Changes in SOM Composition as a Function of Land-use

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1. Introduction

Soil organic matter (SOM) being the largest reservoir of the terrestrial carbon, plays an important role in the global carbon cycle. SOM, which is acting as a carbon-dioxide source and sink, contains a wide range of chemically and kinetically different organic matters and exhibits large variations in relation to land use. Consequently, changes both in the abundance of SOM and in the proportion of SOM pools with different stability result in changes in the fluxes of carbon-dioxide between atmosphere and soil.

Several authors have described that forest clearing and cultivation result in essential changes in SOM abundance [1, 2] and in the amount and composition of its refractory fraction inherited from the forest soil [3].

Recently Rock-Eval pyrolysis has been used to follow organic matter transformation in soil and recent sediments (e.g. 4, 5, 6]. An application of Rock-Eval pyrolysis for the rapid estimation of the relative contribution of the major classes of heterogeneous organic matter differring in origin and thermal stability has been reported [7] only for topsoils (litter layers and A horizons).

This work presents the changes in the composition of SOM and in the transformation of the source biomass from topsoil to subsoil horizons of Chernozem soil under forest use and under 33 years of agricultural use after clearing. The relative contribution of the labile and resistant bio-macromolecules, immature and highly refractory geo-macromolecules has been determined by the mathematical deconvolution of Rock-Eval pyrograms.

2. Materials and Methods

Samples were collected from Chernozem soils from the temperate zone under continental influence (north-west Hungary). In this area the average precipitation is 550-600 mm year^{-1}, the mean annual temperature is 9.5-9.8^{o}C. The topsoil and subsoil horizons of the nearly neutral (pH: 6.8) forest soil under mixed oak vegetation and the adjacent cultivated soil (pH: 8.0), with calcium-carbonate concretions in the subsoil, were sampled (referred to as F_t, F_s and A_t, A_s, respectively). The A_t and A_s samples were taken after 33 years of wheat cropping following the clearing.

Rock-Eval pyrolyses were performed with an Oil Show Analyzer: heating at 180^{o}C for 3 min, programmed pyrolysis at 25^{o}C/min up to 600^{o}C under helium flow and oxidation at 600^{o}C for 7 min under an air flow. The relative contribution of labile (fresh plant and litter) and resistant (lignin and cellulose) bio-macromolecules, immature geo-macromolecules (humic substances sensu lato) and highly refractory geo-macromolecules (naturally stable biological compounds, OM stabilized by physical-chemical processes and black carbon) was calculated by the mathematical deconvolution of Rock-Eval pyrograms.

3. Results and Discussion

Influence of land-use on the amount and composition of the studied SOM is shown both by bulk Rock-Eval data [5] and the relative contribution of the major classes of the organic matter differring in origin and thermal resistance (Table 1).

Table 1
Changes in the relative contribution of the bio- and geo-macromolecules and in the preservation of the biomass from topsoil to subsoil horizons.

Land – use	Horizons	BP_l	BP_r	GP_i	GP_m	BP_l/ BP_r	D_{iOM}
Agricultural	Topsoil (A_t)	20.1	18.6	23.0	38.3	1.08	0.23
	Subsoil (A_s)	19.7	24.8	18.1	37.4	0.79	0.39
Forest	Topsoil (F_t)	31.8	23.7	31.7	12.8	1.34	0.24
	Subsoil (Fs)	11.8	18.3	18.9	51.0	0.64	0.20

BP_l: labile bio-macromolecules, BP_r: resistant bio-macromolecules,
GP_i: immature geo-macromolecules (humic substances), GP_m: highly refractory geo-macromolecules,
D_{iOM}: the degree of the preservation of the primary biomass: $\log [(BP_l + BP_r)/GP_i]$

The low organic carbon contents in the topsoil of the forest (3.9 %,) and cultivated soil (1.6 %) are characteristic of the temperate zone under continental influence and are consistent with the general decreasing trend of SOM due to deforestation and cultivation. Similar values (3.5 and 1.5 %) for Bulgarian Chernozem forest and cultivated topsoils have been reported [4].

Results obtained from the mathematical deconvolution of pyrograms, in agreement with the bulk Rock-Eval data, reveal a moderate transformation of the source biomass to humic substances from the forest topsoil to the subsoil. It is shown by the slight decrease in the degree of the preservation rate (Table 1) and in the proportion of the bio-macromolecules (Table 2), as well as by the parallel increase in the proportion of the immature geo-macromolecules (humic substances) (Table 2). Additionally, these observations are confirmed by the high decrease in the ratio of the labile and resistant bio-macromolecules and by the substantial increase in the relative contribution of the highly refractory geo-macromolecules (Table 1). The significant change in the HI values, together with the HI/OI ratios, also display the early stage of the humification processes [5].

The vertical decrease in TOC content and HI values reflects more limited changes for cultivated soil than forest soil. The drop in the TOC content is twice as high for the forest soil as for the cultivated soil, 69 and 34 %, respectively. The markedly lower difference between HI values measured for the two horizons of the cultivated soil (131 and 102 mgHC/g TOC) compared with forest soil (144 and 80 mgHC/g TOC) is in good agreement with the proportion of labile bio-macromolecules in the SOM (Table 2). The labile biomass accounted for about one-third of the immature fraction both in agricultural topsoil and subsoil. Conversely, a markedly reduced storage of labile bio-macromolecules and a moderate degradation of the total immature fraction were observed from the forest topsoil to the subsoil. Differences in the downward decreasing proportion of labile bio-macromolecules relative to resistant ones (BP_l/ BP_r in Table 1) suggest a slightly higher importance of resistant biopolymers in the forest subsoil than in agricultural subsoil.

Table 2
The proportion of the labile (BP_l) and resistant (BP_r) bio-macromolecules and humic substances (GP_i) in the immature organic matter.

Land – use	Horizons	BP_l	BP_r	GP_i
Agricultural	Topsoil (A_t)	32.6	30.1	37.3
	Subsoil (A_s)	31.5	39.6	28.9
Forest	Topsoil (F_t)	36.5	27.2	36.4
	Subsoil (F_s)	24.1	37.3	38.6

Comparing topsoil and subsoil horizons to each other, deforestation and agricultural cultivation resulted in dissimilar changes in the composition of SOM. Differences detected in the amount and composition of SOM between two horizons of the forest soil decrease during agricultural use. While no differences are observed in the transformation rate of the biomass for topsoils, the degree of the preservation of the primary vegetal input (Table 1) is nearly twice as high in the cultivated subsoil as in the forest subsoil. This conspicuously better preservation rate of the source biomass could be a consequence of the higher proportion of bio-macromolecules in the immature organic matter (Table 2).

4. Conclusion

Bulk Rock-Eval data and the results of the mathematical deconvolution of pyrograms, monitored on the forest topsoil, show a characteristic Chernozem soil developed in the temperate zone under continental influence.

Results, presented here, reveal a moderate increase in the transformation of the source biomass to humic substances from the forest topsoil to the subsoil.

Forest clearing and cultivation did not result in changing the evolution of the humification process in the topsoil. Independently of land-use, a similar degree of the preservation of the primary biomass and a similar proportion of humic substances in the immature organic fractions (sum of bio-macromolecules and humic substances) were found for both topsoils. The higher proportion of labile bio-macromolecules and the lower proportion of resistant bio-macromolecules, detected in the cultivated topsoil, could be a consequence of the different vegetation.

Differences observed in the amount and composition of SOM between the two horizons of the forest soil decreased during agricultural use.

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