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# *C* AND *N* MINERALIZATION IN MINERAL SOIL OF ADJACENT ECOSYSTEMS ON TIMBERLINE (UKRAINIAN CARPATHIAN Mts.)

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Results to the turnover of organic matter in three ecosystems under different vegetations, especially soil microbial C and N and rate of C and N mineralization, are analyzed. Total C and N and microbial C and N contents in mineral soils (0–20 cm depth) differed appreciably in the three ecosystems and were 2,76, 1,81, 1,85 and 1,41 times, respectively, greater on the forest site then at the grassland site. $CO_2$-C production greater at the forest and shrubbery sites, metabolic quotients ($qCO_2$ values) tended to be greater in mineral soil from the forest site. Net N mineralization was similar in shrubbery and forest mineral soils at 0–10 cm depths, but was lower in the grassland sites in 1,87 times. Nitrification was very low in the samples of mineral soil in these ecosystems.

*Key words: soil, C biomass, C mineralization, ecosystem, Ukrainian Carpathians Mts.*

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МІНЕРАЛІЗАЦІЯ ОРГАНІЧНОГО ВУГЛЕЦЮ Й АЗОТУ В ҐРУНТАХ СПРЯЖЕНИХ ЕКОСИСТЕМ НА ВЕРХНІЙ МЕЖІ ЛІСУ (УКРАЇНСЬКІ КАРПАТИ)

Проаналізовано трансформацію органічної речовини у ґрунтах трьох екосистем з різним рослинним покривом: уміст органічного С і N, величину С і N мікробної біомаси, швидкість мінералізації органічних сполук С і N. Загальний вміст органічного і мікробного С і N був вищим у 2,76, 1,81, 1,85 і 1,41 рази в ґрунтах лісової екосистеми порівняно з лучною. Інтенсивність продукування $CO_2$-C була вищою у ґрунтах лісової і чагарникової екосистеми, а метаболічний коефіцієнт ($qCO_2$) вищий у лісовій екосистемі. Мінералізація органічного N була на одному рівні у шарі ґрунту 0–10 см чагарникової і лісової екосистем, але нижчою від лучних ділянок у 1,87 рази. Інтенсивність нітрифікації була дуже низькою у ґрунтах всіх досліджуваних екосистем.

*Ключові слова: ґрунт, вуглець біомаси, С-мінералізація, екосистема, Українські Карпати.*

Indigenous forest, shrubbery and grassland, together whit their associated soils, are major reservoirs of terrestrial *C* (Bouwman, 1900; Post et al., 1990). Content of carbon would be approximately in equilibrium of mature ecosystems, with the amount of C fixed annually through photosynthesis being balanced by the output of $CO_2$-C from above- and belowground respiratory activity. Under the predicted increases in levels of atmospheric $CO_2$ and temperature over the next decades (Anderson, 1991), this equilibrium could be affected and possibly result in increased decomposition of soil organic matter and production of $CO_2$-C. The extents to which this may occur would party depend on the quality of the organic matter input and the metabolic potential of the decomposer organisms.

The present study forms part of the wider investigation in which soil *C* storage and turnover times are being compared in adjacent ecosystems under different vegetations, including European dwarf-pine (Pinus mugho Turra) elfin forest, spruce (Picea abies (L.) Karst.) forest, shrubbery (Juniperus sibirica L.), low shrubbery (Vaccinium myrtillus L.) and grassland (Festuca rubra L., Nardus stricta L.) ecosystems. Three sites on timberline in East Carpathians were here selected.

Results to the turnover of organic matter in three ecosystems under different vegetation, especially microbial C and N rate of *C* and *N* mineralization, are analyzed. Determining their inter-relationships, including q $CO_2$ values (specific respiration activity, which represent the $CO_2$ production her unit *C* biomass and unit time (Anderson and Domsch, 1985) assessed properties of the component microorganisms and organic matter. The distribution of total and microbial *C* and *N* in mineral soils for each soils horizon to 65 cm depth was measured. Others aspects of *C* storage, especially in litter, and turnover time in this and others ecosystems have been reported by Chornobai and Maryskevych (1992) and Shpakivska (1998).

## MATERIAL AND METHODS

*Site and soils*

The forest site (elevation 1320 m asl, slope $12^0$) was located 10 m below the timberline, the low scrublands site (elevation 1350 m asl, slope $25^0$) – 20 m above timberline and the grassland (elevation 1360 m asl, slope $15^0$) – 30 m above timberline on the Northern-Eastern macroslope of Chornohora massive of the Eastern Carpathians in the Carpathian National Park. Mean annual precipitation on the site is 1440 mm and mean annual air temperature 2,8 $^0$C. The clay loam soils are Cambisols type.

The forest site was spruce monodominate of Picea abies (L.) Karst. with close up canopy 0,8, tree diameters at 28 cm height 27,5 m. The low scrubland site was dominated by Vaccinium myrtillus L. in the basal cover of 40 %. The grassland site was dominated by Nardus stricta L. in the basal cover of 45 %.

*Sampling*

At each site, samples of mineral soils at different depth were taken on 10 November 1994 yr. across the slope. Samples were taken at five duplicates. Following collections, the samples were manually homogenized, and rocks and roots > 3 mm was removed. Samples were transported at ambient temperature, and stored at 4 $^0$C. The samples were wet to field capacity by spreading them on muslin sheets, wetting them, and allowing them to drain for 24 h. The soils samples were handed in the plastic bags to minimize evaporative losses and saved during 3 days for stabilization microbial processes.

*Analytical methods*

Soil samples, *pH* (in water), total *C* and *N* concentration were determinate according Arinushkina (1980).

Soil microbial *C* and *N* were determinate according Blagodatskiy et al. (1987) by rehydration methods. Soil samples were dried at 70 $^0$C for 8 h in an oven extracted with 0,5M $K_2SO_4$ (2 ml of extract $g^{-1}$ soil) for 30 min. The suspension was filtrated and 1,6 ml of solution was mixed with 2,4 ml $K_2Cr_2O_7$ (1,28 g $K_2Cr_2O_7$ + 400 ml $H_2O$ + 2000 ml $H_2SO_4$). In the mixture after 24 h was determinate concentration of *C* at 590 nm. Microbial *N* was determinate in same extracts measured concentration of N-$NH_4^+$ at 410 nm with used $K_2(HgJ_4)$ + KOH.

Soil microbial biomass *C* (*N*) were calculated using the formula [(C(N) extractable from rehydrated soils)-[(C(N) extractable from non-rehydrated soils)] / $k_c(k_n)$. $k_c = 0,25$ and $k_n = 0,31$.

$CO_2$-C production was determinate at 25 $^0$C using 40g mineral soils at 60 % of WHC. The $CO_2$ produced was absorbed in 10 ml 0,1M KOH, and estimated by titration of excess alkali with 0,05M HCl, after precipitation of the $K_2CO_3$ formed with 1,0 ml 1 M $BaCl_2$.

Nitrogen mineralization of samples at 60 % of WHC was measured after incubation for 21 days at 25 $^0$C. N-min was calculated as the difference between the min-N ($N=N(NH_4^+ + NO_3^-)$) extracted in 1M KCl before and after incubation.

The specific metabolic activity as specific respiration activity $qCO_2$ (called metabolic quotient of $CO_2$ by Anderson and Domsch, 1985) represented the $CO_2$ production per unit biomass and unit time.

## RESULTS

The analyses of variance showed that the ecosystem by depth interaction was significant for most properties, as indicated by the summarized data in table 1 and 2–4.

Mineral soil was more acidic in the forest and low scrubland than in the grassland. Concentration of total *C* and *N* were higher in low scrubland and forest soils than in the grassland and decline with the profile depth. *C*-to-*N* ratios were lower in mineral soil samples from grassland than from the others. Concentration of extractable *C* and *N* were highest in the soil of low scrubland lowest in the grassland.

Microbial *C* and *N* concentration declined consistently with soil depth (table 2) and were significantly higher in the mineral soils of forest and low scrubland ecosystems. Microbial *C*-to-*N* ratio declined with soil depth, but was similar in all samples of mineral soils.

Rates of $CO_2$-C production were in all samples declined with profile depth (table 3) and lower in 1,2 and 2,5 times in the soil low scrubland and grassland ecosystems. $CO_2$-C produced, as a percentage of total *C*, also tended to decline with sample depth and be greater in the grassland and forest soils than the low scrubland soils.

*Table 1*

**Some properties of the soils (Dystric Cambisols) on the timberline of Chornohora (Ukrainian Carpathians)**

| Soil sample depth, cm | Bulk density, g cm $^{-3}$ | Field moisture, % | pH $_w$ | Total C | | C/N | Extractable* | |
|---|---|---|---|---|---|---|---|---|
| | | | | C | N | | C | N |
| | | | | g kg $^{-1}$ | | | µg g $^{-}$1 | |
| Forest | | | | | | | | |
| 0–7 | 0,51 | 91 | 4,1 | 73,7 | 5,6 | 13 | 215 | 25 |
| 8–25 | 0,73 | 75 | 4,3 | 25,6 | 1,7 | 15 | 165 | 19 |
| 26–48 | 0,97 | 65 | 4,6 | 15,7 | 2,0 | 8 | 97 | 11 |
| 49–68 | ND | 66 | 4,8 | 13,5 | 1,7 | 8 | 45 | 7 |
| Low shrubbery | | | | | | | | |
| 0–10 | 0,35 | 135 | 3,7 | 107,9 | 7,1 | 15 | 275 | 31 |
| 11–43 | 0,51 | 67 | 4,4 | 38,4 | 3,8 | 10 | 193 | 28 |
| 44–65 | ND | 63 | 4,6 | 16,6 | 2,0 | 8 | 75 | 9 |
| Grassland | | | | | | | | |
| 0–4 | 0,70 | 64 | 4,1 | ND | ND | ND | ND | ND |
| 5–11 | 0,85 | 58 | 4,4 | 23,0 | 3,2 | 7 | 122 | 15 |
| 11–21 | 0,98 | 42 | 4,6 | 18,8 | 2,9 | 6 | 116 | 14 |
| 22–27 | 1,05 | 39 | 5,0 | 4,2 | 1,3 | 3 | 74 | 10 |
| 38–65 | ND | 33 | 5,0 | 3,2 | 1,1 | 3 | 38 | 6 |

* Extractable in 0,5 M $K_2SO_4$; ND – not determined.

$qCO_2$ value was lower in the grassland than in the corresponding forest and low scrubland samples, and is generally declined with sample depth (table 4).

Net *N* mineralization during 0–21 days was similar in the low scrubland and forest mineral soils, but was lower in grassland sites in 1,8 and 1,6 times. Nitrification was very low in the samples of mineral soils in these ecosystems.

## DISCUSSION

Soil moisture and organic matter concentration, as shown by total *C* and *N* values, were appreciably greater in the low shrubbery and forest than in the grassland soils sites. In accord with these ecosystem differences in soil organic matter concentration levels of microbial *C* and *N* were also higher in the low scrubland and forest than in the grassland soils.

Relations between microbial biomass and other soil properties are partly dependent on the validity of the microbial *C* and *N* estimated which in rehydration procedure, are dependent on the $k_c$-factors used. Our experimentally determinate $k_c$-factors, for converting extractable-C flush to microbial *C*, which based on the pattern of *C* mineralization during 10–20 days of incubation and the size of the $CO_2$-C flush.

Overall, we consider that the mean $k_c$-factors of 0,25 was satisfactory for estimation microbial *C* by the rehydration method, although possible subject to errors for up 20 % for some of different samples.

Content of microbial *C* generally similar to those found for comparable samples in a spruce forest with Norway spruce (Picea abies (Karst.) L.) (Pietikainen, Fritze, 1995; Priha, Smolander, 1997). Our microbial *C* values were bases on the rehydration and would have included the whole microbial biomass, whereas those evidence that were based on SIR measurements would have comprised mainly glucose-responsive, rather than total, numbers of organisms (Wardle and Parkinson, 1990).

*Table 2*

**Microbial C and N and relationships with total C and N in soils (Dystric Cambisols) on the timberline of Chornohora (Ukrainian Carpathians)**

| Soil sample depth, cm | Soil horizons | Microbial | | Microbial C / Total C | Microbial N / Total N | Microbial C/N |
|---|---|---|---|---|---|---|
| | | C | N | | | |
| | | μg $g^{-1}$ | | % | | |
| Forest | | | | | | |
| 0–7 | A | 1930 | 308 | 2,6 | 5,5 | 6,3 |
| 8–25 | $AB_t$ | 1310 | 218 | 5,0 | 12,8 | 6,0 |
| 26–48 | $B_t$ | 620 | 107 | 3,9 | 5,4 | 5,8 |
| 49–68 | $B_tC$ | 530 | 106 | 3,9 | 6,2 | 5,0 |
| Low shrubbery | | | | | | |
| 0–10 | $A_d$ | 2190 | 247 | 2,0 | 3,5 | 8,9 |
| 11–43 | AB | 1400 | 189 | 3,6 | 5,0 | 7,5 |
| 44–65 | BC | 1230 | 178 | 7,4 | 8,9 | 6,9 |
| Grassland | | | | | | |
| 5–11 | $A_d$ | 1240 | 175 | 5,4 | 5,5 | 7,1 |
| 11–21 | AB | 920 | 142 | 4,9 | 5,0 | 6,5 |
| 22–27 | B | 440 | 76 | 10,4 | 5,8 | 5,8 |
| 38–65 | BC | 200 | 19 | 3,1 | 1,7 | 5,2 |

In each column, values not marked with the same letter are significanty different ($P < 0,05$).

The percentages of total *C* and *N* occurring as microbial *C* and *N*, similar to those found for comparable samples in s boreal coniferous forest with Scots pine (Pinus sylvestris L.) and Norway spruce in Finland (Priha, Smolander, 1997). A trend for microbial *C*-to-*N* ratio to decline with sample depth in forest soil was also previously observed (Ross, Tate, 1993) and could be indicative of higher proportion of fungi than bacteria in the horizon A than the others horizons (Anderson, Domsch, 1980). The microbial *C*-to-*N* ratio of 6,3 in the forest 0–7 depth of mineral soil ($pH_w = 4,4$) was similar to the ratio 6,2 calculated for soil of same depth and acidity ($pH_w = 4,5$) from forest dominated by Picea abies (Kast.) L. (Priha, Smolander, 1997).

Total $CO_2$-C production from mineral soil differed between the soil samples for horizon *A*, and differed little between the forest, low scrubland and grassland samples for horizons *AB*, *B* and *BC* (table 3). This trend $CO_2$-C production from mineral horizons of soils observed for montane forest and grassland ecosystems (Ross, Tate, Feltham, 1996).

The metabolic quotient ($qCO_2$) has been used for a variety of comparative purposes (Insam and Haselwandter, 1989; Anderson and Domsch, 1993) and, as in our present samples, has been found to decline with depth mineral soils. The $qCO_2$ of the forest was significant greater than the $qCO_2$ of the horizon A of the grassland, whereas the $qCO_2$ values of others soil horizons were similar. Although acidity of forest and grassland samples were similar in both ecosystems (table 1). Moreover, the $qCO_2$ values of the forest samples of mineral soil were higher than the $qCO_2$ values of the more acidic similar samples from the low scrubland. These date not coincided with assertion that the soil with more acidic having higher $qCO_2$ values

(Anderson, Domsch, 1993), but similar trend found for lowland beech forest (Ross, Tate, 1993). The composition of the soil organic matter may have been a factor contribution to these $qCO_2$ differences, with lower proportion of readily metabolizable material occurring in the grassland and low scrubland sites than in the montane spruce forest.

*Table 3*

**$CO_2$-C production and $qCO_2$ values of the samples of soils (Dystric Cambisols) on the timberline of Chornohora (Ukrainian Carpathians)**

| Soil sample depth, cm | Soil horizons | $CO_2$-C production | | $qCO_2$, μg $CO_2$-C produced $mg^{-1}$ microbial C $h^{-1}$ |
|---|---|---|---|---|
| | | μg $g^{-1}$ $h^{-1}$ * | Σ 0–10 days as % of total C | |
| | | Forest | | |
| 0–7 | A | 4,40 | 0,60 | 2,28 |
| 8–25 | $AB_t$ | 1,17 | 0,45 | 0,89 |
| 26–48 | $B_t$ | 0,52 | 0,33 | 0,84 |
| 49–68 | $B_tC$ | 0,36 | 0,27 | 0,68 |
| | | Low shrubbery | | |
| 0–10 | $A_d$ | 3,83 | 0,36 | 1,75 |
| 11–43 | AB | 1,50 | 0,39 | 1,07 |
| 44–65 | BC | 0,41 | 0,35 | 0,33 |
| | | Grassland | | |
| 5–11 | $A_d$ | 1,78 | 0,77 | 1,44 |
| 11–21 | AB | 1,03 | 0,55 | 1,12 |
| 22–27 | B | 0,35 | 0,83 | 0,80 |
| 38–65 | BC | 0,16 | 0,50 | 0,80 |

* Mean value over the 0–10 day incubation period.

Net *N* mineralization differed appreciably in horizon *A* of soils from the forest, low shrubbery and grassland. The production of 53,1 and 56,1 mg min-N $g^{-1}$ the forest and low shrubbery appreciably greater than the 29,9 мg min-N $g^{-1}$ produced after 21 days incubation by the soil from grassland. Net N mineralization in the lower depth of mineral soils differed between these ecosystems, but the low shrubbery soils was more active (table 4). A similar trend nitrogen transformation during 6 weeks incubation was found for the lowland coniferous forest (280 m a. s. l.) (Pietikainen, Fritze, 1995).

Total *C* and microbial *C* contents, when expressed on an area basis, differed appreciably between forest, low scrubland and grassland sites (Shpakivska, 1998). For example, in 0–20 cm depth of mineral soil total *C* content averaged 4965 and microbial *C* content 209 g $m^{-2}$ in the forest, 1303 and 176 g $m^{-2}$, 4855 and 245 g $m^{-2}$, respectively, in the low scrubland and grassland ecosystems. Annual *C* input averaged 242 g $m^{-2}$ for the spruce forest, 53 g $m^{-2}$ and 95 g $m^{-2}$ for scrubland and grassland sites. The annual input of *C* was thus 2,5 times greater in the forest than in the grassland, whereas total soil *C* (to 20 cm depth of mineral soil) was only in 1,2 times greater in the forest (fig. 1). The more rapid turnover of decomposable *C* account for this marked proportionate difference between annual *C* input *C* and pools of soil *C* and microbial *C* these two ecosystems.

Results, overall, show that marked differences in soil and microbial properties can occur in adjacent, indigenous ecosystems in almost the same climatic environment. Although soil microbial biomass level were lower in the grassland site than in the scrubland and in the forest site, the potential metabolic activity of the component microorganisms tended to be greater in

*Table 4*

**Value of N-mineralization in the soils (Dystric Cambisols) on the timberline of Chornohora (Ukrainian Carpathians) after incubation 21 days**

| Soil horizons | Ammonification $N\text{-}NH_4^+$ min | Nitrification $N\text{-}NO_3^-$ min | N mineralization $N(NH_4^+ + NO_3^-)$ | N mineralization, % N total |
|---|---|---|---|---|
| | μg $g^{-1}$ | | | |
| | | Forest | | |
| A | 47,1 | 6,0 | 53,1 | 0,95 |
| AB | 20,2 | 2,3 | 22,5 | 1,32 |
| | | Low shrubbery | | |
| $A_d$ | 52,3 | 3,8 | 56,1 | 0,79 |
| AB | 34,4 | 1,9 | 36,3 | 0,95 |
| | | Grassland | | |
| $A_d$ | 29,0 | 0,9 | 29,9 | 0,93 |
| AB | 12,2 | 0,3 | 12,5 | 0,43 |

In each column, values not marked with the same letter are significantly different ($\alpha < 0,05$).

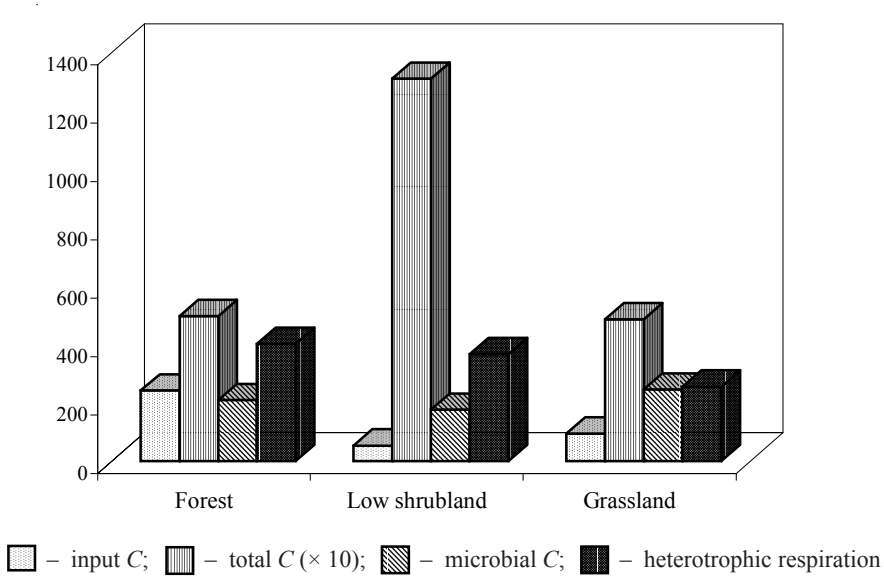


Fig 1. **Distribution of input C, total C and microbial C ( g $m^{-2}$), heterotrophyc respiration $CO_2$-C ( g $m^{-2}$ $yr^{-1}$), expressed on an area basis, to 20 cm depth**

the forest. The lower rates of the $CO_2$-C production per unit of total *C* in mineral soil in the grassland than the in the forest site could account for proportionate differences between *C* inputs and total *C* and microbial *C* pools in the soil of these ecosystems.

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