FORUM

Submitted: March 5, 2023
Accepted: July 3, 2023

An Archaeological Foundation to Soil Sustainability

- Elizabeth Graham
Institute of Archaeology, University College London
e.graham@ucl.ac.uk
- Daniel Evans
School of Water, Energy and the Environment, Cranfield University
daniel.l.evans@cranfield.ac.uk
- Richard Macphail
Institute of Archaeology, University College London
r.macphail@ucl.ac.uk
- Julia Stegemann
Faculty of Engineering Science, University College London
j.stegemann@ucl.ac.uk
- Francesca Glanville-Wallis
Institute of Archaeology, University College London
francesca.glanville-wallis.12@ucl.ac.uk

Abstract

Diverging from traditional archaeology, our ongoing research focuses on decomposition rather than preserved fragments of what people left behind. We are looking at the bulk of what constitutes archaeological deposits: soil. Comparing the thickness of soil where people have lived to thickness where there has been no human occupation shows greater accumulation, or soil formation, where humans have been active. These same

Keywords: anthropic, Belize, Maya, soil, waste

soils are also often characterised by higher fertility than soils formed in the absence of humans. The implication is that the decay of what people throw away, leave behind or bury forms soil. Yet, what we characterise as archaeological sites do not appear to be "wastelands", because they have been altered by time. Given modern threats to soil security, we are applying what we are learning from wastelands of the past to change attitudes today – we need to embrace waste, trash and rubbish as the soil of the future.

Introduction – The Waste of Time

In keeping with this issue's forum theme, our interest is landscapes created from the deposition of waste. The landscapes we have studied, however (Graham *et al.* 2017; Macphail *et al.* 2017), and continue to study, are distinctive from a modern wasteland in two ways. The first is that our waste is so old that it is no longer recognisable as the discard from human occupation; it has instead become soil, a formation process that forces archaeologists to *dig* rather than to pick things up conveniently off a modern surface. The second is that the term "waste" is somewhat inadequate. The landscapes we study indeed include what people have thrown away, such as household rubbish or industrial waste, but they also include abandoned buildings, roads, pavements, old fields or gardens, objects lost and never found and, not least, the buried dead. What many think of as natural soil – through the physical and chemical breakdown of parent materials such as bedrock (Evans *et al.* 2019) – can have an anthropogenic origin (Capra *et al.* 2015; Howard 2017). Our research emphasis, however, is not on humans intentionally generating soil, as the term "anthropogenic" implies and which can be said of plaggen soils (Blume and Leinweber 2004). Instead, our emphasis is on extending the concept of *soil parent materials* to include anything and everything that is human-altered or human-transported (Galbraith 2018) (as listed above) or human-generated (e.g., human waste). Archaeologists are acutely aware of the fact that everything around us will eventually decay or disintegrate. In the process, the products of decomposition contribute to the build-up of the earth around us, to soil chemistry, and often to soil fertility. Based on our work, we envision that much of the earth's observable soils today are in fact derived from human detritus as soil parent material.

Soil Formation and Soil Sustainability

Why is the connection between archaeological sites and soil formation important? Soils are generally considered a non-renewable resource because soils are said not to form on a timescale relevant for humans (Evans *et al.* 2020). We argue that humans have a critical role in soil formation if one considers archaeological timescales and the attendant decomposition of what humans produce and leave behind. If a significant portion of the soil of the Critical Zone (Giardino and Houser 2015; see also the Critical Zone Collaborative Network website[1]) – the earth's boundary layer or outer 'skin' where rock, soil, water and organisms, including humans, interact (Blum *et al.* 2006) – derives from the detritus of human activity (or very old waste), it follows that the future of the planet's

1. See https://www.criticalzone.org/.

Journal of Contemporary Archaeology 10.1 (2023) 70–80
ISSN (print) 2051-3429 (online) 2051-3437 https://doi.org/10.1558/jca.25817

soils is endangered not only by the low priority societies give to soil in sustainability scenarios but also by attitudes toward modern waste and waste practices.

There are several factors that point to the fact that present-day use of soils is not sustainable. Average global crop yields are progressively decreasing, and insufficient nutrients are an agronomic problem in many areas (Foley *et al.* 2011, 337, 340). The ability of many cereal crops to deliver full yields has fallen in the past 30 years (Watts *et al.* 2019, indicator 1.5). Degradation processes characterise the earth's soils (Nachshon 2021); in fact, soil degradation and depletion outstrip soil formation globally (Gibbs and Salmon 2015). Recent work led by Evans (Evans *et al.* 2020) has found that over 90% of conventionally managed soils are thinning, with 16% having lifespans of less than 100 years. What can archaeology contribute to soil sustainability that has not heretofore been considered? For one thing, diachronic factors in modern studies of agricultural viability of soils and land use are not long-term. Additionally, in studies of urbanism and sustainability, the management of waste and products of decay (e.g., human burial, building debris) get far less attention than architectural design or energy use. When waste and rubbish are the focus of attention, "solutions" emphasise recycling (as if recycled material will never be discarded) or burial in sealed landfill deposits so that decay will not take place. What archaeologists can contribute is (1) the perspective of time (Graham *et al.* 2021), and (2) understanding that the detritus of human activity is the main mechanism by which resources are returned to (the) earth. By demonstrating the connection between the decomposition of the products of human activity and soil formation, we also aim to contribute to efforts to change conventional negative attitudes towards waste and decay, thereby creating a favourable environment for true soil sustainability. Conceptually connecting what humans throw away or leave behind to the positive concept of resource renewal adds to the argument that decay and disintegration should be considered culturally as well as ecologically productive (Bardini 2014; DeSilvey 2017).

Research Questions and Approaches

Our overall concerns are to find out how waste – what humans throw away or leave behind – influences or contributes to soil formation, and what its effects are on soil thickness and soil nutrient capacity. To address these issues, we must ask about long-term decompositional processes: what are they, how do they operate and how do they influence the character of modern surface and subsurface soils? Our methods entail two different kinds of investigation: archaeological methods, to determine what humans left behind and the activities that generated the deposits; and soil science, to determine the chemistry, mineralogy and organic components of the deposits and their contribution to the sediment/soil profile as soil parent materials.

Our field study sites, Lamanai and Marco Gonzalez (see summaries in Graham and Howie 2021; Graham *et al*. 2017) are in Belize (Figure 1).

Lamanai was a Maya urban centre for two millennia, and Marco Gonzalez, on the barrier island of Ambergris Caye, was a coastal commercial and manufacturing hub that was part of Lamanai's urban sphere of economic and socio-cultural interaction. Both sites are characterised for most of their long histories (Table 1) by dense populations and intensive activities, particularly circum-peninsular trade and commerce.

FIGURE 1. Map of northern Belize during the Spanish colonial period (AD 1544–1700), showing the sites of Lamanai and Marco Gonzalez (drawn by Debora Trein and Emil Huston).

ISSN (print) 2051-3429 (online) 2051-3437 https://doi.org/10.1558/jca.25817

TABLE 1. Belize Maya chronology.

From AD 1981 to the present	**Independence**
AD 1964–1981	**Self-Governing British Colony**
AD 1862–1964	**British Crown Colony**
AD 1787–1862	**British Settlement**
AD 1660s–1787	**British occupation of the coast**
AD 1641–1700 **AD 1544–1641**	**Spanish colonial period**
AD 1492–1544	**Terminal Postclassic – Early colonial period**
AD 1350–1492	**Late Postclassic**
AD 1200/1250–1350	**Middle Postclassic**
AD 962–1200/1250	**Early Postclassic**
AD 773–962 (898–1025)**	**Terminal Classic**
AD 735–773 (656–891)	**Late Late Classic**
AD 624 (588–659)**–735** (601–870)	**Early Late Classic**
AD 500–600	**Middle Classic** (Provisional)
AD 250–500	**Early Classic**
AD 150–250	**Late facet of the Terminal Preclassic or 'Protoclassic'**
100 BC–AD 150	**Early facet of the Terminal Preclassic**
400–100 BC	**Late Preclassic**
600–400 BC	**Late facet of the Middle Preclassic**
900–600 BC	**Early facet of the Middle Preclassic**
1500–900 BC	**Early Preclassic**

Our Lamanai focus is both land use and the long-term use of mineral-based construction materials (*AZO Materials* 2019) – most familiar to us today as cements – in urban environments (Figure 2). The "disadvantage" to Lamanai is that its extensive built environment makes it difficult to pinpoint areas that have not been intensively altered by humans, and hence baseline (natural) conditions are problematic to establish. In addition, Lamanai's late chronology and occupation (British colonial, twentieth century) need more archaeological study to establish soil formation rates.

Marco Gonzalez, on the other hand, has a more modest built environment than Lamanai, but over 2000 years of occupation remains have been concentrated at the southern tip of the caye. There are small nearby islands with the same underlying geology of Cretaceous and Tertiary limestones, but minimal to no evidence of human alteration that enable us to isolate and assess natural (baseline) conditions and processes. The Colson Point sites in central coastal Belize (Graham 1994) provide a similar opportunity, although with different soil parent materials via the geology of the Maya Mountains. These sites provide distinct case studies not only to explore human–waste–soil relationships but to develop a methodology for tracking decompositional processes over time.

ISSN (print) 2051-3429 (online) 2051-3437 https://doi.org/10.1558/jca.25817

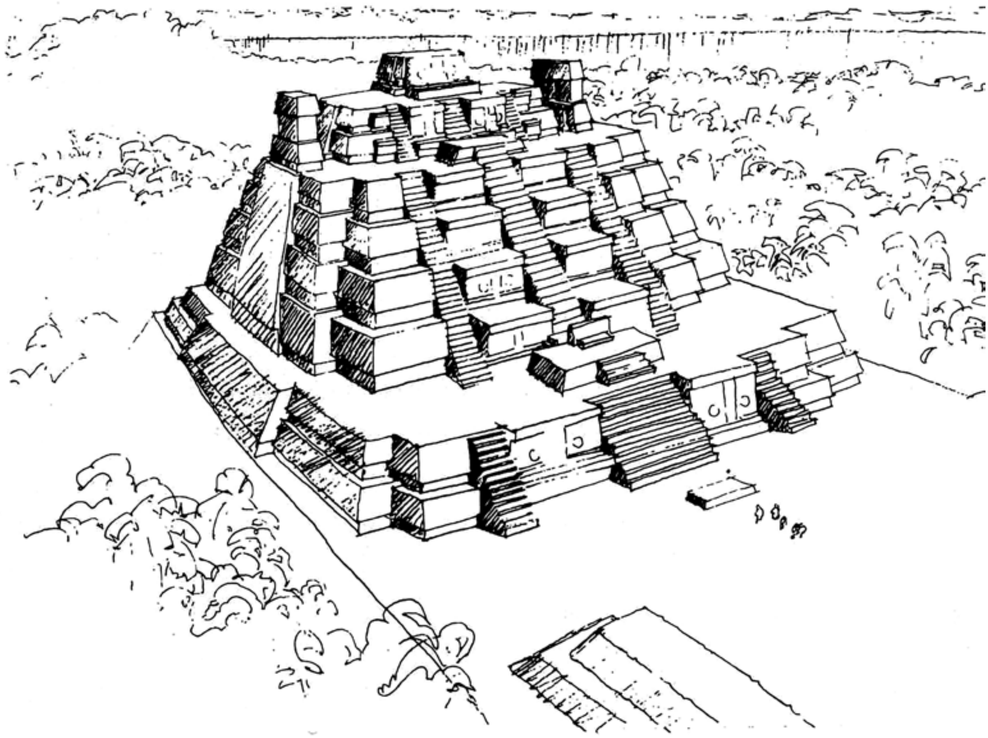

FIGURE 2. Reconstruction of the High Temple at Lamanai, *ca.* 100 BC. The High Temple, at 33 m, is a good example of the intensive use of mineral-based materials (limestone, plaster, mortar) in construction (drawing by H. Stanley Loten for the Lamanai Archaeological Project).

Maya sites may not be the first things to come to mind when one thinks of processes of soil formation that have applicability to soil security (McBratney *et al*. 2014). Pre-Columbian Maya cities and settlements, however, illustrate the importance to soil security of people's engagement with soil (Vis *et al*. 2023a, 2023b). Lamanai and Marco Gonzalez are characterised by the presence of long and continuous sequences, from` Preclassic (Lamanai, *ca*. 1600 BC, Ambergris Caye, *ca*. 400 BC) to modern times. Given the archaeological work that has been carried out at the sites, we have good chronological control to assist in calculating soil formation rates (Figure 3); by this we mean that we can distinguish remains (decompositional products) representing successive activities over time and can date the activities archaeologically, usually to within 200 years or less.

Results So Far

We have been able to identify a Maya dark earth on Ambergris Caye (Macphail *et al.* 2017), but unlike Amazonian dark earths (Arroyo-Kalin 2014) there is no evidence so far for intentional improvement of soils. Instead, the changes in fertility and the accumulation of deposits seem to reflect unintentional behaviour – the detritus of living, working and dying. Work carried out between 2013 and 2016 sponsored by the Leverhulme Trust (Graham *et al.* 2017, Macphail *et al.* 2017, Turner *et al.* 2021) enabled us to provide evidence that the topsoil incorporated components from earlier occupations, particu-

ISSN (print) 2051-3429 (online) 2051-3437 https://doi.org/10.1558/jca.25817

FIGURE 3. One of the test pits at Marco Gonzalez, showing the depositional sequence and upper-level dark earth (photograph by permission of the Marco Gonzalez Archaeology Project).

larly from the disintegration of pottery used to contain brine in salt processing and the fuel used to heat the brine and drive off water to produce salt cakes. Topsoil nutrient capacity was higher than expected in what otherwise would be a mangrove wetland. Recent research in 2023 suggests that dark earth layers may have developed in earlier periods, but these phenomena warrant further study.

Initial research in Life Cycle Analysis (LCA – Duncan 2019) was carried out, an approach that is used today to measure environmental impact. For LCA to be achieved, we discovered that we needed more data on the total amount of human-generated/human-transported deposits at the site, and this effort would require a considerably greater degree of excavation than we were able to accomplish at the time. Some key processes were identified, however, such as the long-term impact of lime production, which acted as a contaminant during the period of manufacture but in time contributed key nutrients to the soil profile (Duncan and Graham 2023). Salt production in the seventh and eighth centuries AD used large amounts of wood from mangrove species as a fuel source; the high demand for wood fuel would have likely degraded the local environment. In time, however, the extensive amount of wood charcoal contributed carbon to the soil. Also, the fragile ceramic containers used in salt production, tempered with quartz from the Maya Mountains, deteriorated easily and contributed quartz to the soil.

Although excavations at Lamanai began in 1974 (Pendergast 1981) and continued until 2019 (Graham 2011; Graham and Howie 2019), land use soil studies only began

ISSN (print) 2051-3429 (online) 2051-3437 https://doi.org/10.1558/jca.25817

in 2022. Preliminary results from a reconnaissance carried out in 2022 by one of the current authors (FG-W) indicate that differences in soil development at Lamanai appear to be driven by processes related to topography (slope position) and moisture status, as well as human activity and land use. Human activity includes not only material inputs from different land uses but also alteration of site topography. Investigations so far suggest that much of the topography in the epicentres of the site (the central precincts changed over time) results from past Maya land use; the extent to which this extends into peri-urban areas is currently under investigation.

Future work

Although initial work demonstrates that Pre-Columbian and premodern activities contributed materials to the soil formation process, it remains for us to work out the details concerning the full range of decompositional components resulting from the materials deposited during each time period; the chemistry, mineralogy or organic composition of these components, as well as their relative impact; the role of bioturbation; and the overall timing involved in the formation of the modern topsoil.

Future work has several aims. A priority is integrating results of archaeologically oriented soil micromorphology – which details components of cultural deposits invisible to the naked eye, as well as initial processes of decomposition – with soil science analyses that are carried out according to soil science protocols and that, at least in the first stages, remain "blind" to cultural categories. A key goal is to develop a methodology – applicable in a range of disciplines – that facilitates assessments of the long-term impacts of human activities under urban conditions today (Evans *et al.* 2021).

The role of ecosystem engineers is a key factor in soil formation, and we have begun with a focus on a species of land crab, *Cardisoma guanhumi*, ubiquitous at Marco Gonzalez and in coastal locations generally in Belize (Glanville-Wallis 2015). Soil fauna and microfauna play key roles in soil formation and in increasing soil nutrient capacity (Carter *et al.* 2007), and we plan to expand research to include other invertebrates and fungi, with a focus on the long-term effects of human burial on soil microecology (Pawlett *et al.* 2019). Our cited published papers have detailed environmental change, but also, rather surprisingly, Pre-Columbian mercury contamination, for which an investigative strategy has been developed (Turner *et al.* 2021). We would like to build on previous LCA studies, although this would require considerable funding to support extensive excavation, which we have not yet been able to acquire. In the interim, however, the goal of developing a methodology that integrates cultural assessments of deposits with studies aimed at clarifying pedogenesis will provide an essential tool in any further strategies for LCA. Non-wood macrobotanical analysis, as well as wood charcoal identification, has been carried out under the Leverhulme project (Duncan 2019) and will continue. In addition to the apparent import of maize and nance (*Byrsonima crassifolia*) at Marco Gonzalez, plant remains should reveal the stage at which it became possible to grow crops. Vegetables and fruit trees are today grown on the island, apparently in association with sites of Pre-Columbian occupation; locals also transport soils from the archaeological sites to their gardens.

ISSN (print) 2051-3429 (online) 2051-3437 https://doi.org/10.1558/jca.25817

Concomitant with and superseding our scientifically oriented goals is our aim of improving and deepening people's engagement with soil (Salazar *et al.* 2020). Our first step is to add a new dimension to an understanding of soil origins. Soil is generally assumed, as noted above, to be a finite resource (Pozza and Field 2020) that can be "modified" by humans. An archaeological perspective introduces the idea that what humans build, destroy, manufacture, discard, bury, excrete, lose or throw away eventually decomposes and becomes soil. This means that engagement with soil involves re-thinking human attitudes not only towards the soil we can see around us but also towards the discarded materials that will in time become soil. "Waste" is not the ideal term to cover material that is connected solely by falling into disuse (buildings or roads), by being discarded (rubbish) or by being buried (bodies), or simply by slipping from everyday consciousness; but no adequate unifying (or connotatively positive) term exists in the English vocabulary. "Remains" places significance on what was once whole, with the focus – as in traditional archaeology – on the past. We aim to shift awareness to include what, in time, becomes of remains. We strive to direct attention to the decay of the material world associated with human behaviour and to how awareness of the importance of decay can inform people's engagement with soil.

References

Arroyo-Kalin, M. 2014. "Amazonian Dark Earths: Geoarchaeology." *Encyclopedia of Global Archaeology*, edited by C. Smith, 168–178. Cham, Switzerland: Springer. https://doi.org/10.1007/978-1-4419-0465-2_2252

AZO Materials. 2019."Mineral Building Materials: Properties and Solutions for Analysis." *AZO Materials*, 18 December. Online: www.azom.com/article.aspx?ArticleID=18761

Bardini, T. 2014. "Decompicultures: Decomposition of Culture and Cultures of Decomposition." *Green Letters* 1 (1): 9–21. https://doi.org/10.1080/14688417.2014.890529

Blum, W. E. H., B. P. Warkentin and E. Frossard. 2006. "Soil, Human Society and the Environment." In *Function of Soils for Human Societies and the Environment*, edited by E. Frossard, W. E. H. Blum and B.P. Warkentin, 1–8. Geological Society Special Publication 266. London: The Geological Society, London. https://doi.org/10.1144/GSL.SP.2006.266.01.01

Blume, H.-P. and P. Leinweber. 2004. "Plaggen Soils: Landscape History, Properties, and Classification." *Journal of Plant Nutrition and Soil Science* 167 (3): 319–327. https://doi.org/10.1002/jpln.200420905

Capra, G. F., A. Ganga, E. Grilli, S. Vacca and A. Buondonno. 2015. "A Review on Anthropogenic Soils from a Worldwide Perspective." *Journal of Soils and Sediments* 15: 1602–1618. https://doi.org/10.1007/s11368-015-1110-x

Carter, D. O., D. Yellowlees and M. Tibbett. 2007. "Cadaver Decomposition in Terrestrial Ecosystems." *Naturwissenschaften* 94: 12–24. https://doi.org/10.1007/s00114-006-0159-1

DeSilvey, C. 2017. *Curated Decay: Heritage Beyond Saving.* Minneapolis: University of Minnesota Press.

Duncan, L. M. 2019. *Archaeological Deposits, Environmental Impact and Local Soil Formation at Marco Gonzalez, Belize*. PhD diss., Institute of Archaeology, University College London.

____. and E. Graham, 2023. "Lime in Precolumbian Construction: Waste and Impact." *Proceedings from British Lime Association, UK-Lime Research Symposium 2021*, *Held 13th October 2021*, 127–132. London: MPA Lime.

Evans, D. L., N. N. Quinton, J. A. C. Davies, J. Zhao and G. Govers. 2020. "Soil Lifespans and How They Can be Extended by Land Use and Management Change." *Environmental Research Letters* 15 (9): Article 0940b2. https://doi.org/10.1088/1748-9326/aba2fd

Evans, D. L., J. N. Quinton, A. M. Tye, A. Rodés, J. A. C. Davies, S. M. Mudd and T. Quine, 2019. "Arable Soil Formation and Erosion: A Hillslope-Based Cosmogenic-Nuclide Study in the United Kingdom." *SOIL* 5 (2): 253–263. https://doi.org/10.5194/soil-5-253-2019

Evans, D. L., B. N. Vis, N. P. Dunning, E. Graham and C. Isendahl. 2021. "Buried Solutions: How Maya Urban Life Substantiates Soil Connectivity." *Geoderma* 387: Article 114925. https://doi.org/10.1016/j.geoderma.2020.114925

Foley, J. A., N. Ramankutty, K. A. Brauman, E. S. Cassidy, J. S. Gerber, M. Johnston, N. D.

ISSN (print) 2051-3429 (online) 2051-3437 https://doi.org/10.1558/jca.25817

Mueller *et al.* 2011. "Solutions for a Cultivated Planet." *Nature* 478 (7369): 337–342. https://doi.org/10.1038/nature10452

Galbraith, J. M. 2018. "Human-Altered and Human-Transported (HAHT) Soils in the U.S. Soil Classification System." *Soil Science and Plant Nutrition* 64 (2): 190–199. https://doi.org/10.1080/00380768.2018.1442682

Giardino, J. R. and C. Houser. 2015. "Introduction to the Critical Zone." *Developments in Earth Surface Processes* 19: 1–13. https://doi.org/10.1016/B978-0-444-63369-9.00001-X

Gibbs, H. K. and J. M. Salmon. 2015. "Mapping the World's Degraded Lands." *Applied Geography* 57: 12–21. https://doi.org/10.1016/j.apgeog.2014.11.024

Glanville-Wallis, F. 2015 *"Of Crabs and Men" – Artefact Analysis of Residual Waste Deposits and a Preliminary Investigation into Crab Bioturbation at Marco Gonzalez, Belize*. BSc diss., Institute of Archaeology, University College London.

Graham, E. 1994. *The Highlands of the Lowlands: Environment and archaeology in the Stann Creek District, Belize, Central America.* Monographs in World Archaeology 19. Prehistory Press, Madison, WI and the Royal Ontario Museum.

____. 2011. *Maya Christians and Their Churches in Sixteenth-Century Belize.* Gainesville: University Press of Florida. https://doi.org/10.5744/florida/9780813036663.001.0001

____. D. Evans and L. Duncan. 2021. "The Waste of Time." In *The Temporalities of Waste: Out of Sight, Out of Time*, edited by F. Allon, R. Barcan and K. Eddison-Cogan, 151–166. London: Routledge. https://doi.org/10.4324/9780429317170-15

Graham, E. and L. Howie. 2021. "Mobility as Resilience: A Perspective on Coastal to Inland Migration in the Eastern Maya Lowlands." In *Mobility and Migration in Ancient Mesoamerican Cities*, edited by M. C. Arnauld, C. Beekman and G. Pereira, 109–130. Denver: University Press of Colorado.

Graham, E., R. Macphail, S. Turner, J. Crowther, J. Stegemann, M. Arroyo-Kalin, L. Duncan *et al.* 2017. "The Marco Gonzalez Maya Site, Ambergris Caye, Belize." *Quaternary International* 437 (B): 115–142. https://doi.org/10.1016/j.quaint.2015.08.079

Harris, J. A., D. L. Evans and S. J. Mooney. 2022. "A New Theory for Soil Health." *European Journal of Soil Science* 73 (4): Article e13292. https://doi.org/10.1111/ejss.13292

Howard, J. 2017. *Anthropogenic Soils*. Cham, Switzerland: Springer. https://doi.org/10.1007/978-3-319-54331-4

Macphail, R.I., E. Graham, J. Crowther and S. Turner. 2017. "Marco Gonzalez, Ambergris Caye, Belize: A Geoarchaeological Record of Ground Raising Associated with Surface Soil Formation and the Presence of a Dark Earth." *Journal of Archaeological Science* 77: 35–51. https://doi.org/10.1016/j.jas.2016.06.003

McBratney, A., D. J. Field and A. Koch. 2014. "The Dimensions of Soil Security." *Geoderma* 212: 203–213. https://doi.org/10.1016/j.geoderma.2013.08.013

Nachshon, U. 2021. "Soil Degradation Processes: It's Time to Take our Head out of the Sand." *Geosciences* 11 (1): Article 2. https://doi.org/10.3390/geosciences11010002

Pawlett, M., J. Rickson, J. Niziolomski, S. Churchill and M. Kešner. 2019. "Human Cadaver Burial Depth Affects Soil Microbial and Nutrient Status." *Archaeological and Environmental Forensic Science* 1 (2): 119–125. https://doi.org/10.1558/aefs.33662

Pendergast, D. 1981. "Lamanai, Belize: Summary of Excavation Results, 1974–1980." *Journal of Field Archaeology* 8 (1) 29–53. https://doi.org/10.1179/009346981791505175

Pozza, L. E. and D. J. Field. 2020. "The Science of Soil Security and Food Security." *Soil Security* 1: Article 100002. https://doi.org/10.1016/j.soisec.2020.100002

Salazar, J. F., C. Granjou, M. Kearnes, A. Krzywoszynska and M. Tironi, eds. 2020. *Thinking with Soils: Material Politics and Social Theory*. London: Bloomsbury Academic. https://doi.org/10.5040/9781350109568.ch-001

Turner, S., E. Graham, R. Macphail, L. Duncan, N. L. Rose, H. Yang, R. Whittet and C. Rosique-Esplugas. 2021. "Mercury Enrichment in Anthrosols and Adjacent Coastal Sediments at a Classic Maya Site, Marco Gonzalez, Belize." *Geoarchaeology* 36 (1). Online first. https://doi.org/10.1002/gea.21868

Vis, B. N., D. L. Evans, E. Graham. 2023a. "Engagement with Urban Soils Part I: Applying Maya Soil Connectivity Practices to Intergenerational Planning for Urban Sustainability." *Land* 12 (4): Article 892. https://doi.org/10.3390/land12040892

____. 2023b. "Engagement with Urban Soils Part II: Starting Points for Sustainable Urban Planning Guidelines Derived from Maya Soil Connectivity." *Land* 12 (4): Article 891. https://doi.org/10.3390/land12040891

Watts, M. A., M. Amann, N. Arnell, S. Ayeb-Karlsson, K. Belesova, M. Boykoff, P. Byass *et al.* 2019. "Review: The 2019 Report of The *Lancet* Countdown on Health and Climate Change." *Lancet* 394 (10211): 1836–1878. https://doi.org/10.1016/S0140-6736(19)32596-6

ISSN (print) 2051-3429 (online) 2051-3437 https://doi.org/10.1558/jca.25817

Elizabeth Graham is Emeritus Professor of Mesoamerican Archaeology at the Institute of Archaeology, University College London. She has been carrying out archaeological research in Belize since 1973. Address for correspondence: Institute of Archaeology, 31–34 Gordon Square, London, WC1H 0PY, UK.

Dan Evans is a Lecturer in Soil Formation at the School of Water, Energy and the Environment at Cranfield University. He leads both fundamental and applied research on soil formation and the parent materials from which soil is formed. His work focuses on the interactions between parent materials and soils, how soil parent materials support soil ecosystem services, and the natural and anthropogenic threats to the parent material zone. He also studies how soil formation can be accelerated, such as the manufacturing of new soils for urban green infrastructure. Address for correspondence: School of Water, Energy and the Environment. Cranfield Campus, College Road, Cranfield, MK43 0AL, UK.

Richard I. Macphail is an Honorary Senior Research Fellow at University College London investigating archaeological sediments, soils and occupation deposits across Europe, especially Scandinavia, and has also worked worldwide. He was a researcher for English Heritage for 20 years, a *Professor Invité* at the University of Tours and the 2021 co-awardee of the International Union of Soil Sciences 10th Kubiëna Medal for Soil Micromorphology. He has published several textbooks. Address for correspondence: Institute of Archaeology, 31–34 Gordon Square, London, WC1H 0PY, UK.

Julia Stegemann is Professor of Environmental Engineering in the Department of Civil, Environmental and Chemical Engineering at UCL. She is a founding Director of UCL's Circular Economy Laboratory, and PI and Director of the UKRI Interdisciplinary Circular Economy Centre for Mineral-Based Construction Materials. Address for correspondence: UCL Civil, Environmental and Geomatic Engineering, University College London, Gower Street, London, WC1E 6BT, UK.

Francesca Glanville-Wallis is an AHRC LAHP-funded PhD candidate at UCL, investigating past urban land-use change at the Maya site of Lamanai, Belize. She received a bachelor's degree in Archaeology and a master's degree in Environmental Archaeology from the Institute of Archaeology, UCL. Her research interests include the pre-Columbian Maya, past tropical urbanism and the study of anthropogenic soils. Address for correspondence: Institute of Archaeology, 31–34 Gordon Square, London, WC1H 0PY, UK.

ISSN (print) 2051-3429 (online) 2051-3437 https://doi.org/10.1558/jca.25817