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

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Urban soils and cultural layers may accumulate carbon (C) in deep horizons over centuries and consequently large C stocks may be sequestered beneath cities. Processes and mechanisms leading to high C accumulation in urban soils remain unknown. Data on soil organic carbon (SOC), soil inorganic carbon (SIC), black (pyrogenic) carbon (BC) and nitrogen (N) contents and stocks in urban soils was collected from 100 peer-reviewed papers. The database (770 data points for SOC, SIC and BC stocks from 116 cities worldwide) was analyzed considering the effects of climate and urban-specific factors (city size, age and functional zoning) on C stocks. The processes of C accumulation specific for urban soils were analyzed and C sequestration rates were assessed.
For the wide range of climatic conditions, total C content in urban soils was 1.5-3 times higher and C accumulation was much deeper compared to natural soils, resulting in 3-5 times larger total C stocks. Urban SOC stocks increased with latitude, whereas SIC stocks were less affected by climate. City size and age were the main factors explaining inter-city differences in C stocks. The intra-city variability of C and N 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 consistent across all climates and for cities of various size and age. Substantial amounts of SOC, SIC and N are sequestered in the subsoils, cultural layers and sealed soils, underlining the importance of these 'hidden' stocks for C assessments.
Long-term input from outside the cities and associated C accumulation coincided with upward soil growth of $\sim$ 50 cm per century, and continuous accumulation of 15-30 kg C m-2 per century in urban soils and cultural layers. We conclude that, despite the relatively small area of cities (2.5%), urban soils are hotspots of long-term soil C sequestration worldwide (between 7 and 13%), and the importance of urban soils will increase in future with global urbanization.