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## Impact of land use on soils microbial activity

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### Abstract

The article considered the influence the various types of land use on microbial activity of soils and thus using this parameter as a universal test of soil quality. Samples for soil respiration studies were taken from agricultural areas, meadows, forests and urban areas (estate cottages). All samples were subjected to the same analytical procedure and the method of measurement was followed by a Substrate-Induced Respiration (SIR) method. Since all the samples were from neighbouring regions and were characterized by similar soil parameters, the obtained results allowed to assess the quality of the soil environment of the surveyed area and to evaluate the total rating of whole area. The obtained results allowed to observe slight divergences between soil samples taken from areas of different use. And although statistically, in this case, these differences were not significant, the characteristics of the respiration curves clearly indicate that there is a dependency between the form of use and the size and rate of soil respiration. In addition, the results have shown that single family housing does not exhibit as much anthropopression to the soil environment as it might seem.

**Key words:** environmental engineering, land use, soil respiration, Substrate-Induced Respiration (SIR)

### INTRODUCTION

The relative equilibrium called homeostasis characterizes relationships among all components of natural ecosystems. Homeostasis forms the stability and temporal immutability of parameters of living environment. Humans seem to be an exception that hardly subordinate their actions to the principle of environmental sustainability. Human pressure most often causes the biological imbalance of the environment [DOWNES *et al.* 2002; GOUDIE 2013]. As a result, unfavorable environmental changes occur. In some cases, human impact on the environment is so intense that it causes a permanent modification. Emerging areas with unfavorable living values can affect the health and life of organisms that inhabit a modified environment [DURUBE *et al.* 2007; JO, KOH 2004; JURKIEWICZ *et al.* 2004]. The facts about increasing soil, air and water pollution in urbanized areas are increasingly reported in the literature. The global impact of human pressure has

the effect of reducing the natural resources of the seas and oceans, clean drinking water and natural forests [CHARLESWORTH *et al.* 2003; GALUŠKOVÁ 2011; MEUSER 2010; MOTYKA *et al.* 2005].

Appropriate planning and subsequent land use, both in macro and micro scale, can help to minimize the anthropogenic impact on the environment. The most appropriate way to achieve sustainable spatial management seems to be a balanced development of available space that includes as many natural and semi-natural habitats as possible, like forests and meadows, and in urban areas – parks and other green areas. Compared with urban or industrial areas, such areas are characterized by a relatively higher biodiversity. Diversification of habitats directly affects the greater ability to immobilize, buffer, filter and transform various substances, often harmful to living organisms, including humans [GOSPODAREK *et al.* 2016; SCHOENHOLTZA *et al.* 2000]. Sustainable land management has particular impact on soils, which, due to their specificity and

functions, can be considered the most important environmental element. Additionally, forests and meadows (or parks and other green urban areas) are characterized by relatively high water retention, which has the potential to affect local microclimates and to regulate groundwater levels [FAO 2013]. The phytosanitary influence of vegetation (trees, bushes and herbaceous plants) on the urban air and thus the reduction of deposition of pollutants into soil is another argument in favor of maintaining a high proportion of biologically active surfaces in urban space [LULEY, BOND 2002; NOWAK 2002; SCOTT *et al.* 1999].

Soil is one of the most complex systems occurring in the natural environment. It is a biological-chemical reactor that is capable of creating or decomposing many different substances. Therefore, the soil participates in the circulation of nutrients and their aqueous solutions throughout the whole ecosystem. These characteristics, combined with climatic conditions, fauna and flora as well as the type of land use, create a distinctive habitat characterized by specific microbial composition. Identification of the qualitative status of the soil environment seems to be possible by analyzing the soil microbial composition or its related parameters. It should be noted that the collection and analysis of any soil data always offers the opportunity to compare the effects of different land uses as well as to draw much deeper conclusions. Analyzing biomass production or the impact of a changing climate on the environment [SANCHEZ *et al.* 2009; TÓTH *et al.* 2013] or creating specialized digital maps of the developed issues [MAKO *et al.* 2017; McBRATNEY *et al.* 2003; VÄGEN *et al.* 2016] may be examples of such a conclusion.

Detailed studies of soil are usually based on many, often complex and expensive laboratory analyzes, which provide a lot of data. The testing of a single sample of soil substrate to obtain an aggregate response that determines the quality of the soil environment might be a cheaper alternative. Such a parameter, which can provide information about the degree and

strength of the soil transformations, can be the microbial activity. This soil parameter is strongly correlated with many other major soil properties [BALOGH *et al.* 2011; BURCZYK *et al.* 2016; HAN *et al.* 2007; STEFANOWICZ *et al.* 2008; TURBIAK *et al.* 2014; WANG *et al.* 2014]. Its value may be a determinant of the specific soil substrate – qualitative determinant of the soil environment. Thus, it allows to know the current state of the analyzed area, and it could be helpful in planning transformation of the relevant part of the soil to achieve a satisfactory effect.

The aim of this work was to confirm the possibility of influencing the various types of land use on microbial activity of soils and thus using this parameter as a universal test of soil quality. The information in such way obtained can be used in the future for example in spatial planning. In order to prove the above thesis, the analysis of soil's microbiological activity of samples taken from different land use was planned. Next the correlation between soil respiration and other soil parameters as well as land use dependence were examined.

## MATERIAL AND METHODS

The study of the impact of land use on the value of soil respiration was based on soil samples collected at the research area at the end of September 2015. The area was about 6 km on the east from the centre of Kraków (Main Square). Samples were collected from agricultural (arable land), meadow, forest and urbanized (single family houses) areas. In total, 16 mean soil samples were collected from a depth of 0–30 cm (4 sampling points for each type of land use) (Fig. 1). Soil samples from forest areas were collected without the litter.

The mean samples collected from each sampling point weighed about 1 kg. Every soil sample was divided into two parts. The first part of fresh sample was sieved through a 2 mm mesh, placed in a refrigerator

and stored at 4°C. Smaller samples were extracted from prepared soil material. Samples were brought to a moisture level corresponding to a 60% water field capacity and then conditioned for 48 h after which soil respiration was started.

Then the measurement of soil respiration were started. The Substrate-Induced Respiration (SIR) with use of glucose as substrate ( $2000 \mu\text{g} \cdot \text{kg}^{-1}$  DM soil) was applied as a method of microbiological activity measurement [ANDERSON, DOMSCH 1978]. The second part of

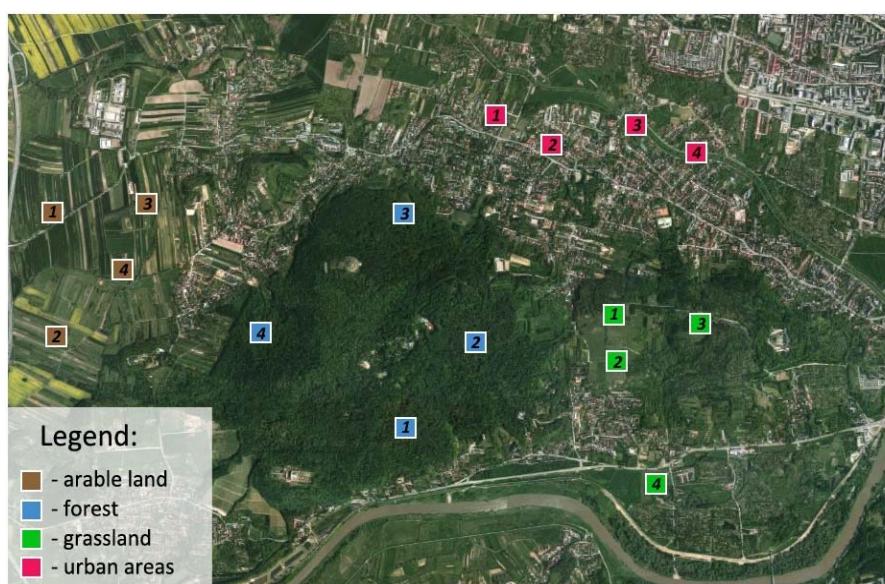


Fig. 1. Location of soil sampling points; source: own elaboration based on GoogleMaps

each mean sample was dried, sieved through a sieve with a mesh diameter of 2 mm, and then used to determine the basic soil parameters such as the granulometric composition (Casagrande method), specific density, value pH (in H<sub>2</sub>O and KCl), electronic conductivity, carbonates content (using Scheibler apparatus) and humus content (by dry combustion at 400°C).

The results were statistically analyzed with use of the Statistica software package. The hypotheses were tested using the analysis of variance (ANOVA), the Tukey test, and the Kruskal-Wallis test. The confidence level of all tests was 0.05 ( $\alpha = 0.05$ ).

## RESULTS AND DISCUSSION

The granulometric composition of all soil samples was very similar (Fig. 2a, b). Soils with a dominant fraction of silt prevailed. The average content of silt was over 77%. The highest content of silt parts was found in soil samples from meadow areas and the lowest in urban areas. Urban areas were characterized by the highest content of sand fraction, which in samples taken from other types of land use was significantly lower. The average content of sand fraction in all samples was almost 15%. In urbanized areas the average

was of 25% whereas for agricultural, forestry and meadow areas it was around 10% (Tab. 1). The average content of the clay fraction was very low and did not exceed 10% in all cases of land use.

Despite slight differences in the granulometric composition of individual samples from different land uses only the fraction of sand could be recorded as statistically significant and only at the significance level  $\alpha = 0.10$ , which was twice as high as originally assumed.

In case of other tested soil characteristics situation was similar. The tests did not show significant differences between soil samples from different areas of use. Only the soil reaction in urbanized areas and forests showed significant variation. By increasing the alpha significance level to 0.10, statistically significant differences also showed in case of the soil density and soil reaction (comparing agricultural and forests areas) and the carbonate content (comparing urban areas and all other land uses). In many studies, a value of  $\alpha = 0.05$  is generally regarded as a limit of acceptable error rate and increasing it to 0.10 is not justified. The higher level of  $\alpha$  means the lower reliability of the tested relationship between respective variables [MANLY 2008].

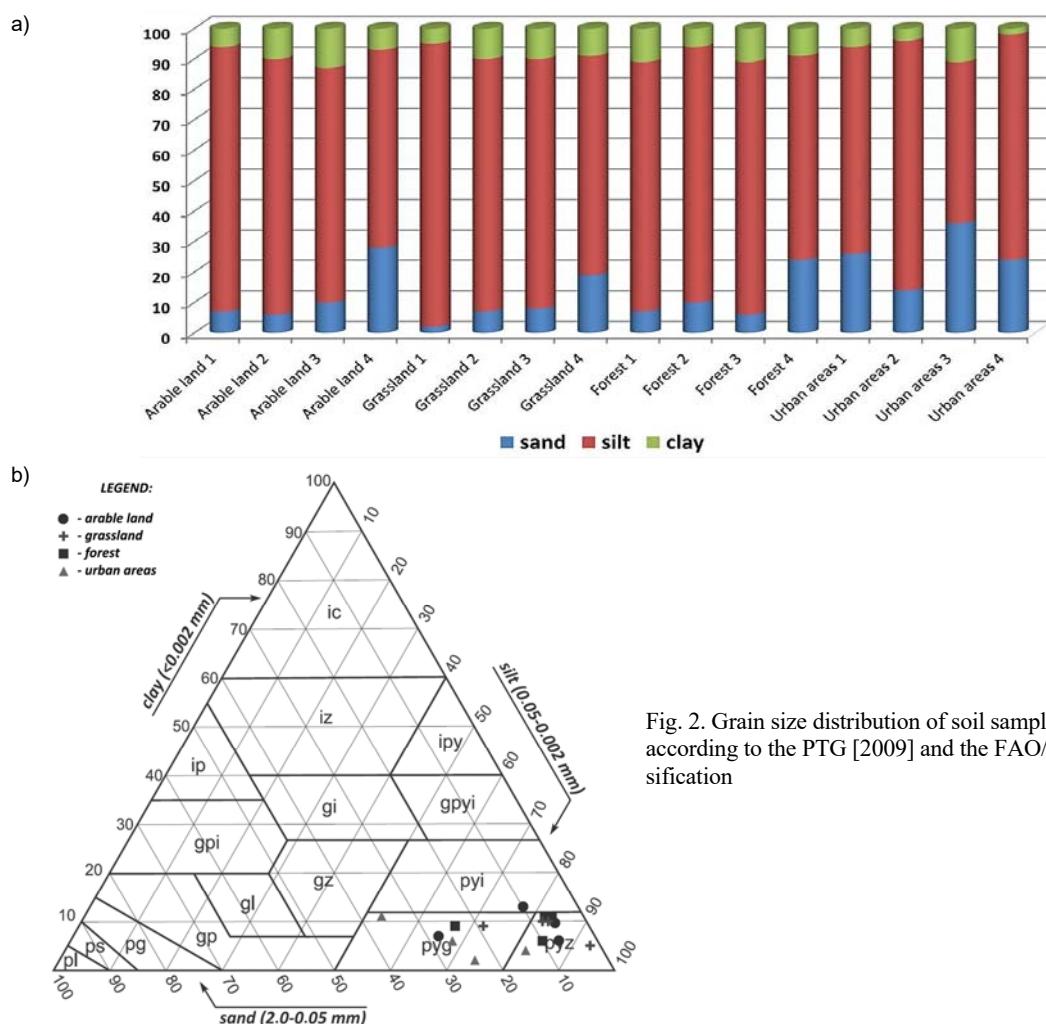


Fig. 2. Grain size distribution of soil samples; source: according to the PTG [2009] and the FAO/WBR classification

**Table 1.** Basic statistics of analyzed soil parameters

Parameter	Unit	Average	Median	Minimum	Maximum	Standard deviation
<b>All cover land</b>						
Sand	%	14.63	10.00	2.00	36.00	10.10
Silt	%	77.25	82.00	53.00	93.00	10.12
Clay	%	8.13	9.00	2.00	13.00	3.05
Soli density	g·cm <sup>-3</sup>	2.57	2.57	2.43	2.64	0.05
pH KCl	—	5.28	5.50	3.30	7.00	1.17
pH H <sub>2</sub> O	—	5.91	6.10	4.10	7.30	0.92
EC	µS·cm <sup>-1</sup>	119.79	117.60	56.10	214.00	44.57
CaCO <sub>3</sub>	%	0.31	0.00	0.00	2.64	0.68
OM	%	1.93	1.90	1.50	2.40	0.27
<b>Arable land</b>						
Sand	%	12.75	8.50	6.00	28.00	10.31
Silt	%	78.25	80.50	65.00	87.00	9.78
Clay	%	9.00	8.50	6.00	13.00	3.16
Soli density	g·cm <sup>-3</sup>	2.60	2.60	2.57	2.64	0.03
pH KCl	—	4.93	4.95	4.20	5.60	0.64
pH H <sub>2</sub> O	—	5.88	5.90	5.40	6.30	0.38
EC	µS·cm <sup>-1</sup>	84.88	68.55	56.10	146.30	41.37
CaCO <sub>3</sub>	%	0.06	0.05	0.00	0.15	0.08
OM	%	1.80	1.80	1.58	2.00	0.19
<b>Grassland</b>						
Sand	%	9.00	7.50	2.00	19.00	7.16
Silt	%	82.50	82.50	72.00	93.00	8.58
Clay	%	8.50	9.50	5.00	10.00	2.38
Soli density	g·cm <sup>-3</sup>	2.57	2.57	2.54	2.60	0.02
pH KCl	—	5.70	6.00	4.30	6.50	0.97
pH H <sub>2</sub> O	—	6.28	6.45	5.50	6.70	0.53
EC	µS·cm <sup>-1</sup>	130.78	118.10	93.90	193.00	43.03
CaCO <sub>3</sub>	%	0.05	0.00	0.00	0.19	0.10
OM	%	2.05	2.05	1.80	2.30	0.21
<b>Forest</b>						
Sand	%	11.75	8.50	6.00	24.00	8.34
Silt	%	79.00	82.50	67.00	84.00	8.04
Clay	%	9.25	10.00	6.00	11.00	2.36
Soli density	g·cm <sup>-3</sup>	2.51	2.51	2.43	2.61	0.08
pH KCl	—	4.03	3.70	3.30	5.40	0.94
pH H <sub>2</sub> O	—	4.73	4.50	4.10	5.80	0.76
EC	µS·cm <sup>-1</sup>	116.23	117.45	77.70	152.30	32.72
CaCO <sub>3</sub>	%	0.00	0.00	0.00	0.00	0.00
OM	%	2.18	2.25	1.80	2.40	0.26
<b>Urban areas</b>						
Sand	%	25.00	25.00	14.00	36.00	9.02
Silt	%	69.25	71.00	53.00	82.00	12.26
Clay	%	5.75	5.00	2.00	11.00	3.86
Soli density	g·cm <sup>-3</sup>	2.59	2.59	2.56	2.63	0.03
pH KCl	—	6.45	6.50	5.80	7.00	0.49
pH H <sub>2</sub> O	—	6.78	6.80	6.20	7.30	0.45
EC	µS·cm <sup>-1</sup>	147.30	136.75	101.70	214.00	49.85
CaCO <sub>3</sub>	%	1.12	0.80	0.22	2.64	1.06
OM	%	1.70	1.70	1.50	1.90	0.18

Explanations: EC = electrical conductivity, OM = organic matter.

Source: own study.

The mean values of specific density were 2.57 g·cm<sup>-3</sup> and the lowest values were noted in the forest areas (Tab. 1) while the highest in the agricultural land. The forest areas also had the lowest mean values of the other tested parameters: pH level, salinity and car-

bonate content, which in soil samples from the forest were not found at all. The highest average values for these features were recorded for soil samples from urbanized areas (Tab. 1). Increased salt content in urbanized areas may be result from the use of salts for road deicing [CHUDECKA 2010; JAKUBIAK, URBAŃSKI 2015; KOCHANOWSKA, KUSZA 2012]. The crushed rock fragments, which along with the construction work was moved closer to the surface of the soil, or the deposition of alkaline ashes from domestic fireplaces into home gardens might have affected the higher pH.

Analysis of the results from the soil respiration test showed high similarities between samples from different land uses. In each case the growth of carbon dioxide cumulation was almost identical. A rapid increase in CO<sub>2</sub> production (rapid respiration) was observed approximately until 24<sup>th</sup> h of study. After that the soil respiration slowed down (Fig. 3). The most rapid changes in this process have been observed for urbanized areas. The curve in 24 h period is clearly going down. The mildest form take cumulative respiration charts for forest areas. A better illustration of this phenomenon are the graphs of successive CO<sub>2</sub> increments for particular areas where the characteristic peaks can be observed (Fig. 4).

Similarly, for urban areas, the climax around the 15<sup>th</sup> h of the study is very clear. While, for forest areas, only a small bulge of the chart in this place was visible. Forestland samples were characterized by the greatest uniformity of CO<sub>2</sub> increments during the measurement period as well as the smallest fluctuations between successive readings of carbon dioxide concentration. Comparison of cumulative respiration graphs and successive increments graphs (Fig. 3a, 4) allowed to observe other differences. For urbanized and forested areas as the curves for all four samples were cumulated in a small range. It shows the high similarity between the individual samples in the group. However, for agricultural land and meadows, the distribution of curves on the graph was much higher. Most likely, it was due to the higher diversity of soil characteristics between the individual samples.

Comparing the maximum values obtained for the 72-hour period, it turned out that the agricultural land had the highest average respiration (over 6,000 ppm CO<sub>2</sub>). Meadows were on the next place (5,918 ppm), then urbanized areas (5,758 ppm) and forests (5,544 ppm) (Tab. 2, Fig. 5).

**Table 2.** Respiration rate in a specified time interval for different land use patterns

Land use	Mean value, ppm		
	24 h	48 h	72 h
All	3 252	5 122	5 997
Arable land	2 906	5 179	6 037
Grassland	3 584	5 004	5 918
Forest	2 954	4 744	5 544
Urban areas	3 747	5 116	5 758

Source: own study.

This trend was not retained throughout the whole respiration measurement period. In the first hours of measurements, samples from urbanized areas received the highest values of cumulative CO<sub>2</sub>. After 24 h the value was over 3700 ppm. For comparison, the same reading for farmland samples showed the value of 2900 ppm (Tab. 2, Fig. 5). During the first 24 h of the study, also the soil from the meadows had relatively high level of respiration (compared to other samples). The level of respiration after 24 h was almost 3600 ppm of accumulated CO<sub>2</sub>. However, the further study of these samples showed a slowdown of soil respiration. After next 24 h the measured value was about 5000 ppm (Tab. 2, Fig. 5).

Despite the observed differences in total soil respiration in a period of 72 h, the statistical tests conducted did not confirm their significance. All the analyzed soil respiration distributions for individual samples were also characterized by very high correlation, which further confirms the high similarity between the soil samples of the examined forms of land use. Slight differences in soil respiration probably resulted from the small differences of the physico-chemical properties of soil samples. Therefore, the obtained results do not allow to confirm unequivocally the thesis of the influence of different land use on microbiological activity parameter and using this parameter as a universal test of soil quality. However, this assumption cannot be rejected. The study has shown that even a small difference in soil parameters between samples as well as type of land use directly affect the value of soil respiration. Examined urbanized areas were represented by single family housing estates. Pro-

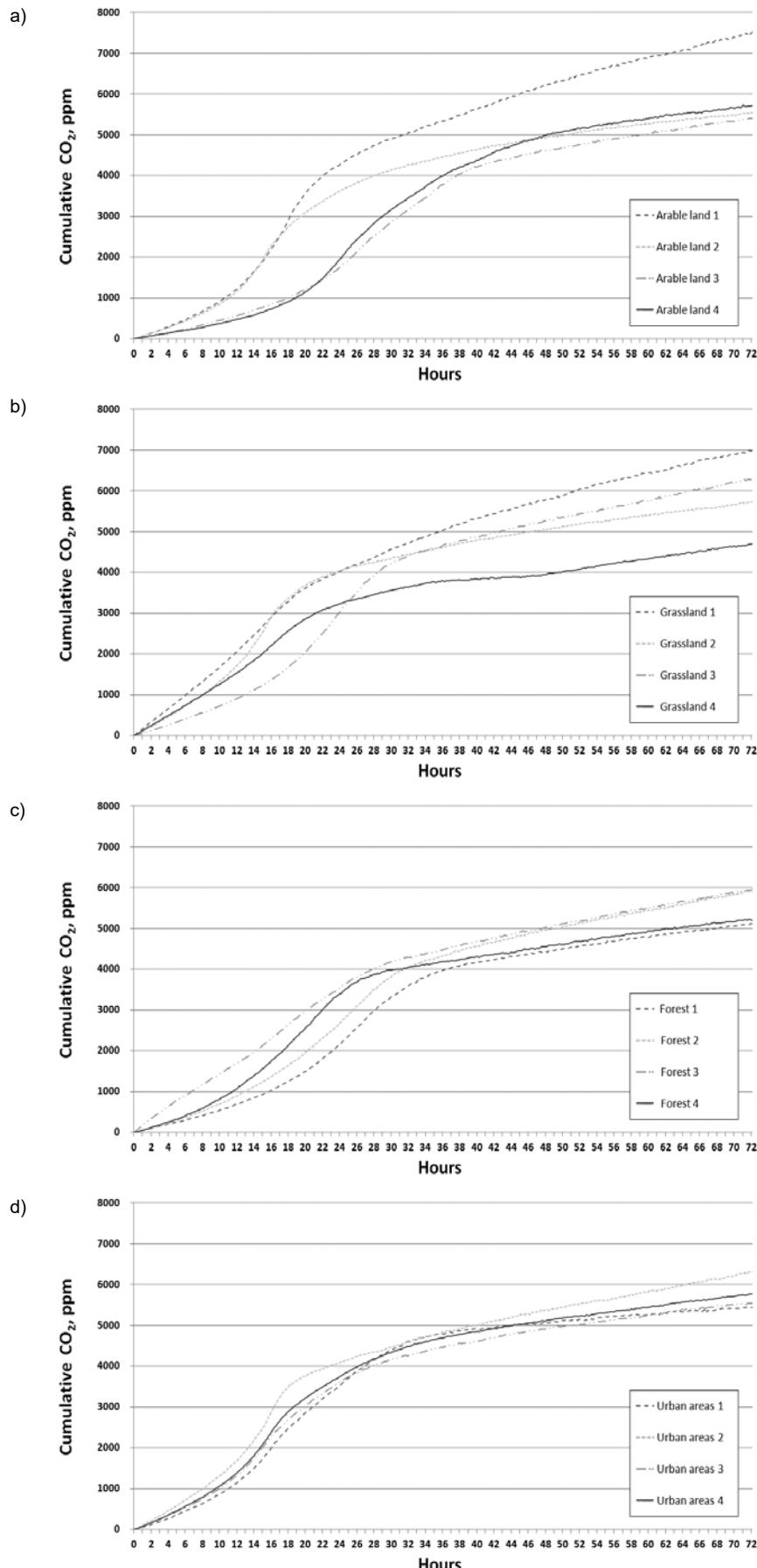


Fig. 3. Soil respiration diagrams for soil samples from different forms of land use:  
a) arable land, b) grassland, c) forest, d) urban areas; source: own study

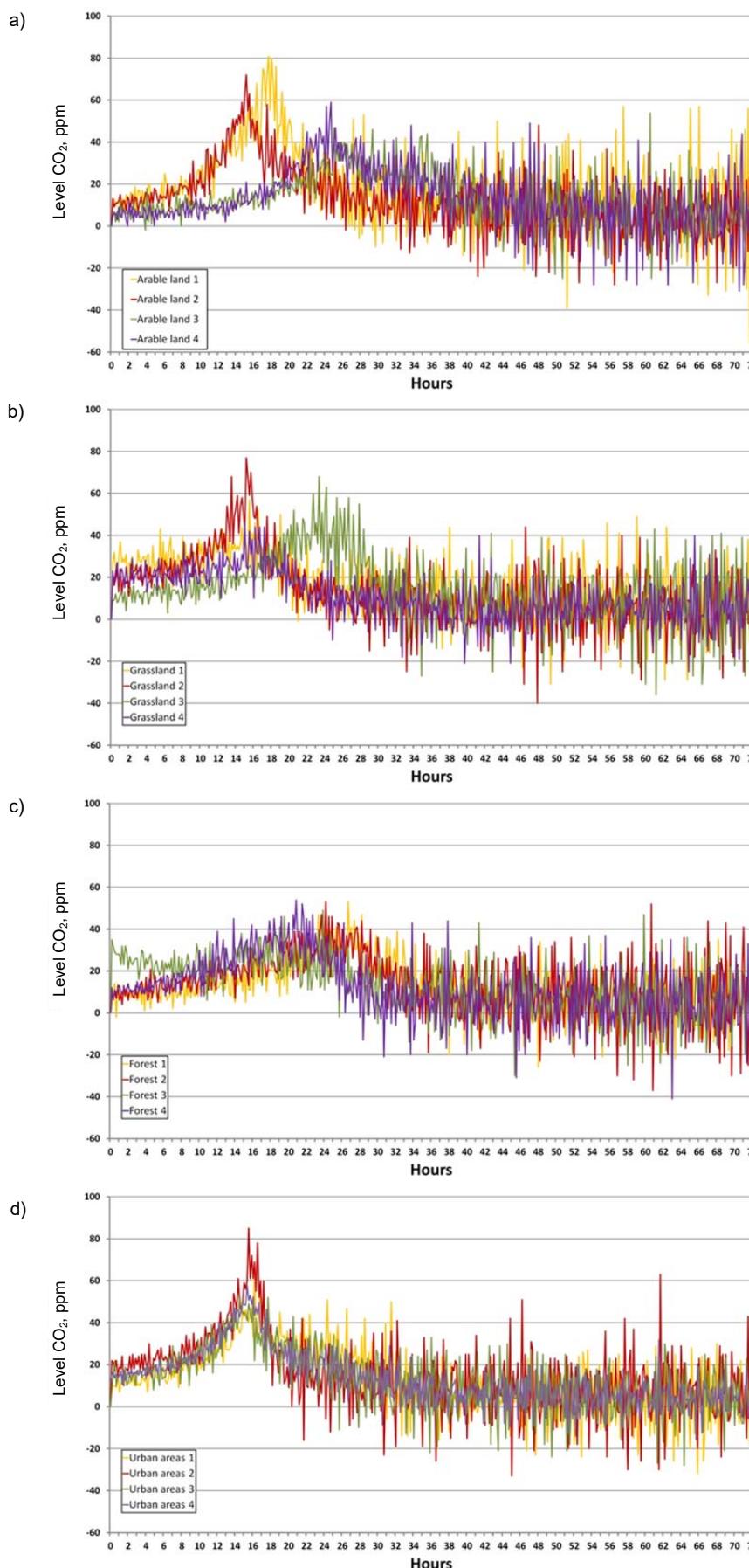


Fig. 4. Increases CO<sub>2</sub> in time between next measurements in different forms of land use: a) arable land, b) grassland, c) forest, d) urban areas; source: own study

bably the degree of anthropogenic transformation of these areas was so small that the study did not show significant differences between them and the other tested land use types. In addition, samples from urban areas were taken from residential lawn, what could also affect the similarity in respiration values comparing urban areas and meadows.

## CONCLUSIONS

The possibility of using soil respiration (one of the parameters determining the microbial activity of the soil) was considered in the article as a supporting parameter in the evaluation of soil quality. The measurements allowed to observe slight discrepancies between the soil samples taken from sites with different land use. Although the differences were not statistically significant, the characteristic curves of respiration clearly show a relationship between form of land use and the size and rate of respiration of soil. Perhaps, the expected large influence of urban areas anthropopression on the soil environment was not observed in a satisfactory scale. However, this impact was not completely excluded. On the contrary, the results indicate the need for further, more detailed study of this issue. It can be assumed that the variation in soil respiration rate could be higher in some cases, e.g. when urban areas are developed as multifamily housing estate, industrial areas or even when soil samples would be collected from a greater variety of urban areas. In case of the conducted research, the urban areas were represented by a single family housing estate. The results of the respirations did not differ significantly from other forms of land use such

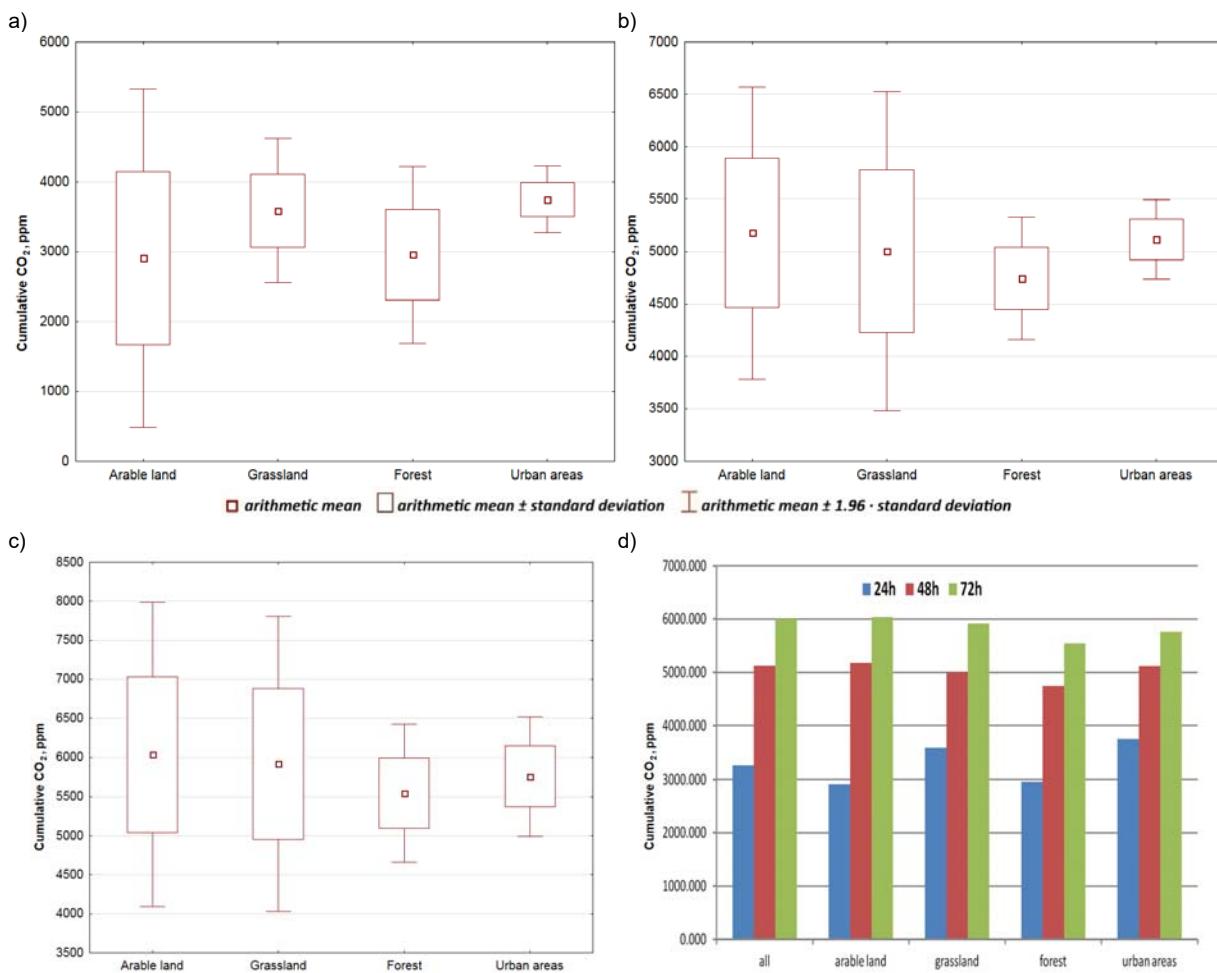


Fig. 5. Changes in mean soil respiration after specific time intervals for different land use patterns: a) after 24 h, b) after 48 h, c) after 72 h, d) mean values; source: own study

as forest, arable land or meadows. It allowed to conclude that such sites are very similar in terms of microbial activity of soils. Thus, at least theoretically, these sites could be considered as areas that positively affect the overall balance of biochemical changes occurring in the soil environment and favourably affect biological balance, the balance, which is the basis for the ability to immobilize, buffer, filter, and transform various substances into the soil environment.

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**Krzysztof URBAŃSKI, Mateusz JAKUBIAK****Wpływ użytkowania terenu na aktywność mikrobiologiczną gleb****STRESZCZENIE**

W artykule rozpatrywano wpływ różnego rodzaju użytkowania terenu na aktywność mikrobiologiczną gleb i tym samym możliwość wykorzystania tego parametru jako uniwersalnego testu jakości podłoża glebowego. Do badań respiracji glebowej wykorzystano próbki pobrane z terenów użytkowanych rolniczo, łąk, lasów oraz terenów zurbanizowanych (zabudowa domków jednorodzinnych). Wszystkie próbki poddano identycznej procedurze analitycznej, a jako metodę pomiaru zastosowano metodę indukowanej substratem respiracji (ang. SIR – Substrate-Induced Respiration). Ponieważ wszystkie próbki pochodziły z sąsiadujących ze sobą rejonów i charakteryzowały się podobnymi parametrami glebowymi, uzyskane wyniki umożliwiły ocenę jakości środowiska glebowego badanego terenu i dokonanie oceny sumarycznej rejonu badań. Uzyskane wyniki pozwoliły zaobserwować niewielkie rozbieżności między próbками glebowymi pobranymi z terenów o różnej formie użytkowania. Statystycznie różnice te nie były istotne, jednak na podstawie charakterystyki krzywych respiracji jednoznacznie można stwierdzić, że między formą użytkowania a wielkością i szybkością respiracji glebowej zaznacza się pewna zależność. Dodatkowo uzyskane wyniki dały podstawy do stwierdzenia, że osiedla domków jednorodzinnych nie wykazują tak dużej antropopresji na środowisko glebowe, jak mogłoby się wydawać.

**Slowa kluczowe:** aktywność mikrobiologiczna gleb, inżynieria środowiska, metoda indukowanej substratem respiracji (SIR), użytkowanie terenu, właściwości gleb