SU|TMA 11
11 th Conference on Soils of Urban, Industrial, Traffic and Mining Areas
Soils and the food, water, energy nexus
05.09.– 09.09 2022 Berlin, Germany

Carbon stocks and fluxes in urban soils: challenges and perspectives for climate mitigation

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Urbanization coincides with remarkable environmental changes including vegetation, soil and climate and consequent effects on carbon balance. The recent IPCC assessment report highlights cities as global warming hotspots, where climate change is exacerbated by urban heat island and urban dryness effects. Actions on climate adaptation and carbon (C) neutrality are claimed a priority by more than a hundred cities all over the world (e.g., C40 or Cities Alliance). Development of urban green infrastructures is considered among the main nature-based solutions for climate mitigation and adaptation in cities. City governments and investors have very high expectations from C sequestration by urban green infrastructures and promote such initiatives as Million Trees in New York or My Street in Moscow as a universal recipe to reach C neutrality. However, none of these or similar projects consider the role of urban soils in C balance. This ignorance increases uncertainty in C accounting and probably overestimates the real potential of urban green infrastructures for C sequestration. Understanding whether urban soils are C sinks or sources under different management and climatic conditions is highly relevant to integrate knowledge and technologies of urban soil science into climate change mitigation and adaptation solutions in cities.

The research reviews complex interrelationships between urban climate and carbon stocks and fluxes in urban soils at multiple scales. At the local scale, soil-like materials (e.g., peat, wastes, sand-peat mixtures etc) and Technosols constructed from these materials were studied. C stocks (C contents for materials) were compared to microbial respiration (measured in lab or in field) to assess decomposition constants and half-life time. Microbial CO_2 emission (C efflux) was also compared to biomass growth (C input) to estimate net ecosystem exchange. The effect of construction technologies (e.g., depth and sequence of layers) and different vegetation (e.g., trees or lawns) was investigated. At the city scale, digital soil mapping of soil C stocks was integrated with mesoclimatic COSMO-CLM modeling to project the effect of urban heat island on microbial respiration. Relationships between basal respiration, soil temperature, moisture, C content and pH established in laboratory experiments were extrapolated to the Moscow city area. The highest respiration (and the lowest half-life time) was reported for the green areas in the city center where implementation of C-rich soil-like materials for urban greening coincided with the strongest urban heat island effect. Finally, at the regional scale C stocks and CO_2 emissions in urban soils were observed across the bioclimatic gradient from forest-tundra to dry steppe conditions in Central European Russia. In each location, dynamics of CO2 emissions and micrometeorological parameters were observed in urban soils in comparison to natural references in 2020 and 2021. Considering that summer 2021 was among the warmest for the whole history of observations, the difference in CO2 emissions between the years allowed projecting the effect of climate change.

The research was supported by Russia Science Foundation project #17-77-200-46