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SOILS FROM BUFFER ZONES IN THE AGRICULTURAL CATCHMENT – SELECTED PHYSICAL, CHEMICAL, AND BIOLOGICAL PROPERTIES

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ABSTRACT:The research was undertaken to analyze selected physicochemical and biological properties of soils from the buffer zones of a small watercourse located in the agricultural catchment area of North-Eastern Poland. Research points were located in the buffer zone. Samples were taken from the surface soil level. In samples were measured the pH, organic carbon, total nitrogen, nitrates as well as the emission of carbon dioxide and nitrous oxide. The quantitative and qualitative composition of the microscopic fungi (micromycetes) communities that inhabit the analyzed soils was also determined. It was found that the soil in the buffer zone, which is formed by shrubs and which separates arable land from the river, is more abundant in selected solutes, has a higher carbon dioxide emission, also has a richer quantitative and qualitative structure of fungi. It was found that soils from buffer zones are the place of dynamic processes that affect biological and chemical properties.

KEY WORDS: buffer zone, soil, *micromycetes*

 JEL: Q19, Q25

Introduction

Progressive agricultural intensification leads to changes in various ecosystems (Kamiński, Chrzanowski, 2007). It directly affects areas used for agriculture and areas adjacent to them. One such adverse impact is the impact on the eutrophication of surface waters located in agricultural areas, from which nutrients move with surface and ground runoff. This leads to a series of adverse environmental changes (Koc et al., 2003; Kwaśna, 2014; Krasowska, Banaszuk, 2015). Therefore, various measures are taken to reduce the migration of nitrogen and phosphorus compounds from agricultural sources (Pietrzak, 2012). Among other things, attention is paid to the need to create buffer zones (biogeochemical barriers) along surface watercourses, i.e. belts of trees and shrubs or permanent grassland. On the one hand, they are a natural part of the landscape, on the other hand, can effectively prevent the pollution of rivers and water reservoirs by biogenic compounds, which migrate from the crop fields (Borin, Bigon, 2002; Lam et al., 2011; Frątczak et al., 2012). The barrier slows the subsurface and surface outflow. It prolongs the contact time of water with the soil and plant roots, and thus allows microorganisms to decomposition of biogenic compounds, which leads to a reduction in the concentration of pollutants (Correll, 2005; Hefting et al., 2005; Liu et al., 2008).

Soil belongs to the most important and the most complicated environments in which microorganisms that take part in the decomposition of organic compounds from organic matter of plant and animal origin develop. Part of the decomposition products is used by plants for the production of biomass, some are incorporated into the biomass of microorganisms, some are in turn included inhardly decomposable soil organic matter (Barabasz, Vořišek, 2002; Bogacz et al., 2004; Niklińska, Stefanowicz, 2015). It was determined that 1 g of soil contains from several thousand to several billion cells of bacteria. The number of actinomycetes is similar. Among the soil fungi, saprophytic organisms dominate, which deal with the decomposition of organic compounds (Kwaśna, 2014). Thus, microscopic fungi (*micromycetes*) are an important ecological ingredient that determines the type of biological decomposition of organic matter and biomass production. Also, the structures of fungal communities depend on the ecological conditions of the environment. They are a component of biocenosis that reacts the most quickly to changes in the parameters of this environment. Therefore, they can be used as an indicator of environmental changes, including changes in soils (Błaszczyk, 2007; Mułenko, 2008; Frączak, 2010; Traczewska, 2011).

Undoubtedly, knowledge of individual elements of the natural environment that affect the functioning of buffer zones is important from the point of view of assessing their role in agricultural catchments. For these reasons, soil research was undertaken in the buffer zones of a small watercourse in the agricultural landscape of North-Eastern Poland. These zones differed in vegetation and the research concerned the determination of selected physicochemical parameters of soils and the character of the *micromycetes* communities inhabiting them.

Research area

Research areas have been established in the agricultural catchment, in which there are both arable and grassland. The research was conducted near the small watercourse zone in North-Eastern Poland. The watercourse is a left-bank tributary of Horodnianka and is located about 1 km from Choroszcz.

The research surfaces were located at a distance of about 2 m from the watercourse, on both sides. These areas formed buffer zones, which differed in vegetation and land use above the riverbed. One of the research areas was under trees and shrubs, while the other was covered with turf. The crop structure was dominated by cereal crops and fodder maize. The meadows were mown once and then grazed.

The analyzed soils are mucky-black soils mounds that are made of clay sands (Systematyka Gleb Polski, 2011; Marcinek, Komisarek, 2015). The surface level from which the samples originated was characterized by a black color and crumbling structure. The crumbs were durable, well-formed, and they reached sizes ranging from 0.5 to 1.5 cm.

Methods

The soil samples came from a depth of 10-20 cm. In order to perform physicochemical analyzes, they were taken four times: on 2, 7, 13 and 22 November 2016, while microscopic fungal communities were assessed in a sample that was collected on November 7.

In the samples, the pH in H_2O was determined, which was measured potentiometrically. The organic carbon was measured by the catalytic oxidation method, total nitrogen was measured by the Kjeldahl method, and nitrate ions were determined spectrophotometrically. The emission of carbon dioxide (CO_2) and nitrous oxide (N_2O) was also determined. Measurements of CO_2 and N_2O emissions were made using the chamber method. The chamber was placed in a frame that was embedded in the soil. Gas samples were taken from the chamber for 1 hour every 15 minutes with gas-tight syringes. The CO_2 and N_2O concentrations were determined in the laboratory using a gas chromatograph.

For the isolation of micromycetes fungi, the method of soil tiles Warcupa (1950) in the modification of Mańka was used (Johnson, Mańka, 1961; Mańka, 1964; Mańka, Salmanowicz, 1987). The similarity between fungal communities was determined using the Jaccard coefficient (Zak, Willig, 2004). In addition, air and topsoil temperatures (at a depth of approx. 5 cm) were measured on the day of sampling and the depth of groundwater retention was also measured.

Results and discussion

The average temperature of the air and the topsoil was about 4°C. The depth of ground water level at the beginning of the study (November 2) was 80 cm, while at the end of the study (November 22) it was 50 cm. The groundwater level was at the level of 75 cm on the day of sampling for mycological analyzes (November 7).

The analysis of the results of selected physicochemical properties of soils from the zone at the riverbed in arable land and grassland allows concluding that the mean values of determined parameters in both soils were similar to each other. The analyzed soils were slightly acidic (Gonet et al., 2015). The content of organic carbon (OC) and total nitrogen (TN) in both soils had comparable values. Although on 13 and 22 November in soil under the turf, the Cog content was higher the soil under shrubs and trees than in the soil under and trees. However, the content of nitrate nitrogen (N-NO_3) was higher in the soil from the buffer zone with bushes and trees (table 1).

Table 1. Emission of nitrous oxide (N_2O) and carbon dioxide (CO_2) from buffer zone soils

Measurement date	pH in H_2O		OC [%]		TN [%]		N-NO_3 [mg/100g soil]	
	I	II	I	II	I	II	I	II
02 November 2016	6.12	6.62	3.52	3.12	0.22	0.22	0.34	0.09
07 November 2016	6.06	6.59	3.40	3.06	0.23	0.23	0.36	0.07
13 November 2016	6.27	5.78	2.73	4.21	0.33	0.37	0.43	0.06
22 November 2016	6.26	6.06	3.14	4.33	0.26	0.27	0.41	0.54

Explanations:

I – buffer zone with shrubs and trees near the arable land

II – buffer zone with turf near grassland

Source: author's own work.

Based on measurements of emissions of selected greenhouse gases, it was found that the average value of emissions of nitrous oxide and carbon dioxide from the analyzed soils was bigger from the buffer zone under shrubs and trees (table 2). The analyzes showed that CO_2 and N_2O emissions increased with increasing carbon content in soils (tables 1 and 2), these gases are associated with soil biological activity, including the denitrification process (Turbiak, Miatkowski, 2010). These results correspond with the current knowledge that soil microorganisms develop more intensively in habitats rich in a dead organic matter (Paul, Clark, 2000; Błaszczyk, 2010). The inverse relation was demonstrated in the case of total nitrogen (TN) and nitrate nitrogen ($N\text{-}NO_3$). It was found that the CO_2 and N_2O emissions increased with the decrease in the content of nitrogen compounds in the soil (tables 1 and 2). These results confirm the observation that the decomposition of organic compounds (rich in nitrogen) is accompanied by active microbiological processes, the effect of which is CO_2 production. Also, denitrification works better in habitats that are rich in nutrients, including nitrogen (Paul, Clark, 2000; Błaszczyk, 2010; Frączek, 2010; Traczewska, 2011; Kucharski et al., 2015). One of the groups of microorganisms that can use various nitrogen compounds are *micromycetes* inhabiting soils (Kalbarczyk, 2012).

Table 2. Characteristics of selected physicochemical properties of the analyzed soils

Measurement date	N_2O [$mg \cdot m^{-2} \cdot d^{-1}$]		CO_2 [$mg \cdot m^{-2} \cdot d^{-1}$]	
	I	II	I	II
02 November 2016	0.92	0.28	2658.90	1846.40
07 November 2016	0.79	0.30	2028.05	1958.87
13 November 2016	0.38	0.07	467.26	920.34
22 November 2016	0.52	0.19	1080.44	1508.26

Explanations:
I – buffer zone with shrubs and trees near the arable land,
II – buffer zone with turf near grassland.
Source: author's own work.

The emissions of carbon dioxide (CO_2) and nitrous oxide (N_2O) were also affected by air and soil temperatures. It has been found that at higher temperatures more of these gases are formed (figure 1). In other words the activity of soil microorganisms increased with increasing temperature. It was observed that more gases were formed in the soil of the buffer zone with shrubs and trees. This allows us to assume that the soil under the trees is characterized by a higher microbiological activity compared to the buffer zone soil under the turf.

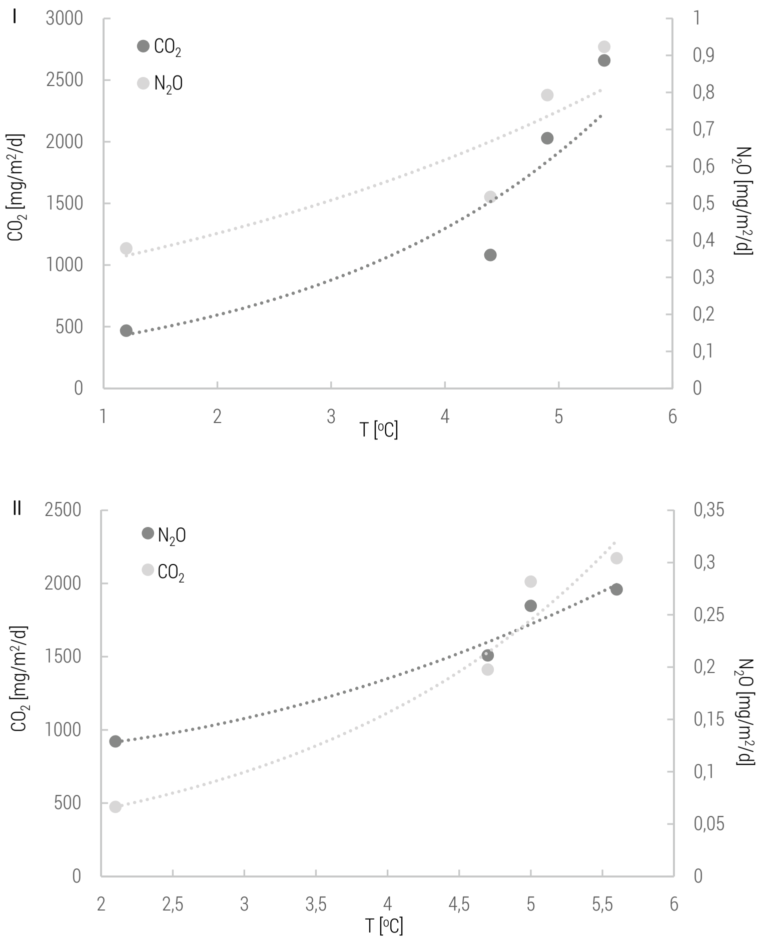

Figure 1. The relationship between the emission of nitrous oxide (N_2O) and carbon dioxide (CO_2) and the air temperature (I – buffer zone with shrubs and trees near the arable land, II – buffer zone with turf near grassland)

Source: author's own work.

Similar conclusions can be drawn by analyzing the composition of soil fungal communities. A total of 141 fungal isolates were obtained. They were represented by 37 different species. A more diverse quantitative and qualitative structure was possessed by the fungal community originating from the buffer zone with shrubs and trees in comparison to the buffer zone with turf. The authors received 82 isolates and 29 species from the soil under shrubs and trees. On the other hand 59 isolates and 25 *micromycetes* species were found in the soil under turf.

The similarity between fungal communities was at 41.7%. It follows that the communities differed despite their common features. There were found 7 species of fungi in soil from both research stands. The remaining species were found only in soil from one or the other research area. These results are not surprising because the biological decomposition of organic matter that causes fungi depends on climatic factors, soil properties, its fertility, pH, oxidoreductive potential, land use and agrotechnical treatments (Paul, Clark 2000; Błaszczyk 2010; Kucharski et al., 2015). Plant cover also affects the structure of *micromycetes* communities (Barabasz, Vořišek, 2002). The analyzed soil fungal communities came from buffer zones differing mainly with vegetation. The difference also concerned the way the land was used in the vicinity of the examined surfaces. On the one hand soil fungi shape the physical chemical and biological properties of soil by participating in the decomposition of organic matter and on the other hand, they depend on the properties listed (Kwaśna, 2014).

Selected fungal species that occurred most frequently in both analyzed soils are summarized in table 3. The most numerous species in both communities was *Pseudogymnoascus roseus* and its turnout was comparable. The frequency (number) of other species was on the level of 1 to 3 isolates. It should be emphasized that the most were species with low attendance (from 1 to 3 isolates). First of all, they determined the diversity of *micromycetes* quantitative and qualitative structures.

Table 3. The most abundant *micromycetes* species that inhabit the soil of both buffer zones

Species of fungi	frequency [no.]	
	I	II
Chrysosporium pannorum (Link) Hughes	7	3
Leptosphaeria coniothyrium (Fuckel) Sacc.	1	8
Penicillium brevicompactum Dierckx	5	2
Penicillium oxalium Curie and Thom	8	4
Penicillium verucosum var. ***cyklopium***(Westling) Samson. Stolk & Hadlok	5	-
Pseudogymnoascus roseus Raillo	16	15

Explanations:

I – buffer zone with shrubs and trees near the arable land.

II – buffer zone with turf near grassland.

Source: author's own work.

Conclusions

- Based on physicochemical analyzes. it was found that the average values of determined parameters in soils from both buffer zones were similar to each other.
- More carbon dioxide (CO_2) and nitrous oxide (N_2O) were produced at higher air and soil temperatures. It follows that the biological activity of the soil increased with increasing temperature. It was also found that the soil of the buffer zone under shrubs and trees near the arable ground was characterized by a higher microbiological activity compared to the buffer zone under turf near grassland.
- The fungal communities in the analyzed soils under the two buffer zones, which differed in vegetation and the way of using the neighboring area, differed in the quantitative and qualitative structure of the *micromycetes* communities. The community obtained from the buffer zone soil under shrubs and trees near the arable land had a richer composition and a richer qualitative structure compared to the community that inhabited the buffer zone under the turf.
- The nature of vegetation and land use have an impact on the microbiological activity of buffer zones of agricultural catchments. It seems that the buffer zone under shrubs and trees more effectively prevents contamination of surface water by biogenic compounds. which are moved from the area of agricultural land – due to the higher microbiological activity – in comparison with the buffer zone under the turf.

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The contribution of the authors

Małgorzata Krasowska – conception, literature review, methodology and interpretation of data – 50%
Zofia Tyszkiewicz – conception, literature review, methodology and interpretation of data – 50%

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