

ANALYSIS OF CARBON DIOXIDE EMISSION FROM LAWN ECOSYSTEM WITH CONTRASTING SOIL PROFILES

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Land-use change is among the main factors contributing to climate change. Urbanization is a land-use change pathway, conjugate with a rapid growth of urban territory and irreversible change of soil features and functioning. Greenhouse gases' emissions (primarily CO₂ emission) and carbon sequestration are among important soil functions. Ecological risks of increased CO₂ emissions in urban soils are determined by different factors of anthropogenic impact. This paper aims to analyze the impact of different soil constructions on CO₂ emissions from urban lawns. The research plot is situated in northern Administrative district of Moscow (NAD) and included urban soil constructions with organic layers of different genesis (turf, sand-turf mixtures and soils-sand mixtures) and of different depth (5, 10 and 20 cm). As a result an average CO₂ emission from turf (20 cm dept of organic layer) was 22 g/m² day, whereas the sand-turf mixture (10 cm of the organic layer) emitted 16.15 and peat soil (5 cm of organic layer) — 19.23 g/m² day respectively. Therefore, was observed dependence of CO₂ emissions on genesis and depth of soil organic layers. Also was revealed dependence of CO₂ emissions on climate conditions for nine-months of observations.

Key words: CO₂ emission, urbanization, urban land use, greenhouse gas, soil respiration

INTRODUCTION

Soil is a key natural resource with major ecological functions [1—3]. Current realities include continuous expansion of urban areas. Urban soils have recently attracted the attention of researchers [9; 5; 4; 8]. Artificial urban soils with prevalence of turf grass in their vegetation, account for a considerable part of the urban soils. This particular soil type is becoming the main object when studying the soils of urban ecosystems [28; 7]. However, the functioning of urban soils is evidently subject to drastic changes owing to human impact, as any other component of the urban ecosystems [6; 10].

It is estimated that artificial changes in land-use have, until now, produced a cumulative global loss of carbon from the land of about 200 thousand million tones. Widespread deforestation has been the main source of this loss, estimated to be responsible for nearly 90 percent of losses since the mid-nineteenth century. Losses primarily occur due to the relatively long-term carbon sinks of forests being replaced by agricultural land. Land-use change is driven by a host of social, political and economic factors around the world. Increased awareness of the most sensitive way to manage land and the better agricultural practice, combined with political agreement on food trade and avoidance of deforestation, are required if land-use change is not to continue being a net global source of carbon to the atmosphere in years to come. Indeed, having degraded large areas of the terrestrial carbon sink, sensitive land-use change may in fact provide a sink for atmospheric greenhouse gases in the future.

Carbon dioxide is released from the soil through soil respiration, which includes three biological processes, namely microbial respiration, root respiration and faunal respiration primarily at the soil surface or within a thin upper layer where the bulk of plant residue is concentrated [18], and one non-biological process, i.e. chemical oxidation which could be pronounced at higher temperatures [19]. Soil micro-flora contributes 99% of the CO₂ arising as a result of decomposition of organic matter [22], while the contribution of soil fauna is much less [20]. Root respiration, however, contributes 50% of the total soil respiration [21].

Temperature has a marked effect on CO₂ evolution from the soil. Edward found a strong relationship between CO₂ evolution and mean daily litter temperature [23]. Wiant observed no CO₂ evolution at 10 °C followed by a logarithmic increase in CO₂ evolution between 20 and 40 °C; above 50 °C, it declined rapidly [24]. At higher temperatures partial inhibition of microbial respiration occurs, which is attributed to inactivation of biological oxidation systems. But Bunt and Rovira [19] found increased CO₂ evolution with a rise in temperature above 50 °C as well. Maximum CO₂ evolution rate was noted in mid-July (190 kg CO₂ ha⁻¹d⁻¹), which is attributed to the increasing role of root activity and organic matter decomposition with the increase in temperature. Increase in CO₂ emission with temperature is a matter of concern, as the possible global warming would increase CO₂ evolution from the soil that would accelerate the depletion of soil carbon and soil fertility [25].

Soil moisture affects soil respiration and hence CO₂ evolution [26]. In general, increasing soil moisture would increase CO₂ evolution up to an optimum level, above which it would reduce CO₂ evolution. Periodic drying and wetting of soil has a pronounced influence on CO₂ evolution. When the soil is moisten the activity of the microbes, which were in a latent state in the dry soil, increases accompanied by releasing of air trapped in the soil pore contributing to an increase in CO₂ evolution [27].

The research work aimed to analyze the carbon dioxide emissions from the artificial soil construction under urban lawns. To achieve the aims the following research steps were taken:

- 1) to analyze the emissions of carbon dioxide for the contrasting soil structures;
- 2) to analyze the dynamics of the flow of carbon dioxide, temperature and moisture of contrasting soil structures;
- 3) to assess the impact of the genesis and depth of organic substrates on carbon dioxide flows and temperature of urban lawns.

MATERIALS AND METHODS

The research field is situated in Moscow Timiryazev Agricultural Academy. On the field there are 28 different containers with different substrates of different depth. All the containers have the size of 100 cm × 100 cm × 50 cm and were made from plastics (Fig. 1A). The containers contained different soil constructions were divided into groups according to the type of the organic substrate and the depth of the organic layer. The organic layer is the first layer from the top, containing the substrate used for the experiment; the second layer is sand and the third is the native sod-podzolic soil (B horizon) (Fig. 1B).



Figure 1. The research field of Moscow Timiryazev Agricultural Academy (A) and an artificial soil construction with three different layers (B)

The following substrates have been chosen for the experiment: control (C), turf-sand mixture (Ts), turf (T) and peat-soil mixture (Pso) with two different depths (5 cm and 20 cm). In order to measure the CO₂ flux, moisture, soil temperature and air temperature, an infrared gas analyzer (IRGA) Li-820, chamber, soil thermometer (HI98501) and soil moisture meter (HH2) were used. The observations of CO₂ emissions were held from March to September 2014. The dynamics of total soil respiration (9 times for the whole period) was analyzed for each container. The IRGA chambers (diameter 20 cm, height 15 cm) were installed on the bases (diameter 20 cm, depth 4 cm) on top of soil construction and hermetically fixed. The chambers were connected with the IRGA with flows of incoming and outgoing air. With the integrated air pump an air sample from chamber was pumped into the IRGA, whereby the device registered the rise of CO₂ concentration in the chamber at a frequency of 1 Hz. Based on the data obtained from the concentration of growth, taking into account the temperature and pressure of the air inside the chamber, CO₂ flux (g/m² day) was calculated using ideal gas equations.

RESULTS AND DISCUSSION

The dynamics of CO₂ fluxes between turf-sand (20 cm depths), turf-sand (5 cm) and control (turf-sand; 10 cm) were compared to understand the variation of the CO₂ fluxes from different soil constructions. The results show that in July 2014 the carbon dioxide efflux from the turf-sand (20 cm) was 12.91 (g/m² day) and for the control construction it was 6.3 (g/m² day), whereas CO₂ efflux from turf-sand (5 cm) was 6.95 (g/m² day). The CO₂ flux from turf-sand (20 cm) was 7.43 more than from turf-sand (5 cm) and 0.82 more than from control. Therefore, it can be claimed that CO₂ efflux was higher from the urban soil constructions, containing more organic carbon (Fig. 2). Analysis of the peat-soil samples with different depths gave the following results: an average CO₂ efflux from the control site was 24.64 (g/m² day), whereas the amount of CO₂ emitted from the peat soil (5 cm) was 20.68 g/m² day. In average the 20 cm peat soil mixture emitted 15 and 30% more CO₂ that the 5 cm peat soils and the control soil mixture respectively (Fig. 3). This outcome confirms a positives correlation between the amount of emitted CO₂ and carbon contents in substrate.

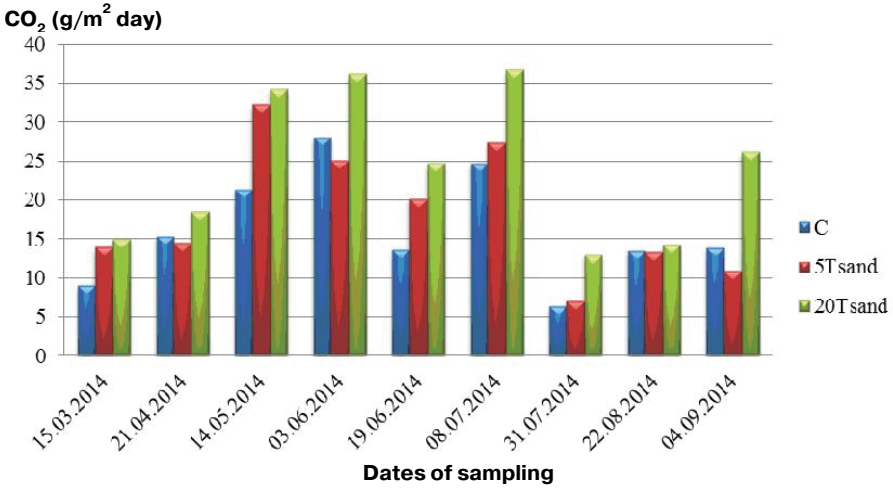


Figure 2. CO₂ fluxes from control (C), 5 cm turf-sand (5T sand) and 20 cm turf-sand (20 T sand) for the period March 15 — September 4 2014

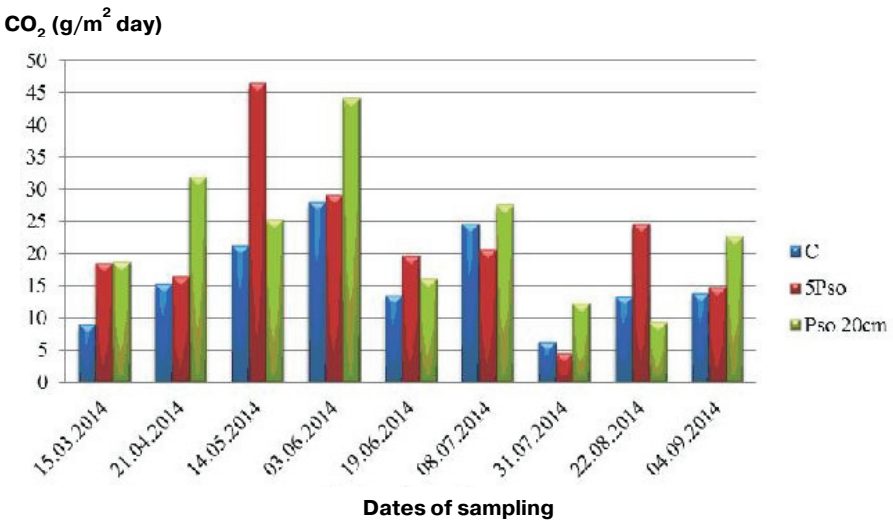


Figure 3. CO₂ fluxes from control (C), 5 cm peat-soil (5Pso) and 20 cm peat-soil (20 Pso) for the period March 15 — September 4 2014

Comparisons of the dynamics of CO₂ fluxes between turf-soil (20 cm), turf-soil (5 cm) and control (turf-sand; 10 cm) for one day — 14th of July 2014 — resulted in following: the highest CO₂ emission was found for the turf-soil (5 cm) and was 53.95 (g/m² day), whereas and a 20cm turf-soil and control emitted just half of this value — 25 and 21 (g/m²day) respectively. In average for the season 20 cm turf-soil mixture emitted more CO₂ than other, whereas CO₂ emission from the control site was the lowest (Fig. 4).

In order to analyze the seasonal dynamics of CO₂ fluxes the three soil constructions with the same depth (5 cm) were monitored along the nine month of the experiment. The lowest emission was obtained for the 31th of July 2014, whereas the highest amount was monitored on 14th of May 2014 (Fig. 5).

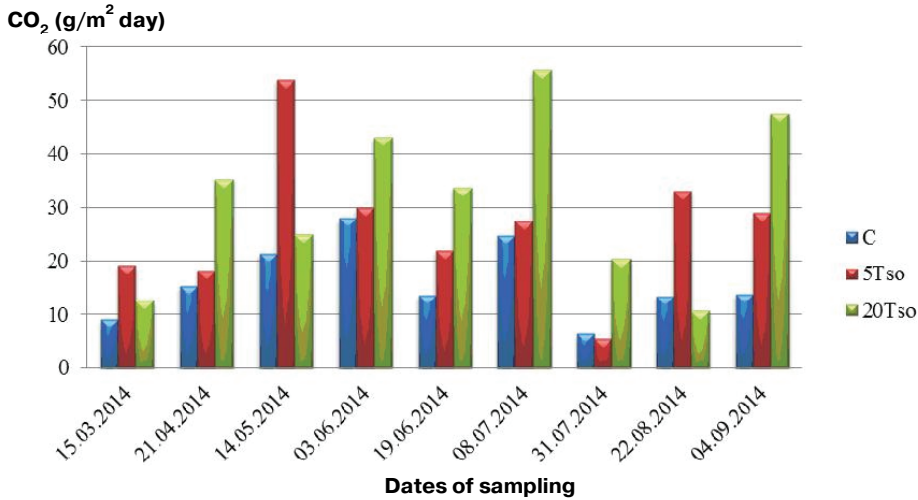


Figure 4. CO₂ fluxes from control (C), 5 cm turf-soil (5Tso) and 20 cm turf-soil (20 Tso) for the period March 15 — September 4 2014

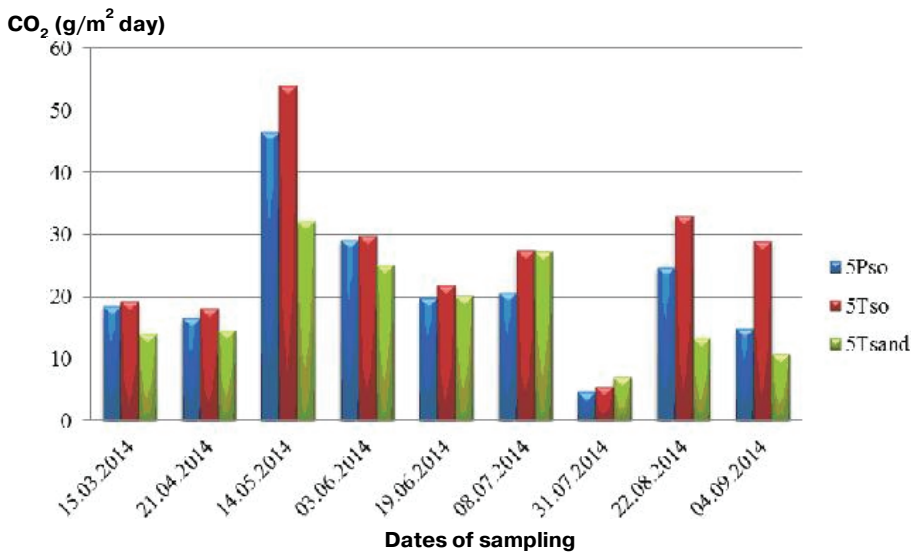


Figure 5. Seasonal dynamics of CO₂ fluxes from three construction with the same depth of organic layer (5 cm), but different substrates: peat-soil (5Pso), Tso (5Tso) and turf-sand (5Tsa)

The experiment has demonstrated the evaluation of carbon dioxide from different artificial soil construction with different soil sample for lawn ecosystem and as a result we have got to understand how the carbon dioxide from the soil is related to the moisture and the temperature. This outcome is necessary to estimate the total losses of organic carbon from urban soil constructions from the intensive emission. soil management practices like increasing soil organic carbon content. Obtained results show that there is dependence between CO₂ emission and type of soil. The CO₂ emission can be reduced by sequestering C in the soil for those that lost high amount of organic carbon due to mineralization of organic carbon.

CONCLUSIONS

As a result of the research data of CO₂ emissions from lawn ecosystem with a contrasting structure of soil profile has been obtained. The lowest CO₂ emissions was shown for the soil constructions on the basis of peat soil mixture show, which is obviously related with the lowest average temperature and soil moisture. It is observed that artificial soil construction based on a mixture of peat soil lost less total carbon stocks due to CO₂ emissions. The most optimal functioning has been shown for the peat soil sample (a mixture of soil and land capacity 5 cm), for which the low rates of decorative lawns combined with a high positive value of the carbon balance. In this paper, it was clearly shown how 'fragile' can be a mixture based on turf sand, turf-soil. These soils are very unstable. The optimal designs of lawn ecosystems remain a priority for urbanized research and for applications of landscape construction.

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АНАЛИЗ ЭМИССИИ УГЛЕКИСЛОГО ГАЗА В ГАЗОННЫХ ЭКОСИСТЕМАХ В УСЛОВИЯХ КОНТРАСТНЫХ ПОЧВЕННЫХ ПРОФИЛЕЙ

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Изменение землепользования является одним из главных факторов, способствующих изменению климата. Урбанизация является землепользованием, которое связано с быстрым ростом городских территорий, вследствие чего происходят необратимые изменения особенностей почвы и ее функционирования. Эмиссия парниковых газов (преимущественно эмиссия CO₂) и депонирование углерода являются одними из важнейших функций почв. Экологические риски увеличивающейся эмиссии CO₂ в городских почвах определяются различными факторами антропогенного воздействия. Целью данной статьи является анализ воздействия различных почвенных конструкций на эмиссию CO₂ в газонных экосистемах. Объект исследования расположен в северном административном

округе (САО) г. Москвы и включает в себя почвенные конструкции с различными по происхождению (торф, торфяно-песчаная смесь и почво-песчаная смесь) и мощности (5, 10, 20 см) органическими горизонтами. По полученным данным, средняя эмиссия CO_2 в варианте с торфяным органомным горизонтом мощностью 20 см составила $22,00 \text{ г/м}^2$ в день, в то время как в варианте с торфяно-песчаной смесью мощностью 10 см эмиссия составила $16,15 \text{ г/м}^2$, а торфяной почвы мощностью 5 см — $19,23 \text{ г/м}^2$ в день. Следовательно, наблюдается зависимость эмиссии углекислого газа от таких показателей, как генезис органического вещества почвы и мощность органомного горизонта. Также в течение 9 месяцев наблюдений была выявлена зависимость эмиссии углекислого газа от климатических условий.

Ключевые слова: эмиссия CO_2 , урбанизация, экологические риски, парниковые газы, почвенное дыхание