IOŚ-PIB
Environmental Protection and Natural Resources
Ochrona Środowiska i Zasobów Naturalnych
sciendo
Vol. 29 No 4(78): 20-25
DOI 10.2478/oszn-2018-0018

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Influence of soil macrofauna on soil organic carbon content

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Keywords:
Macrofauna, organic carbon, litter, soil

Abstract

Macrofauna plays a very important role in the functioning of the natural environment. It plays an important role in the decomposition of organic matter by mixing and crushing organic matter in soil. Invertebrate faeces influence the development of microorganisms and their dead bodies stimulate mineralization in the soil. They also influence the humification processes. The aim of the study was to determine the influence of macrofauna and litter distribution and the accumulation of organic carbon in soil. The study showed a significant influence of this thick animal on the processes taking place in the soil. Significant correlations were observed between the organic carbon content in the litter and the organic carbon content in the soil, macrofauna activity with litter decomposition and its influence on the organic carbon accumulation.

1. INTRODUCTION

The soil environment is shaped by physical and biotic elements. Physical elements include humidity, temperature and light, and biotic relations within and between species of organisms. Numerous organisms that live in the soil contribute to the acceleration of the circulation of matter in the forest and determine soil fertility to a large extent. In forest soils, in addition to fungi, rays and bacteria, saprophagic soil animals, and in particular invertebrates, which are numerous and active, play an important role. Macrofauna is a group of animals in a specific environment with a size of 2–20 mm. These include legworms, spiders, blades, beetles, whirlwinds, snails, ants and mowers. Macrofauna plays a very important role in the functioning of the soil environment. It plays an important role in the decomposition of organic matter by mixing and crushing it. Invertebrate faeces influence the development of microorganisms and their dead bodies stimulate mineralization in the soil. They also influence the humification processes. Meso- and macrofauna in some ecosystems account for 0.3 to 0.5% of the biomass of all soil organisms and up to 7.5% of the biomass of all fauna in fertile forests [Dunger 1983, Blair 2000]. The activity of soil animals consists of mechanical crushing of organic matter and its chemical decomposition, which promotes the development of soil microflora. The decomposition of organic residues can take place inside animal organisms with the participation of microflora or after the food passes through the digestive tract. These organisms therefore influence soil fertility through animal metabolism, respiration, food intake, excretion and secretion, and participate in the formation and consolidation of the soil structure. The activity of organisms influences the flow of energy in nature. In soil environments, saprophagic and predatory organisms prevail, and herbivores are less numerous [Witkamp 1966, Górny 1975]. The decomposition of organic matter and its inclusion in the soil depend on the order of its consumption by animals and soil microorganisms and on the activity of soil animals forming organ-mineral molecules.

2. AIM OF THE WORK

The aim of the study was to determine the influence of soil macrofauna on soil processes. The study was used to determine the relation between the quantitative distribution of macrofauna in the soil profile with the size of biomass and its production, as well as the content of organic carbon in litter and mineral soil.

3. DESCRIPTION OF RESEARCH AREA

The research was carried out in a didactic-research forest facility located in Martew forestry in the West Pomeranian Voivodeship. The research plots were established in 5 stands with different usage history. The first plot was established in a 95-year-old beech stand on rusty soil made of weakly loamy sands on loose sands (plot no. 1a). It was created from beech undergrowth and shrub layer after the removal of the approximately 130-year-old pine stand. The second plot was established in a 46-year-old pine stand on rusty soil made of weakly loamy sands on loose sands. It was created after the removal of 130 pine stands with beech undergrowth (area no. 1b) with complete felling. The third one was established in a 109-year-old pine stand with beech undergrowth on podzolic-brown soil made of weakly loamy sands on loose sands (area no. 2). The area was also established in an approximately 24-year-old stand made up of beech plantings on brown-rusty post-farm soil made of poor loamy sands (area no. 5). The samples were also collected on plot no. 21. It is a 90 year old pine stand with the participation of oak, beech and birch growing on forest soils of a fresh mixed forest habitat.

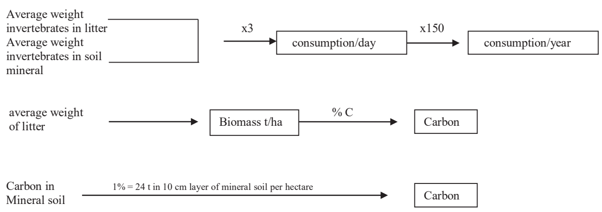
Figure 1. Research area No 1a

Figure 2. Research area No 1b

Figure 3. Research area No 2

4. METHODOLOGY OF COLLECTION AND ANALYSIS OF COLLECTED MATERIAL

The research was carried out annually in 2016–2018. 3 soil and 3 litter samples were collected on each research area. In order to determine the macrofauna biomass, litter was taken from each plot of 0.5 x 0.5 m up to mineral soil. In order to determine the biomass of soil macrofauna, 3 soil samples of 0.2 x 0.2 m to the depth of 20 cm were also taken at each research stand. Additionally, each litter sample was sieved with a Reitter sieve. The prepared litter and soil samples were reviewed on white sheets and with the use of an exhaustor collected all the animals present there, and then weighed and converted into ha. Macrofauna consumption and organic carbon content were also calculated according to the following diagram [Szyszko, Schwerk 2013]:



These calculations are burdened with a certain error, however, they allow to estimate the relationship. The following formula was used to calculate the amount of carbon accumulated in soil [Szyszko 2010]

$Zc = (h \times D \times Mo)/10$ [kg/m^2]

h - thickness of soil levels [cm]

D - volumetric density [g/cm^3]

Mo - organic carbon content at soil level

10 - unit conversion rate

Figure 4. Research area No 21

Figure 5. Research area No 5

Figure 6. Collection of litter from the determined test area

Figure 7. Sifting the bedding with a Reitter sieve

Table 1. Results of research conducted in 2016–2018

	Number of research areas				
	21	1a	1b	2	5
Biomass of litter t/ha	42.6	41.4	92.2	148	96.8
C t/ha in litter	12.2	14.9	38.1	68.1	47.7
C t/ha in soil	63.1	51.4	38.4	33.6	21.6
Macrofauna biomass in litter kg/ha	6.47	18.1	6.63	10.3	4.82
Consumption kg/day	19.4	54.4	19.9	30.8	14.5
Consumption t/year	2.91	8.16	2.98	4.62	2.17
Biomass of macrofauna in soil kg/ha	34.5	22.0	20.3	2.47	1.25
Consumption kg/day	104	66.1	60.9	7.41	3.75
Consumption t/ha/year	15.5	9.92	9.13	111	0.560

5. RESULTS

The results for individual research plots are presented in Table 1. Each research plot is presented in terms of organic carbon content in litter and soil and the amount of macrofauna biomass, with particular emphasis on daily and annual consumption.

Significant differences were observed in the biomass of litter as well as in the organic carbon content in the soil profiles studied. This dependence results from the type of stand and previous soil use (forest and post-agricultural).

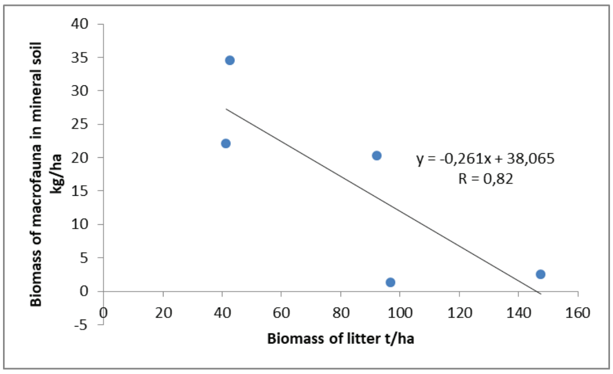


Figure 8. The relationship between biomass of litter and biomass of macrofauna

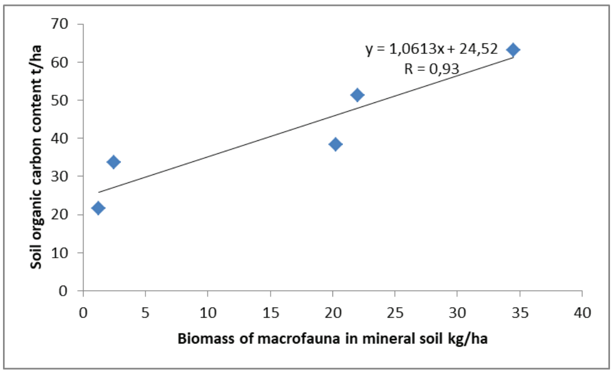


Figure 9. The relationship between soil organic carbon content and biomass of macrofauna

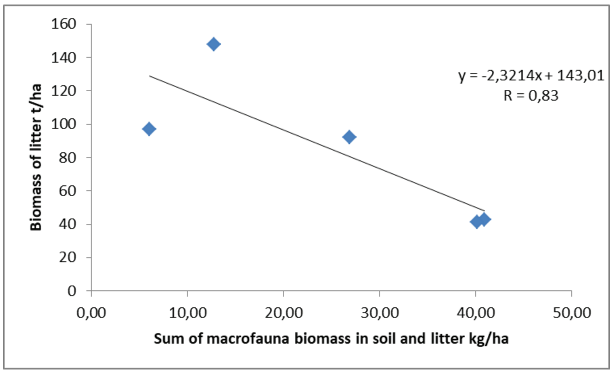


Figure 10. The relationship between biomass of litter and macrofauna biomass in soil and litter

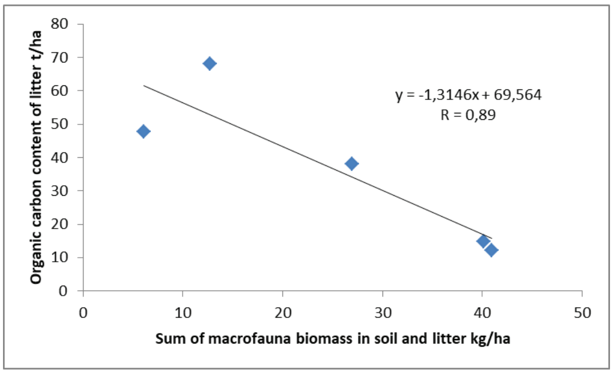


Figure 11. The relationship between soil organic carbon content and macrofauna biomass in soil and litter

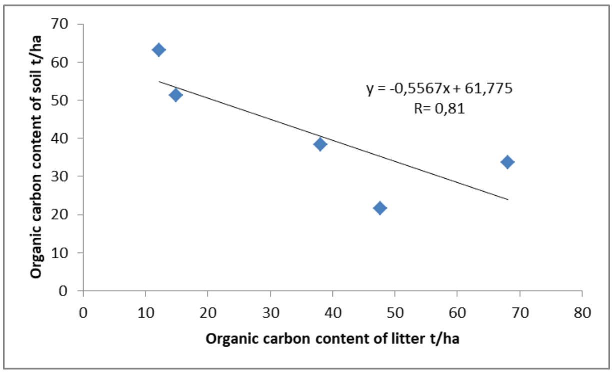


Figure 12. The relationship between soil organic carbon content and organic carbon content of litter

Figure 8 shows a linear correlation between litter biomass and macrofauna in mineral soil. The high correlation coefficient indicates that the litter biomass decreases with the growth of macrofauna biomass in mineral soil.

The high correlation coefficient between the soil organic carbon content and macrofauna biomass in soil allows us to state that the increase in the amount of soil fauna has a significant impact on the increase in soil organic carbon content (Figure 9). This also applies to the whole biomass of macrofauna in the studied part of the soil profile, which is indicated by the high correlation coefficient of these parameters (Figure 11).

A dependence of the whole biomass of macrofauna in the studied part of the soil profile on the litter biomass was also observed (Figure 10). This also applies to the relation between the amount of organic carbon in soil and its amount in litter (Figure 12). These conclusions are supported by high coefficients of R correlation at the level, respectively, of 0.83 and 0.81 [Dziubiński, Świętkowski, 1980].

6. RESULTS AND DISCUSSION

It was found that the richest source of food is litter, which is formed from plant and animal remains. Litter decomposed by one organism and transformed into humus is the food source for saprophages. An abundant source of food are also decomposed by saprophages, which relatively quickly breathe off the roots of plants. Litter and humus are the largest food source for soil organisms, therefore, the vertical distribution of these organisms is closely related to the layout of individual soil layers [Górny 1975]. Studies have shown that the biomass of litter and organic carbon content in soil changes with the biomass of macrofauna in soil and litter. The higher the litter biomass, the lower the macrofauna biomass in the soil (Figure 8), and thus, the litter biomass decreases with the increase in the share of soil fauna (Figure 8, Figure 10). The organic carbon content increases with an increase of macrofauna biomass in soil (Figure 9) and in soil and litter (Figure 11). This is probably related to the functioning of this group of animals in nature. Soil animals fragmentaring organic remains accelerate their settlement by microorganisms and then by saprophagic animals. The litter absorbed from the surface is passed through the gastrointestinal tract of the fauna. Soil animals excrete undigested food in the form of faeces containing various humus substances. This causes the organic material to migrate deep into the soil. No statistically significant differences were found in the amount of macrofauna biomass in litter, organic carbon content and litter biomass. In the studied stands, the highest consumption in litter takes place on the plot 1a established in the beech stand and amounted to 8.16 t/ha/year (Table 1). The shredding of litter with the participation of soil animals takes place the fastest in deciduous stands [Górny 1975]. It is caused by numerous soil invertebrates. This is confirmed by the conducted research, as the largest biomass of macrofauna – 18.13 kg/ha – was also shown there (Tab.1). Soil animals play the biggest role here. The dominant soil is rusty soil produced by weak loamy sands on loose sands; these are poor soils. Therefore, soil fauna determines, to a large extent, the circulation rate of the food substance and its availability. Their activity as well as consumption and faeces determine their availability. By shredding dead organic matter and excreting faeces, they influence the decomposition of organic matter. In addition, the presence of arthropods stimulates the development and increases the mobility of micro-organisms. This enables them to settle new areas of soil (Hanlon, Anderson 1980). Mineral compounds are partly stored in the bodies of organisms. As a result, it is immobilized in this form for some time. This inhibits the leaching of substances into the deeper layers of the soil.

There was also a strong correlation between soil organic carbon content and litter carbon content. The higher the soil carbon content, the smaller is the litter. It is caused by the decomposition of organic matter and penetration into the soil profile. The carbon cycle in the environment of afforested former agricultural soils is closed mainly in the litter-litter system and it is conducive to its accumulation, while in the environment of afforested forest soils the carbon cycle runs in the litter- mineral soil- litter system and is associated with their relatively rapid decomposition [Szyszko 1983]. This has been confirmed by the studies carried out. The largest mulch biomass was found in the area of 2 established in the stand formed on post-farm podzolic-rusty soil made of weak-clayed markers on loose sands, where the mulch biomass amounted to 147.61 t/ha. The smallest on the area of 21 and 1a planted in stands on forest soils, where the biomass amounted to 42.6 and 41.4 t/ha, respectively (Tab.1). The rate of decomposition is strongly related to the quality of the decomposed material and the quantity of organisms responsible for decomposition. The fastest decomposition of litter occurs in the beech stands and the smallest in the pine stands [Coûteaux et al. 1995; Aerts 1997 Niewinna 2010].

7. CONCLUSIONS

- There was a high correlation between soil organic carbon content and litter content. The less organic carbon in litter, the more in soil and vice versa. This is caused by the more intensive decomposition of litter through macrofauna in forest habitats and rapid penetration of organic matter into deeper soil layers, in contrast to post-farmer soils.
- It was observed that the distribution of litter is the fastest in the beech forest stand, where the macrofauna biomass in the litter was the largest, and thus also consumption.
- It can be concluded that the distribution of litter depends on the content of soil fauna. The higher the macrofauna content in litter and soil, the lower the litter biomass.
- The highest litter biomass was observed in the pine stand established on former agricultural soils. This confirms the earlier results that the carbon cycle in the environment of the afforested agricultural soils is closed mainly in the litter-litter system.
- Along with the growth of macrofauna biomass in the soil, the content of organic carbon in the soil increases. Soil animals, by crushing organic residues, consuming and passing through the digestive tract, influence the chemical composition and structure of organic matter, and thus, the accumulation of organic carbon in the soil.
- It can be stated that the main factor influencing the quantitative occurrence of soil macrofauna is the quality of the nutritional base.

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