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EDITORIAL

Anthromes and terrestrial carbon

There is a growing movement in paleoecology, archaeology, human history, and historical ecology communities that shows the millennia-long history of direct human influence on the landscape (Ellis, 2021; Ferreira et al., 2022; Fletcher et al., 2021; Fricke et al., 2022; Kaplan, 2015; Levis et al., 2018; McMichael et al., 2017; Roberts et al., 2017; Scerri et al., 2022; Whitaker et al., 2023). Since the end of the last ice age 12,000 years ago, people have inhabited and interacted with ecosystems that cover more than 70% of Earth's land surface (Ellis et al., 2021). Throughout the Holocene (the modern interglacial climate period), people and their actions have been integral to the structure and function of the majority of land ecosystems. At the broad scale, these ecosystems have been labeled anthropogenic biomes (anthromes) to explicitly recognize the "global patterns of sustained direct human interaction with ecosystems" (Ellis & Ramankutty, 2008). People actively manipulate the land around them to suit their needs; as a result, anthromes are often more dynamic, with higher plant and soil turnover rates, than the few remaining ecosystems that have minimal human influence. Thus, the dynamics of anthromes are driven by socio-economic processes in addition to ecological processes.

Earth's land ecosystems store vast quantities of carbon in myriad live and dead organic forms. Changes in these terrestrial carbon stores have contributed to rising atmospheric CO_2 in the past but are currently removing CO_2 from the atmosphere (Friedlingstein et al., 2025), slowing the pace of atmospheric CO_2 increase and climate change. Terrestrial carbon is the most dynamic global carbon pool due to extensive human influence. This influence operates both directly and indirectly. Direct impacts include clearance for agriculture, peatland drainage, agricultural practices, timber extraction and plantation forestry, housing and urban development, land abandonment, fire suppression, Indigenous fire management, and megafauna hunting and extinction (Kimmerer & Lake, 2001; Kaplan et al., 2011; Klein Goldewijk et al., 2011; Fricke et al., 2022; Lapola et al., 2023; Mander et al., 2025). Indirect impacts include rising atmospheric CO_2 and its physiological and climatic effects, modification of other elemental cycles, and the introduction of non-native species, pests, and pathogens (Friedlingstein et al., 2025; Rockström et al., 2023; Walker et al., 2021).

Understanding the influence of people on terrestrial carbon is a transdisciplinary problem that requires expertise across multiple disciplines: Earth system science, ecology, agriculture, anthropology, social sciences, political economy, and economics. This Special Collection across *Plants, People, Planet* and *New Phytologist* seeks to explore the inter-relationship of people and terrestrial carbon dynamics from the deep past and into the climate change mitigation–motivated near-future. We bring together a collection of work that provides multi-scale views of the diverse, interconnected impacts of people on terrestrial carbon through time, and submissions across disciplines (e.g., ecology, environmental and Earth system science, anthropology, political science, economics, and many others) were encouraged. The aims of this Special Collection and corresponding Symposium held in April of 2023 (talks of which can be found on the New Phytologist Cassyni page: https://cassyni.com/s/npf-events) were to: 1) build community across disciplines; 2) explore how the anthromes conceptual framework transforms our understanding of land–atmosphere carbon exchanges and broader ecosystem dynamics; 3) discuss the impacts of people through the deep past, industrial period, and into the future on terrestrial ecosystem carbon; 4) consider net-zero as a driver of land carbon change.

This Special Collection investigates how looking through an 'anthromes lens' can inform our view of terrestrial carbon dynamics. The Collection includes 15 papers covering a range of topics, and we will add to the Collection as relevant papers are accepted at *Plants, People, Planet* and *New Phytologist*. The Collection includes papers that address concepts in relation to anthromes, historical perspectives on how people have shaped carbon in ecosystems, carbon in present-day anthromes, carbon in urban settings, and how policy can shape carbon in future ecosystems. With this Special Collection and the 2023 Symposium, we hope to advance the discussion on people as primary ecological agents whose influence cannot be ignored in any ecological study.

1 | THEORY & CONCEPTS

We open the Special Collection with a paper from the science and technology studies discipline of sociology by Ehrenstein and Root-Bernstein (2025). They take a deep dive into the use and history of the anthromes classification schema, pointing out that conceptual frameworks such as these are hypotheses to be tested and cautioning against codification. They explore how the anthromes hypothesis relates to other hypotheses in the domain of human land use, tracing a key component of the anthromes hypothesis to land use intensification theory (Boserup, 1965). Highlighting uncertainty in the anthromes hypothesis, they recommend that researchers continue to reflect on common assumptions within anthromes-based research that shape the process and outcomes of study, and provide suggestions for how to better integrate research on human-land interactions across disciplines.

Next, Williams et al. (2025) develop a widely applicable schema for assessing the quality of inference when attributing causes to vegetation change in environments with complex histories. The schema considers whether evidence is qualitative or quantitative, correlative or mechanistic, and, where mechanistic, whether either a single hypothesis only or multiple alternative hypotheses have been evaluated. They apply the schema to studies of vegetation change in Australia, where recent climate change occurs against the long history of tens of millennia of coevolved Indigenous land use and care, followed by the more recent rupture of British invasion and colonization.

Lapola et al. (2025) make the case that rising atmospheric CO_2 can be viewed as an ecosystem-degrading disturbance through its effects on plant water relations and subsequent climate interactions, even in the absence of direct human influence. Such a framing calls into question whether the anthromes category of "wild woodlands" even exists—the term is already contested, given that "wildlands" has been used to exclude Indigenous peoples (Fletcher et al., 2021). Mander et al. (2025) use the term "anthro-natural ecosystems" to describe this kind of human influence on peatlands, as discussed further below.

2 | A HISTORICAL PERSPECTIVE ON PEOPLE & CARBON

We then present a suite of papers that explore the interactions of people with ecosystems and ecosystem carbon in the deep past, 2,000 years ago, through to the present. Nascimento et al. (2024) explore the impacts of colonialism and phases of different colonial practices post 1492 on Indigenous peoples and ecosystems of the Amazon. Noting that in 1492 the Amazon was already a patchwork of forests with significant human influence, they first explore the influence of Indigenous peoples. They then review the impacts of successive waves of colonial invasions from the initial "great dying" where 90–95% of the Indigenous population died from disease, warfare, and slavery, the Jesuit period (1549–1767), the rubber boom (1850–1920), and developmentalists (post 1920). They explore how these various cultures and historical processes have left a patchwork of legacies on Amazon forest structure and function. These legacies also affect the rates of tree growth and turnover and thus long-term carbon dynamics. It is important to note that Indigenous and developmentalist (broadly defined) cultures continue to manage significant tracts of Amazon forest land, with collective Indigenous property rights leading to secure carbon reserves (Baragwanath et al., 2023; Baragwanath & Bayi, 2020).

Witteveen et al. (2025) apply a novel paleoecological approach, recommended by Nascimento et al. (2024), to reconstruct over 2,000 years of human history and quantify the corresponding changes in forest biomass using *Poaceae* phytoliths and charcoal found in lake sediments. Witteveen et al. (2025) show how modern forest cover and biomass are related to past fire and cultivation history. The methodology developed by their study is generalizable, and could be applied to the phytoliths, pollen, or charcoal recovered from any lake sediment core in the Amazon, providing a way to reconstruct long-term biomass changes across the various Amazonian habitats and regions.

Los et al. (2025) present an elegant modeling study that takes a deeper dive into the aboveground carbon stock effects of Indigenous and local food production practices in tropical forests. Their analysis illustrates a wide range of possible carbon outcomes from various food production systems. Food production methods in forests that preserve just the largest 1% of trees can maintain carbon stocks at 40% of old-growth stocks. Also, slash-and-burn swidden methods with more stochastic return intervals can preserve some large trees and similar carbon stocks by retaining the largest 1% of trees. The importance of large trees in explaining carbon stock variability has also been illustrated in old-growth forests (Needham et al., 2022).

3 | CARBON IN THE PRESENT

Turning to present-day carbon dynamics, several papers explore anthrome-related considerations for major modern-day carbon stocks in forests (Hogan et al., 2025), peatlands (Mander et al., 2025), and globally (Walker et al., 2025). Hogan et al. (2025) use forest inventory data to analyze the carbon stocks of various anthrome classes, showing little difference in aboveground carbon stocks between intensive and cultured anthromes for temperate and boreal forests, but some difference between them in tropical forests.

Mander et al. (2025) point out that while peatlands cover only 3% of the land surface, they store up to one-third of terrestrial carbon and are especially vulnerable to human influence. They discuss how peatlands are under threat and call for protection and restoration.

Walker et al. (2025) reanalyze the global carbon budget (Friedlingstein et al., 2019, 2025), showing that deeper consideration of human influence requires harmonization of the two land carbon flux terms. They harmonize some of the inconsistencies in the two terms, which leads to a consistent missing carbon sink in the budget of around two-thirds of a petagram per year since the 1930s.

4 | URBAN CARBON

The collection's focus then shifts to carbon in the most anthropogenic environment of all—the urban environment. Three papers analyze carbon dynamics in these highly modified landscapes. Ferlauto et al. (2024) explore the effect of leaf litter removal on soil carbon in suburban yards in Maryland, USA. Using a neat paired study design, they show that long-term (median 11 years) litter removal reduced soil carbon and decomposition rates. These reductions were not easily reversible with two years of litter addition. Because the scale of urban and suburban litter removal is so large, these results suggest a potentially substantial influence on carbon storage in these anthromes, with potential implications for additional ecosystem services such as stormwater retention.

Sampling the leaves of *Taraxacum officinale* and *Fraxinus pennsylvanica* in the city of Saint Paul, USA, Heskel et al. (2025) indicated that radiocarbon in the leaves may be related to distance to the nearest major road. While their analysis did not show any relationship to historical practices of discrimination, their limited case study provides a basis for more extensive sampling and more in-depth analysis.

Tan et al. (2025) examine the carbon content of secondary forest islands within the urban landscape of Singapore. They used drone-based LiDAR surveys in 2013 and 2023 to show that secondary forests that include non-native species accumulate carbon at similar rates as more native secondary forests.

5 | CARBON MANAGEMENT & NET-ZERO FUTURE

The collection concludes with four papers investigating aspects of carbon management policy and future scenarios. Fleischman et al. (2025) use Himachal Pradesh, a well-governed state in India with a long history of forestry that peaked in the late 1980s, as a case study showing that tree planting has been a multi-objective goal for decades and highlighting that forest restoration is not a new phenomenon. They show that tree planting was primarily funded by governmental organizations rather than markets or donors and that, despite rhetoric to the contrary, most tree planting was done without formal local participation. However, informal local participation has likely led to a shift from timber production species to more diverse hardwoods with diverse local uses, although timber plantations remain a large proportion of planted trees today.

Anderson-Teixeira et al. (2025) document a process for translating data from the largest forest carbon database, ForC (Anderson-Teixeira et al., 2024; https://github.com/forc-db/ForC), to an Intergovernmental Panel on Climate Change (IPCC) database for emissions factors. This IPCC database is critical for informing net-zero goals, and yet, with current support, Anderson-Teixeira et al. (2025) have only been able to transfer 7% of eligible records from ForC, and these make up 19% of the forest record in the IPCC database.

Felzer (2025) presents a traditional modeling study of the carbon balance in the conterminous United States under two alternative future scenarios, showing that land use change and climate effects largely offset the physiological effects of increasing CO_2.

Camargo-Alvarez et al. (2025) model the effects on carbon and agriculture of strictly protecting 30 or 50% of land for biodiversity conservation. They simulate substantial net carbon gains by 2060, showing a major co-benefit to important biodiversity conservation, albeit with some losses from agricultural expansion in non-protected areas. They discuss human impacts, including potentially increased food costs and the disproportionate impact on communities in the Global South. Often, Indigenous communities have the highest carbon and biodiversity on the lands they control (Baragwanath et al., 2023; Baragwanath & Bayi, 2020; Ellis et al., 2021) and should be included at the forefront of conservation efforts.

The multidisciplinary and multiscale papers in this Special Collection represent a wide range of research into the integral role of humans in terrestrial carbon cycling, giving a taste of the breadth and necessity of research in this area. We have much still to learn. The history of Western science from the times of Francis Bacon and René Descartes follows the basic conceptual framework that humans are separable from the rest of nature (Federici, 2014). As ecologists, it is tempting to want to study ecosystems in a state without human influence. However, as the disciplines of paleoecology, human history, and archaeology converge, it becomes increasingly evident that humans have been integral to ecological processes for millennia. The integral nature of humans and their legacy is apparent even in the Amazon (and other tropical rainforests), ecosystems long thought by Western science to have been subject to relatively little human influence (Curry, 2016; Fletcher et al., 2021; Levis et al., 2018; McMichael et al., 2017; Nascimento et al., 2024; Peripato et al., 2023; Roberts et al., 2017; Scerri et al., 2022). As a result, many of us ecologists and biogeochemists need to ask ourselves if we are sufficiently incorporating our own species into the work we do. This Special Collection of articles highlights the importance of considering and understanding the integral role of humans in ecological processes, including carbon cycling. We suggest that moving forward, researchers from all environmental disciplines should consider humans as integral players in the ecosystems of the past, present, and future.

AUTHOR CONTRIBUTIONS

APW drafted the manuscript; RZA, KB, MEC, YM, and CNHM all contributed to editing the manuscript.

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None.

DATA AVAILABILITY STATEMENT

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Anthony P. Walker[1]
Rose Z. Abramoff[2]
Kathryn Baragwanath[3]
Matthew E. Craig[1]
Yadvinder Malhi[4,5]
Crystal N. H. McMichael[6]

[1]*Environmental Sciences Division and Climate Change Science Institute, Oak Ridge National Laboratory, Oak Ridge, TN, USA*
[2]*School of Forest Resources, University of Maine, Orono, ME, USA*
[3]*Department of Economics, The University of Melbourne, Grattan Street, Parkville, Victoria, Australia*
[4]*Environmental Change Institute, School of Geography and the Environment, University of Oxford, Oxford, UK*
[5]*Leverhulme Centre for Nature Recovery, University of Oxford, Oxford, UK*
[6]*Department of Ecosystem and Landscape Dynamics, Institute for Biodiversity and Ecosystem Dynamics, University of Amsterdam, Science Park 904, GE, Amsterdam, Netherlands*

Correspondence
Anthony P. Walker, Environmental Sciences Division and Climate Change Science Institute, Oak Ridge National Laboratory, Oak Ridge, TN, 37831, USA.
Email: walkerap@ornl.gov

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ORCID

Anthony P. Walker https://orcid.org/0000-0003-0557-5594
Rose Z. Abramoff https://orcid.org/0000-0002-3393-3064
Kathryn Baragwanath https://orcid.org/0000-0002-8950-3506
Matthew E. Craig https://orcid.org/0000-0002-8890-7920
Yadvinder Malhi https://orcid.org/0000-0002-3503-4783
Crystal N. H. McMichael https://orcid.org/0000-0002-1064-1499

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