Author(s): Narasinha J. Shurpali

Title: Urbanization associated changes in biogeochemical cycles

Year: 2023

Version: Published version

Please cite the original version:

Shurpali, N. J. (2023). Urbanization associated changes in biogeochemical cycles. Global Change Biology, 00, 1– 3. https://doi.org/10.1111/gcb.16698

Received: 2 March 2023 | Revised: 22 March 2023 | Accepted: 23 March 2023

DOI: 10.1111/gcb.16698

COMMENTARY

Global Change Biology WILEY

Urbanization associated changes in biogeochemical cycles

Narasinha J. Shurpali

Atmosphere Biosphere Interactions, Grasslands and Sustainable Farming Research Group, Production Systems Unit, Natural Resources Institute Finland (Luke), Halolantie 31 A, 71750, Maaninka, Finland

Correspondence
Narasinha J. Shurpali, Atmosphere Biosphere Interactions, Grasslands and Sustainable Farming Research Group, Production Systems Unit, Natural Resources Institute Finland (Luke), Halolantie 31 A, 71750 Maaninka, Finland.
Email: narasinha.shurpali@luke.fi

Funding information
Academy of Finland, Grant/Award Number: 334422; The Finnisg Ministry of Forestry and Agriculture, Grant/Award Number: VN/28562/2020-MMM-2

Urban land use change has significant impacts on biogeochemical cycling, altering the flow of energy and nutrients through ecosystems. These impacts can be observed at multiple scales, from local to global, and affect both natural and human systems. Urbanization often involves the conversion of natural ecosystems into impervious surfaces such as roads, buildings, and pavements. This change in land use can result in a reduction in the amount of carbon stored in the soil and vegetation. A study by Seto et al. (2020) found that global urbanization between 2000 and 2030 could result in the loss of up to 1.2 billion metric tons of carbon from terrestrial ecosystems. A study conducted by the Global Carbon Project estimated that urban areas are responsible for approximately 75% of global CO_2 emissions. Urban land use change is a significant contributor to these emissions, particularly in rapidly growing cities in developing countries, where land is often converted from forests and agricultural areas without adequate planning or regulation.

One of the main sources of greenhouse gas (GHG) emissions from urban land use change is the construction and operation of buildings, which account for approximately 40% of global energy-related CO_2 emissions. As cities grow, more buildings are constructed, and energy demands for heating, cooling, lighting, and other services increase, leading to higher emissions. Transportation is another major source of GHG emissions from urban areas, particularly from private vehicles, which emit CO_2 and other pollutants such as nitrogen oxides and particulate matter. As cities expand, transportation infrastructure is also developed, which can lead to increased car dependency and higher emissions.

Urbanization can significantly impact the structure and functioning of soils, leading to changes in soil carbon, nitrogen, and water dynamics. These changes can influence GHG emissions, particularly nitrous oxide (N_2O) and methane (CH_4) emissions, which contribute to global warming. One of the main ways urbanization affects soil structure is through soil compaction. Construction activities and heavy traffic can compact soil, reducing pore spaces and limiting water infiltration, which can alter the soil's ability to store and cycle nutrients. Compacted soils may also have decreased microbial activity and a reduced capacity to support plant growth, leading to a buildup of carbon and nitrogen in the soil. As a result, the soil can become anoxic, favoring the production of N_2O and CH_4 by anaerobic microorganisms. Several studies in the recent decades have demonstrated that urban soils, particularly those in highly developed areas, have higher N_2O and CH_4 emissions than rural soils. For instance, a study in Beijing, China, found that soil N_2O and CH_4 emissions were positively correlated with urbanization levels, with the highest emissions observed in the most urbanized areas (Wang et al., 2017). Another study in the United States found that urban soils had 18 times higher N_2O emissions and eight times higher CH_4 emissions than rural soils (Groffman et al., 2006). In addition to soil compaction, urbanization can also affect soil organic matter (SOM) content and composition, which can influence GHG emissions. Urban soils tend to have lower SOM content than rural soils due to the removal of vegetation and the use of synthetic fertilizers, which can lead to a decrease in soil microbial activity and nutrient cycling. However, urban soils may also have a higher proportion of labile organic matter, which can contribute to increased N_2O and CH_4 emissions. For instance, a study in Guangzhou, China, found that soil labile carbon was positively correlated with N_2O emissions (Gong et al., 2019). While the precise mechanisms underlying the relationship between

This article is a Commentary on Zhan et al., 10.1111/gcb.16652.

soil structure and GHG emissions are complex and site-specific, soil management practices that aim to reduce soil compaction and enhance SOM content can help mitigate the environmental impacts of urbanization.

There are very few studies that estimate the relative urban shares of global GHG emissions. One of the challenges is in defining and delineating consistently the rural and urban areas globally. Another challenge is that of a severe lack of data on GHG emissions associated with land use changes from agricultural, forestry or natural ecosystems to urban systems. There is no comprehensive statistical database on urban GHG emissions. Available global estimates of urban emission shares are either derived from bottom-up or top-down approaches. In the absence of a more substantive body of evidence, large uncertainties remain surrounding the urban GHG estimates. A search on the number of research articles published per year on the topic of GHG emission measurements associated with the impacts of urbanization reveals that this topic is beginning to receive the needed scientific attention only in the last few years with a single publication on the topic in 1997 to 187 publications in 2022 and 63 already in the first 2 months of 2023 (Figure 1). It is heartening to note that the latest papers on the topic are being generated mostly from regions of currently intensive urbanization in the world.

In view of the severe lack of available data and attention devoted to the topic thus far, the novel meta-analysis by Zhan et al. (2023) presented in this issue of Global Change Biology is a welcome step towards enhancing our understanding of the impacts of urbanization on non-CO_2 GHG emissions. As the authors point out, the observations available for analysis in this synthesis article were made primarily in North America, with a few studies in Europe, Australia, or Asia. While urban applications of the eddy covariance technique to monitor urban turbulent CO_2 flux measurements have been increasing in the recent years, not many studies have addressed changes in soil methane and nitrous oxide emissions from urbanization. The conversion of agricultural or natural land to urban land use has significant impacts on the physical and chemical properties of the soil. Some of the key changes that occur in soil properties after conversion to urban land use include soil compaction and changes soil pH (Cui et al., 2018), SOM dynamics, soil nutrient, and water status (Lal, 2018). These changes in soil properties can have significant impacts on ecosystem services and urban sustainability through changes in biogeochemical cycling of soil C and N and soil plant atmosphere interactions. The synthesis by Zhan et al shows that non-CO_2 GHG emissions from soils of urban greenspaces are significantly higher than emissions from non-urban soils, owing to increases in soil N_2O emission (+153%), while uptake of atmospheric CH_4 by soils was decreased by about 50% in urban greenspaces. Although the analysis presented here is the first of its kind, the authors, however, appropriately recognize that their analysis could be biased owing to an uneven data coverage and an unbalanced selection of ecosystem types highlighting the need for a better understanding of the importance of urbanization impacts on soil non-CO_2 GHG fluxes in a global context.

It is worth noting that in the fifth assessment report (AR5), the IPCC has identified enhancing our understanding of the impacts of urban land use change on biogeochemical cycles as an important step towards reducing the uncertainty in the global C and N budgets (IPCC, 2018). The United Nations' sustainable development goals (SDGs) also address the issue of urban land use change and its impacts on biogeochemical cycling—SDG 11: Sustainable Cities and Communities aims to make cities and human settlements inclusive, safe, resilient, and sustainable. SDG 15: Life on Land seeks to protect, restore, and promote the sustainable use of terrestrial ecosystems, including through the conservation and restoration of forests and other natural habitats. In view of this, it is crucial that an international effort across demographic, socioeconomic, cultural borders be urgently initiated to generate data and knowledge on how urbanization contributes to climate change. Such a concerted

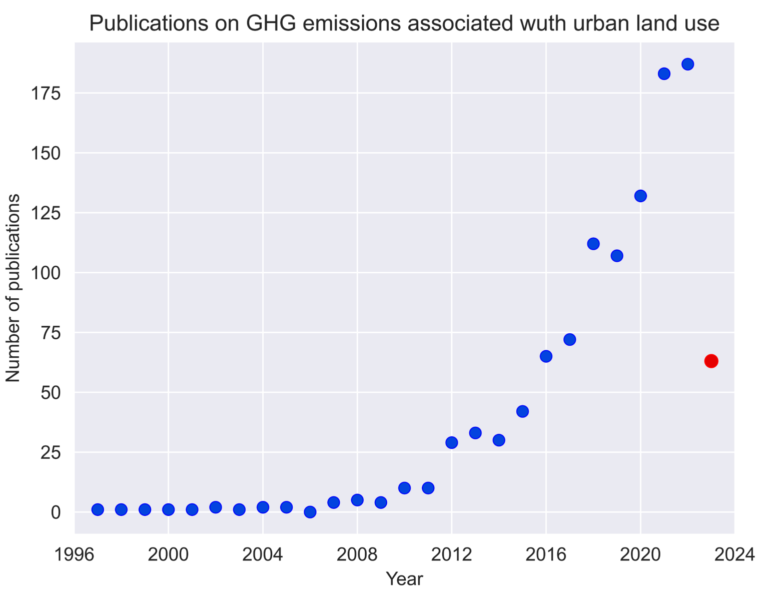

FIGURE 1 Number of research articles published per year on the topic of GHG emission measurements associated with urbanization, blue full circles show the exponentially increasing number of publications from 1997 to 2022, the red dot shows the publication number as of 27.02.2023 (Science Direct search engine, filters—original research articles, environmental science). GHG, greenhouse gas.

effort will pave the way for adopting suitable mitigation, adaptation and policy options for reducing the GHG load associated with urban land use change.

ACKNOWLEDGMENTS

I acknowledge the funding from the Finnish Ministry of Agriculture and Forestry (Project NC-GRASS: VN/28562/2020-MMM-2) and the Academy of Finland (Project ENSINK, Decision number 334422).

CONFLICT OF INTEREST STATEMENT

The author does not have any conflict of interest.

DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no datasets were generated or analysed for this commentary.

ORCID

Narasinha J. Shurpali https://orcid.org/0000-0003-1052-4396

REFERENCES

Cui, Y., Zhang, C., Cao, S., & Zhu, Y. (2018). Effects of urbanization on soil physicochemical properties and microbial communities. *Science of the Total Environment*, *645*, 1339–1350.

Gong, J., Liu, C., Zhou, J., Huang, Y., Wang, M., & Wu, J. (2019). Labile carbon drives soil N_2O emissions in urban park soils. *Journal of Environmental Quality*, *48*(4), 1147–1155.

Groffman, P. M., Altabet, M. A., Böhlke, J. K., Butterbach-Bahl, K., David, M. B., Firestone, M. K., Giblin, A. E., Kana, T. M., Nielsen, L. P., & Venterea, R. T. (2006). Methods for measuring denitrification: Diverse approaches to a difficult problem. *Ecological Applications*, *16*(6), 2091–2122.

IPCC. (2018). *Global warming of 1.5°C*. https://www.ipcc.ch/sr15/

Lal, R. (2018). Soil degradation as a reason for inadequate human nutrition. *Food Security*, *10*(5), 1261–1273.

Seto, K. C., Parnell, S., & Elmqvist, T. (2020). A global outlook on urbanization. In J. Seto & A. Reenberg (Eds.), *Rethinking global land use in an urban era* (pp. 1–14). MIT Press.

Wang, X., Zhou, W., Liu, S., Song, C., & Wu, J. (2017). Nitrous oxide emissions from urban soils: Influence of urbanization levels and soil properties. *Science of the Total Environment*, *575*, 481–489.

Zhan, Y., Yao, Z., Groffman, P. M., Xie, J., Wang, Y., Li, G., Zheng, X., & Butterbach-Bahl, K. (2023). Urbanization can accelerate climate change by increasing soil N_2O emission while reducing CH_4 uptake. *Global Change Biology*, *00*, 1–14. https://doi.org/10.1111/gcb.16652

How to cite this article: Shurpali, N. J. (2023). Urbanization associated changes in biogeochemical cycles. *Global Change Biology*, *00*, 1–3. https://doi.org/10.1111/gcb.16698