# The contribution of abiotic and biotic factors to the annual $CO_2$ production dynamics of the artificial soils (Moscow botanical garden)

*Olga Goncharova; Maria Udovenko; Georgy Matyshak; Anna Bobrik*
Moscow State University, Department of Soil Science
goncholgaj@gmail.com

Introduction

Urban regions are major sources of atmospheric $CO_2$, and 78% of global C emissions are attributed to cities. Furthermore, built-up urban areas exert significant influences on their local climates. Human activity in urban development is associated with the construction of artificial soils and sealing of natural soils. In contrast to natural soils, the properties and pedogenesis of urban soils may be dominated by their anthropogenic origin. As urban areas dramatically increase globally, more studies on the effects of urbanization on biogeochemical cycling are urgently needed.

Currently in the world, there are about 2300 botanical gardens and arboreta, which are centers of floristic and geobotanical research, public environmental education. In Russia today there are 99 botanical gardens, most of which belongs to the higher education institutions – universities, agriculture, forestry and medical institutions.

Botanical gardens in the cities are unique artificial ecosystems in which, thanks to continual investment of resources, it is possible to partially offset the negative impact of the urban environment and create a high level of biodiversity.

Research objectives: 1) evaluate the seasonal dynamics of CO2 effluxes and CO2 concentration profiles of soils of Moscow State University Botanical Garden Arboretum planted with Picea obovata (pinetum) and Carpinus betulus (hornbeam forest), 1) estimate contribution of soil properties, vegetation, moisture and temperature conditions in the spatial and temporal variability of the carbon dioxide production.

Materials and methods

The Botanical Garden of the Lomonosov Moscow State University is located 800 meters south-west from the edge of the high right bank of the Moscow River (55.708°N, 37.526°E). The Botanical Garden was founded in October 1950. Arboretum covered an area about 10 hectares, planted more than 20,000 trees and shrubs 700 species. Because of the significant soil disturbance during the construction of the Moscow State University main building, it was necessary carry out work on remediation of topsoil. For this, significant amounts of lowland peat were used.

Moscow has a humid continental climate with severe winters, no dry season, warm summers and strong seasonality. The mean annual temperature is 5°C, total annual precipitation averages 689.2 mm. The terrain is composed of poorly water permeable silty clay and loam, which lies on the moraine.

Soils of Moscow State University Botanical Garden differ from other urban soil and from natural soils near Moscow. According to published data, soils of MSU Botanical Garden are characterized by high fertility and relatively slightly contaminated.

All studies were carried out on the two stationary sites from November 2014 to November 2016. The experimental sites are located in plantations of Picea obovata and Pinus sylvestris.

Air and soil temperatures were measured at each of the two sites six times per day with Thermochron ibutton™ data loggers. Air temperatures were made at 1.5m above the ground. Soil temperatures were measured at 2, 10, 20, 40 and 60 cm.

Carbon dioxide efflux from the soil surface was measured by the closed chamber technique in a triplicate at each site. Measurements were taken every 1-2 weeks from 13 to 15 pm. To measure carbon dioxide concentrations at different depths, sealed tubes were placed in the soil, 1 cm in diameter and perforated on the bottom part. Sampling was conducted with a rubber stopper once a week. $CO_2$ concentrations were measured with a portable IRGA DX6210.

Results

According to the World Reference Base for Soil Resources, soils of the key sites can be classified as Technosols or Anthorosols. The soils have a thin litter, gray sandy loam surface organo-mineral horizon of 20-50 cm thick underlying brown silty loam mineral horizon. Some soil horizons have artefacts (brick, coal, rubber, metal, glass, and carbonate). The content of total organic carbon was noted from 0.2 to 8.4%. The pH measured in the water ranged from 6.9 to 7.3. The upper soil horizons are characterized by high biological activity, resulting in the high content of the microbial carbon and high potential respiration.

Soils of all plantations are characterized by similar annual temperature regimes. The average annual temperature varies very slightly with depth and it is about 7°C.The observed small differences in temperature conditions among soils are attributed to varying in projective cover degree, canopy density, as well as the depth and duration of snow cover. Soil freezing in winter was limited to the upper 10-20 cm. Soils were in the frozen state only one or two months.

Soil respiration showed a distinct seasonal variation. Carbon dioxide efflux from the soil surface at both sites during the years ranged from a minimum 0 in February to a maximum of July 600-700 $mgCO_2/(m^2*hr)$. In winter, about 0 efflux values were observed about only 3-4 weeks. For both soils, sharp increase in carbon dioxide efflux started in April and has reached its maximum in early July. The sharp emission reduction observed since the end of September, and was associated with a sharp decrease in the temperature of air and soil.

There was a significant correlation in the annual cycle of $CO_2$ efflux for both soils ($r^2 = 0.9$; $p<0.05$). Annual carbon dioxide soil surface efflux of soil planted with Picea obovata was 1370 gCO2/($m^2$*yr), soil planted with Carpinus betulus - 1590 $gCO_2/(m^2*yr)$. Contribution of the summer season in the annual $CO_2$ emissions is about 70%, winter-spring-– 20%, autumn – 10%.

Over the year, the $CO_2$ efflux was weakly correlated with the air temperature ($r^2 = 0.5$; $p<0.05$) and correlates well with the temperature of the soil at a depth of 10 cm ($r^2 = 0.9$; $p<0.05$).

Moisture has little effect on $CO_2$ emissions ($r^2 = 0.03$) in the annual cycle. However, during the summer period (when the soil temperature above 10°C) moisture plays a more significant role than the temperature ($r^2=0.4$, $p<0.05$).

In the period from May to January, soil profile $CO_2$ concentrations is relatively stable: the minimum value observed in the upper 10-cm layer of soil (1600-3000 ppm), with a gradual increase in concentration with depth. The $CO_2$ concentration at the depth of 60 cm from 2 to 4 times higher than that at a depth of 10 cm. At a depth of 60 cm was observed a significant increase of $CO_2$ concentration since the beginning of June to the end of August, from 7 to 15 thousand ppm. It is associated with the accumulation of carbon dioxide in the soil air during the growing period. The sharp outburst of $CO_2$ concentration at all depths (except 60 cm) was observed in February, March and April. The sharp increase in concentration is due first to the jamming of gas in the soil profile during the period when the upper 10 cm layer was still in a frozen state.