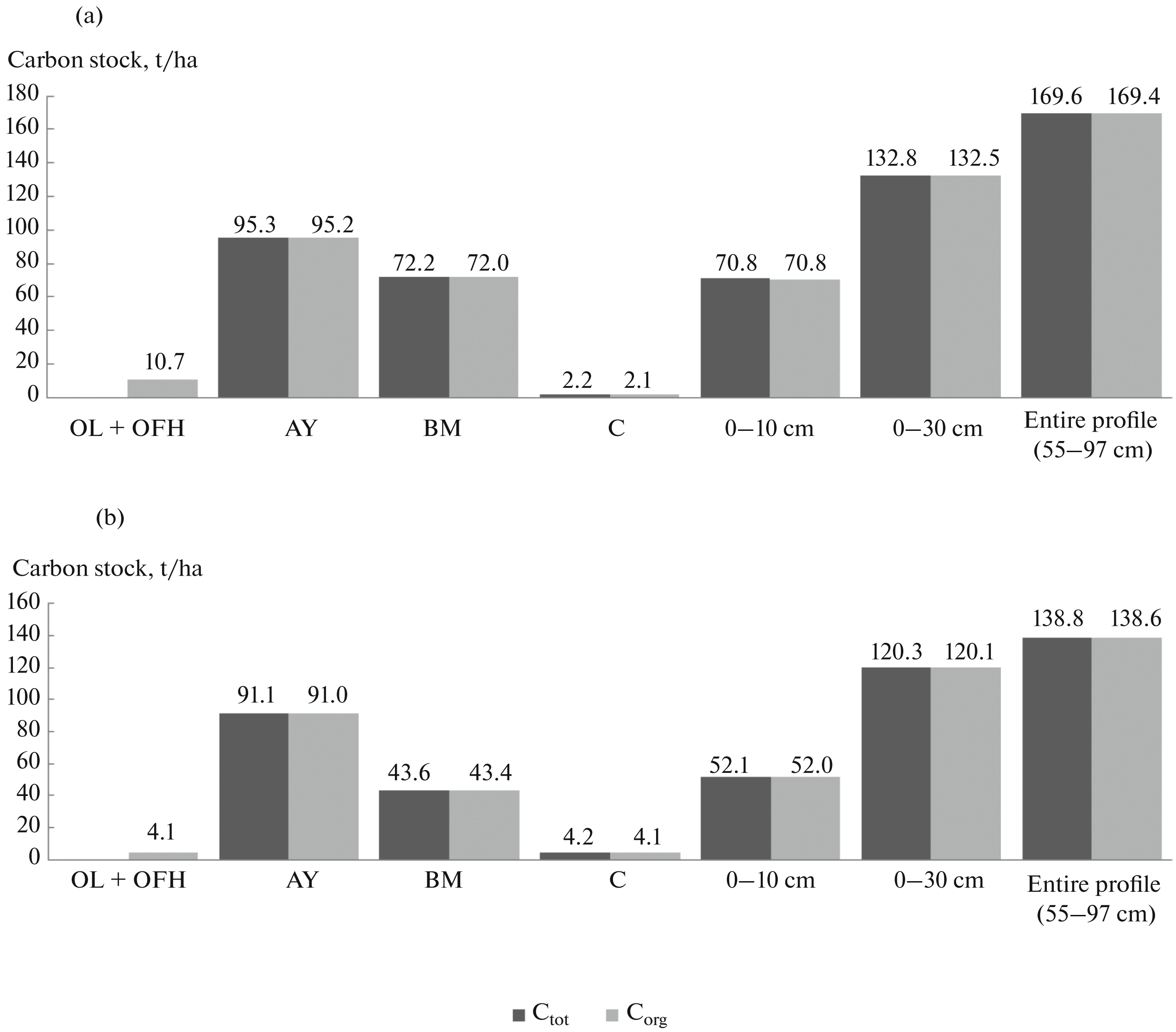

Fig. 4. Weighted averages of total and organic carbon stocks in Haplic Cambisols of two types of forest biogeocenoses (*n* = 15): (a) mixed-shrub Korean pine stand with yellow birch and linden and (b) mixed-shrub–herb oak–linden–maple stand.

characterized by minimum C_{tot} and C_{org} stocks in the AY horizon. The lowest C stock in the litter of Haplic Cambisols under broadleaved forests is characteristic of the black birch mixed-shrub EBGA. However, this EBGA has maximum C_{tot} and C_{org} stocks in the AY horizon. Close patterns are seen in the Haplic Cambisols of horsetail–herb mixed-shrub EBGA. Characteristic of the Haplic Cambisols in maple mixed-shrub EBGA was a relatively high C stock in both the litter and humus horizons.

DISCUSSION

The studied Haplic Cambisols are characterized by the low content of the carbon of carbonates which could be brought into the upper horizons by the soil fauna activity clearly seen in all the described soil pits [50].

The observed differences in the pH_{H_2O} values of forest litters in different EBGAs are determined by the specificity of plant litter composition and the microbial groups involved in litter decomposition [1, 3, 17, 29, 36, 38]. Maximum pH_{H_2O} values recorded in litters of maple mixed-shrub and hazel mixed-shrub EBGAs agree with the data of several studies suggesting a high content of ash and bases in the maple and hazel leaf waste [4, 15]. A widespread decrease in acidity in the lower subhorizon of forest litters most likely results from intensive decomposition of organic material arriving onto the soil surface during the warmest and humid summer–fall season; in this process, the organic acids formed in the OL subhorizon are neutralized by the bases released from the litter in the OFH subhorizon [5, 33, 34].

Table 4. Physical properties and C stocks in Haplic Cambisols of different EBGAs under mixed-shrub Korean pine stand with yellow birch and linden (*n,* sample size)

Horizon	Bulk density, g/cm^3	Fine earth content, %	C_{tot} stock, t/ha	C_{org} stock, t/ha
Mixed-shrub Korean pine ($n = 4$)				
OL	–	–	5.0 ± 0.7*a*	
OFH	–	–	6.9 ± 0.8*a*	
AY	0.7 ± 0.1*a*	91.9 ± 3.6*a*	118.8 ± 13.1*a*	116.5 ± 12.9*a*
BM	1.2 ± 0.2*a*	84.4 ± 4.4*a*	66.0 ± 8.9*a*	66.0 ± 8.9*a*
C	2.3 ± 0.1*a*	7.9 ± 0.3*a*	2.7 ± 0.5*a*	2.7 ± 0.5*a*
Mixed-shrub linden ($n = 3$)				
OL	–	–	4.0 ± 2*b*	
OFH	–	–	3.9 ± 0.1*b*	
AY	0.6 ± 0.1*b*	91.6 ± 3.1*a*	108.6 ± 12.0*b*	104.0 ± 11.8*b*
BM	0.8 ± 0.2*b*	87.2 ± 5.0*b*	42.3 ± 3.2*b*	42.1 ± 3.0*b*
C	2.2 ± 0.1*a*	8.2 ± 0.5*a*	1.3 ± 0.3*b*	1.3 ± 0.3*b*
Mixed-shrub hazel ($n = 2$)				
OL	–	–	2.3 ± 0.2*c*	
OFH	–	–	10.4 ± 1.2*c*	
AY	0.8 ± 0.1*a*	88.1 ± 2.9*ab*	105.4 ± 9.2*b*	105.2 ± 9.1*b*
BM	1.2 ± 0.2*a*	86.1 ± 3.0*ab*	112.4 ± 4.6*c*	112.4 ± 4.6*c*
C	2.1 ± 0.2*a*	8.3 ± 0.4*a*	1.8 ± 0.1*c*	1.8 ± 0.1*c*
Mixed-shrub ($n = 2$)				
OL	–	–	3.9 ± 0.7*b*	
OFH	–	–	3.0 ± 2.2*d*	
AY	0.7 ± 0.1*a*	82.8 ± 2.3*b*	63.1 ± 6.5*c*	63.1 ± 6.5*c*
BM	1.2 ± 0.1*a*	81.6 ± 1.1*c*	86.8 ± 7.9*d*	86.8 ± 7.9*d*
C	2.1 ± 0.2*a*	8.1 ± 0.3*a*	1.9 ± 0.4*c*	1.9 ± 0.4*c*
Korean pine without ground cover ($n = 2$)				
OL	–	–	4.2 ± 0.5*b*	
OFH	–	–	14.9 ± 0.9*e*	
AY	0.6 ± 0.1*b*	96.1 ± 4.6*c*	42.2 ± 2.0*d*	42.2 ± 2.0*d*
BM	1.1 ± 0.1*a*	80.1 ± 3.2*c*	65.9 ± 2.6*a*	65.9 ± 2.6*a*
C	2.2 ± 0.1*a*	7.4 ± 0.2*b*	1.4 ± 0.1*b*	1.4 ± 0.1*b*
Mixed-shrub maple ($n = 2$)				
OL	–	–	3.6 ± 0.3*b,c*	
OFH	–	–	9.4 ± 0.6*a,c*	
AY	0.5 ± 0.1*c*	95.0 ± 3.5*c*	60.0 ± 2.6*ce*	60.0 ± 2.6*ce*
BM	1.1 ± 0.1*a*	86.1 ± 2.9*ab*	96.3 ± 5.9*e*	96.1 ± 5.8*e*
C	2.3 ± 0.2*a*	9.1 ± 0.3*c*	2.1 ± 0.1*cd*	2.1 ± 0.1*cd*

(–) Not determined.

In addition to an increase in pH_{H_2O}, the removal of decomposition products from OL to OFH subhorizons is accompanied by intensified mineralization of organic compounds, which is confirmed by a narrower range of C/N variation. High biogenicity of the forest litters of Haplic Cambisols in the studied region enhances mineralization of plant litter [27, 38]. The organic compounds of forest litters are most intensively mineralized over a long time interval (from April to October), which is determined by the hydrothermal regime optimal for the decomposition of plant residues [15, 26, 30, 34]. However, the amount of precipitation in the south of Primorskii krai sharply decreases starting from the second half of September

Table 5. Physical properties and C stocks in Haplic Cambisols of different EBGAs under mixed-shrub–herb oak–linden–maple stand (*n,* sample size)

Horizon	Density, g/cm^3	Fine earth content, %	C_{tot} stock, t/ha	C_{org} stock, t/ha
Mixed-shrub oak ($n = 2$)				
OL	–	–	1.4 ± 0.1*a*	1.4 ± 0.1*a*
OFH	–	–	2.9 ± 0.3*a*	2.9 ± 0.3*a*
AY	0.7 ± 0.1*a*	98.0 ± 0.5*a*	78.3 ± 13.4*a*	78.3 ± 13.4*a*
BM	1.6 ± 0.2*a*	49.8 ± 14.9*a*	42.1 ± 12.6*a*	42.1 ± 12.6*a*
C	2.1 ± 0.1*a*	8.9 ± 0.2*a*	3.9 ± 0.6*a*	3.9 ± 0.6*a*
Mixed-shrub linden ($n = 3$)				
OL	–	–	1.5 ± 0.2*a*	1.5 ± 0.2*a*
OFH	–	–	2.9 ± 0.4*a*	2.9 ± 0.4*a*
AY	0.8 ± 0.1*b*	94.5 ± 3.1*b*	84.3 ± 6.6*b*	83.8 ± 6.6*b*
BM	1.0 ± 0.1*b*	66.7 ± 15.3*b*	36.2 ± 9.5*b*	35.9 ± 9.3*b*
C	1.9 ± 0.3*b*	9.0 ± 0.3*a*	4.7 ± 0.4*b*	4.7 ± 0.4*b*
Mixed-shrub fern–herb ($n = 3$)				
OL	–	–	2.0 ± 0.3*b*	2.0 ± 0.3*b*
OFH	–	–	2.1 ± 0.4*b*	2.1 ± 0.4*b*
AY	0.8 ± 0.1*b*	94.3 ± 0.5*b*	91.3 ± 9.9*c*	90.5 ± 9.5*c*
BM	1.4 ± 0.3*ac*	66.6 ± 13.8*b*	56.7 ± 11.4*c*	56.5 ± 11.2*c*
C	2.2 ± 0.1*a*	9.2 ± 0.2*b*	4.1 ± 0.3*ab*	4.1 ± 0.3*ab*
Mixed-shrub maple ($n = 3$)				
OL	–	–	0.9 ± 0.2*c*	0.9 ± 0.2*c*
OFH	–	–	3.0 ± 0.5*c*	3.0 ± 0.5*c*
AY	0.9 ± 0.1*bc*	92.6 ± 2.4*c*	143.0 ± 8.2*d*	142.7 ± 8.0*d*
BM	1.3 ± 0.2*ac*	66.6 ± 12.7*b*	21.2 ± 3.4*d*	21.1 ± 3.3*d*
C	2.3 ± 0.1*c*	8.7 ± 0.5*a*	2.7 ± 0.3*c*	2.6 ± 0.3*c*
Mixed-shrub black birch ($n = 2$)				
OL	–	–	1.0 ± 0.1*c*	1.0 ± 0.1*c*
OFH	–	–	1.2 ± 0.1*d*	1.2 ± 0.1*d*
AY	1.1 ± 0.2*d*	85.8 ± 1.3*d*	167.6 ± 9.3*e*	167.5 ± 9.2*e*
BM	2.3 ± 0.1*d*	8.7 ± 0.4*c*	8.1 ± 0.1*e*	8.1 ± 0.1*e*
C	2.4 ± 0.1*c*	8.0 ± 0.6*c*	3.6 ± 0.3*ac*	3.6 ± 0.3*ac*
Mixed-shrub fern–herb ($n = 2$)				
OL	–	–	1.0 ± 0.3*c*	1.0 ± 0.3*c*
OFH	–	–	2.0 ± 0.3*b*	2.0 ± 0.3*b*
AY	1.0 ± 0.1*cd*	89.9 ± 1.5*cd*	134.0 ± 14.6*cd*	134.0 ± 14.6*cd*
BM	1.8 ± 0.4*ce*	53.1 ± 14.7*d*	25.2 ± 2.7*bd*	25.1 ± 2.7*bd*
C	2.3 ± 0.1*c*	20.9 ± 2.6*d*	7.4 ± 0.8*e*	7.4 ± 0.8*e*

(–) Not determined.

against the background of sufficiently high air temperature leading to drying of forest litters and slowing down decomposition of organic compounds [15, 16]. At the moment of litter sampling (September 12–21), the C content in the OFH subhorizon amounted to 64.1–70.6% (mean values) of the C content in the OL subhorizon. The data by Kostenkova [15, 16] suggest a change in the relative C content in litter subhorizons in June and July, when the mineralization of plant waste litter reaches its maximum intensity, so that the difference between the C contents in the OL and OFH subhorizons can considerably decrease. The recorded levels of the N content in forest litters of Haplic Cambisols are determined by the specific regional features in the decomposition of plant litter in the soils under coniferous–broadleaved forests in the studied territory and are the result of the secondary N synthesis by the functional groups of the microorganisms that saturate the forest litter with inorganic N-containing compounds (mainly, ammonia nitrogen) [7, 38].

The annual input of abundant plant litter and its intense mineralization predetermine the input of a considerable amount of C compounds to the humus horizon of Haplic Cambisols. Earlier data demonstrate that the low molecular weight organic compounds leached out from the litter into the AY horizon are form complexes with alkaline and alkaline-earth elements as well as with sesquioxides [5, 15, 16, 33]. A sharp switch from humid to dry season and from positive to negative temperatures in the fall, as well as the subsequent deep soil freezing and shallow or absent snow cover in winter leads to the conservation of organic compounds and fixation of humic substances in the upper part of the profile [34]. A significant C/N ratio in the humus horizon of Haplic Cambisols confirms the predominance of immobile humic acids in the system of humic compounds accumulating in the humus horizon. A significant C_{tot} content in the C horizon is a specific regional feature of the Haplic Cambisols formed on granites and basalts of the low mountains under coniferous–broadleaved forests [9, 11, 27, 31]. Taking into account the presence of humus tongues (to a depth of 50–60 cm) and the abundance of skeletal material in the soil profiles, the most likely cause of a sufficiently high carbon content in the C horizon is a mechanical transport of C compounds from the above horizons with fine earth.

The calculated weighted average C stock suggests a higher potential of the Haplic Cambisols under Korean pine stand in accumulating and stabilizing carbon in the profile as compared with the Haplic Cambisols under broadleaved forest (Fig. 4). Taking into account similar thicknesses of the AY horizon in Haplic Cambisols of two BGCs and similar fine earth content there, as well as a lower bulk density of the humus horizon under Korean pine stand, plant litter composition, conditions of its decomposition, and qualitative composition of the formed organic matter most likely have a more significant effect on the C content and C stock in the upper part of the soil profile under Korean pine stand [1, 4, 8, 15, 19, 34]. More pronounced conservation of plant litter confirmed by a larger litter stock, as well as a longer period of its transformation and a gradual input of labile freshly formed reactive organic compounds to the upper part of the mineral profile are accompanied by the formation of a larger amount of stable organomineral complexes in the upper 10-cm-thick layer of Haplic Cambisols under Korean pine stand. Litter decomposition and the removal of C compounds into the humus (AY) horizon are more intense under linden mixed-shrub EBGA in comparison with those under the EBGA without living ground cover. Shrub litter under mixed-shrub Korean pine EBGA increases the decomposition of litter material in the humus horizon and the input rate of C compounds to this horizon. The differences in the thickness, density, and fine earth content in the BM horizons of Haplic Cambisols of the two examined BGCs suggest higher intensity of weathering and illuviation of clay particles without destruction (lessivage) in the thicker middle-profile horizons of Haplic Cambisols under Korean pine stand on the southwestern slope. The weighted average C stocks in the BM horizon and in the entire profile of these soils are somewhat higher. A comparison of C_{org} stock of Haplic Cambisols under Korean pine stand with that in the soils of broadleaved forests of China at approximately the same latitude (168.4 t/ha) indicates their close values; the C stock in the soils of mixed forests of China is somewhat higher (188.2 t/ha) [49].

Though the C content in the middle-profile and lower horizons of Haplic Cambisols under broadleaved forests is higher, a lower thickness of the BM horizon and a lower content of fine earth in it determine a lower weighted average C stock in this horizon. These specific morphological features most likely enhance the input and accumulation of C compounds in the C horizon. The C and N contents and C/N ratio in forest litters under broadleaved forest suggest intensified destruction and mineralization of the initial plant litter as compared with these processes in the litters under Korean pine forest. The analysis of C stocks in the litters and in the AY horizons of Haplic Cambisols under different EBGAs of broadleaved forest suggests a higher decomposition rate of the litter material and a more intense accumulation of C compounds in the AY horizon of the soils under black birch mixed-shrub and horsetail–herb mixed-shrub EBGAs. Rather active input and accumulation of C compounds in the AY horizon during long-term decomposition of forest litter material is characteristic of the Haplic Cambisols under maple mixed-shrub EBGA. Though there are certain differences in the qualitative composition of plant litter and the rate of its decomposition noted in the scientific literature [1, 19, 35, 36], linden and oak mixed-shrub EBGAs of broadleaved forests are generally characterized by the lower input of C compounds from the litter into the humus horizon, which reflects less favorable conditions for C accumulation in Haplic Cambisols. In general, our data on the C_{org} stock in the entire profile of Haplic Cambisols under broadleaved forest correspond to the worldwide average value of C stock in the soils under deciduous forests of temperate latitudes (122 t/ha) [39].

The observed variation in C_{tot} and C_{org} stocks in the individual horizons and in the entire profile of studied Haplic Cambisols is largely determined by the variation in the fine earth content. This factor has to be taken into account when calculating C_{tot} and C_{org} stocks for a more adequate assessment of C sequestration in the studied Haplic Cambisols and, presumably, in the soils of similar genesis. The C_{org} content and stock in these soils can be calculated from data on the C_{tot} content, because the content of carbonate C is very low and can be neglected when assessing the content and stock of C compounds in the Haplic Cambisols of the studied region.

CONCLUSIONS

Haplic Cambisols developed under mixed-shrub Korean pine forests with yellow birch and linden and under mixed-shrub, herbaceous oak–linden–maple forests have a slightly acid reaction, low carbonate content, and abundant skeletal material. Zonal specificity of organic matter transformation coupled with the downward branch of the biological cycle in monsoon forest landscapes of the Far East of Russia results in the high rates of plant litter mineralization, which is accompanied by the formation of a thin (2 to 5 cm) litter horizons and limited litter stocks. The studied soils are characterized by distinct differentiation of C and N contents in the soil profiles. Abundant input of plant litter and its intensive decomposition determine the high input and accumulation of C compounds in the humus horizon. In the BM horizon, the C and N contents sharply decrease, while a more gradual decrease in their contents is observed in the lower part of the profile. The high C content in the lower part of the soil profile is explained by the mechanical transport of C compounds with fine earth from the overlying horizons. Most of C compounds in the studied Cambisols are represented by organic C (98.7 to 99.9% of C_{total}); the contribution of inorganic (carbonate) C is very low, so that the total C content and stock are approximately equal to the organic C content and stock.

Comparative analysis of research result conducted using methodological recommendations demonstrated that the processes of C stabilization and accumulation in the profiles of Haplic Cambisols are more pronounced under Korean pine stands than under broadleaved forests. The soils under the canopy of Korean pine are characterized by higher C content and stocks in the forest litter and higher weighted average C stock in the upper and middle-profile mineral horizons, as well as in the layers of 0–10 and 0–30 cm. The processes of forest litter decomposition and the leaching of C compounds into the underlying humus are more active under the linden mixed-shrub EBGA than under the Korean pine EBGA without living ground cover.

A specific feature of Haplic Cambisols under broadleaved forests is a more intense destruction and mineralization of organic matter in the litter horizon as compared with that in the litter of Korean pine stands. Forest litter transformation is accompanied by input of C compounds into the underlying horizons, and this process is most active in the black birch mixed-shrub and mixed-shrub horsetail-herb EBGAs. It is slower in the linden and oak mixed-shrub EBGAs. A higher C stock in the lower part of the profile of Haplic Cambisols under broadleaved forests attests to the active removal of C compounds from the overlying horizons into the lower part of the profile and, probably, beyond.

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ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This work does not contain any studies involving human and animal subjects.

CONFLICT OF INTEREST

The authors of this work declare that they have no conflicts of interest.

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