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Urban soils as hotspots of anthropogenic carbon accumulation: Review of stocks, mechanisms and factors

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Urban soils and cultural layers accumulate carbon (C) over centuries and consequently large C stocks are sequestered below the cities. These C stocks as well as the full range of processes and mechanisms leading to high C accumulation in urban soils remain unknown. We collected data on organic (SOC), inorganic (SOC) and black (pyrogenic) (BC) C content in urban and natural soils from 100 papers based on Scopus and Web-of-Knowledge databases. The yielded database includes 770 values on SOC, SIC and BC stocks from 118 cities worldwide. The collected data were analyzed considering the effects of climatic conditions and urban-specific factors: city size, age and functional zoning.

For the whole range of climatic conditions, the C contents in urban soils were 1.5-3 times higher than in respective natural soils. This higher C content and much deeper C accumulation in urban soils resulted in 3 to 5 times higher C stocks compared to natural soils. Urban SOC stocks were positively correlated with latitude, whereas SIC stocks were less affected by climate. The city size and age were the main factors controlling intra-city variability of C stocks with higher stocks in small cities compared to megapolises and in medieval compared to new cities. The inter-city variability of C stocks was dominated by functional zoning: large SOC and N stocks in residential areas and large SIC and BC stocks in industrial zones and roadsides were similar for all climates and for cities of different size and age. Substantial stocks of SOC, SIC and N were sequestered for long-term in the subsoils and cultural layers of the sealed soils, which underline the importance of these 'hidden' stocks for C assessments.

Typical and specific for urban soils is that the anthropogenic factor overshadows the other five factors of soil formation. Substantial C stocks in urban soils and cultural layers result from specific mechanisms of C accumulation in cities: i) large and long-term inputs from outside the city (e.g. suburban, agricultural and forest areas), and ii) C accumulation in parallel with upward soil growing without complete mineralization (common in natural soils). These mechanisms result over long period in gradual growing-up of urban soils and C accumulation. The average rate of urban soils' uprising growth of 50 cm per century and the average SOC contents of 3-5% led conclude that urban soils accumulate 15-30 kg C m-2 per century without steady state (common for all natural soils). These factors lead to high potential of urban soils for long-term C sequestration. We conclude that despite small area under the cities, urban soils are hotspots of belowground long-term C sequestration worldwide and the importance of urban soils will increase in future with global urbanization.