Strapline: Urban soils

Title: Urbanisation's Impact on Soil Carbon

Standfast: As urban extent continues to grow, the impact this major land use change has on soils and their carbon stocks is an increasingly important question. A recent global study suggests that the effects are not straightforward.

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Whilst urban areas only make up a fraction of a percent of the Earth's land surface, this area is projected to expand by 2-6 times over the course of this century[1], making urbanisation a growing driver of environmental change. Urbanisation brings with it a wide variety of factors that can have a dramatic effect on soils and their carbon stocks, with implications for global climate regulation, as well as processes that play important roles in climate resilience, such as local water flow regulation[2], and urban cooling[3]. Writing in Global Change Biology, Fangjin Xu and colleagues[4] suggest that globally, soil organic carbon (SOC) stocks decline with increasing intensity of urbanisation, however, the impacts on SOC may distinctly vary across climate zones and development stages.

Once a relatively neglected field of study and a literal blank on past soil maps, research into urban soils, their properties and functions has grown rapidly over the past 10-15 years[5]. Soil organic carbon has been a strong focus of this research given soil's importance in the global carbon cycle. Soils are a major store of organic carbon, holding more than that in the atmosphere and vegetation pools combined[6], meaning that relatively small losses or gains to this pool can accelerate or help mitigate climate change. Whilst a recent global study suggested only 0.27% of the global terrestrial SOC stock is stored in urban greenspaces[7] (this neglects the carbon stored below built infrastructure), the projected expansion of this land use raises questions regarding how to retain and enhance SOC in these ecosystems.

Urbanisation has a complex effect on soil carbon and can lead to reductions or increases in SOC stocks (Fig. 1). This is because urban soils are subjected to a wide range of interacting disturbances. Removal and disturbance of topsoils and subsoils during construction and removal of vegetation can lead to major losses of SOC. Losses may also result from accelerated decomposition rates, driven by increases in temperatures due to urban heat islanding[8] or priming effects from anthropogenic additions of labile carbon in managing urban greenspaces[9]. Conversely, gains in SOC can occur due to the introduction and cultivation of productive plant species, and the introduction of nutrients via fertilizers or elevated atmospheric deposition. Compaction and soil sealing may also slow down microbial processes, slowing decomposition and reducing loss of CO_2 from soils.

Whilst many studies have examined SOC stores underneath various greenspaces and built infrastructure in towns and cities, no consistent trends between urbanisation and SOC change have been found, in part limited by a lack of temporal measures. The study by Xu et al. addresses this by taking a global space-for-time approach to understanding how urbanisation affects SOC stocks. Using a gradient analysis method borrowed from ecology, they examine SOC stocks, as estimated by a global digital soil mapping system, across urban-rural gradients, characterising urban intensity using global impervious surface data which describes the extent to which land is covered by artificial surfaces such as roads, car parks, paving and buildings.

They found that SOC stocks generally decline with urban intensity at the global level. However, the changes to SOC appear to take three stages – with initial declines as land transitions from zero to low levels of urban intensity (0-25% impervious surface cover), a slight rise in SOC through the mid-level of urban intensity (25-75%) and again declines at high levels of urban intensity (75-100%). The authors attribute this decline-rise-decline pattern to initial losses as previous land use is replaced by human developments, the accumulation of carbon as ecosystems recover and humans incorporate green infrastructure at mid-intensity development stages, and finally the reduction and fragmentation of green infrastructure caused by high levels of urbanisation.

The analysis also suggests, however, that the effects of urbanisation may vary across climate zones, with tropical climates accumulating carbon with urban intensity and soils in dry climate exhibiting SOC declines across all urbanisation levels. This leads the authors to recommend that special attention should be paid to soils during urban development in water-scarce environments. However, care must be taken when interpreting these results. The SOC estimates used derive from SoilGrids, which employs machine learning to predict properties of the soil profile across the world on a 250m resolution. Urban soils data for training this model are scarce, and this product has been shown to have its lowest prediction accuracy in urban areas[10]. The authors attempt to counter this limitation by comparing the SoilGrids predictions to literature data collected from 188 studies, which illustrates that the predictions in dry climate zones may be of higher inaccuracy, underestimating stocks by >35%.

Caution must also be taken in interpreting the results of a space-for-time approach. Each soil is shaped by its own long and complex history of multiple environmental and human influences. This is intensified in urban settings where soils may have been severely disturbed by humans via multiple mechanisms for hundreds to thousands of years (Fig. 1). Untangling these drivers is not easy in a space-for-time approach. For example, age of settlement can play an important role in determining current urban SOC stocks[11], and urban intensity as used in this study is likely non-linearly related to settlement age. Also, where society chooses to settle is not random. The surrounding soils will determine the availability of food, water and mineral resources, topography and stability of soils will effect their suitability for supporting built infrastructure, and the quality of soils will play a part in land price, tenure, protections and permissions. The starting point for SOC in urban areas is biased compared to natural/rural settings.

Nevertheless, the space-for-time approach taken by Xu and colleagues[4] helps explore the effects of urbanisation on SOC at a global level, which is important for gaining an understanding of the broad and long-term implications of this global trend. It helps highlight the expectation that the effects vary across climate zones and with development intensity, suggesting that differing practice and policy measures to retain and enhance urban SOC may be required in different regions. However, many questions remain on how the multiple drivers associated with urban land use impact urban soils, their carbon stores and other properties and functions. Better global data are needed to help characterise this vital ecosystem at the foundation of our towns and cities, and new experiments and models will be vital in helping us understand how soils may respond to the complex interacting drivers that accompany urbanisation.

The author declares no competing interests.

Fig. 1: Urban soil profile, Manchester UK. Urban soils can be highly heterogenous and shaped by a long history of human influence. This profile includes visible cultural layers due to past uses. For example, the dark layer at the 40 cm mark is likely attributable to organic matter additions made during it's time as a timber yard in the 19th Century. Credit: Roisin O'Riordan.

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