



The persistence of ancient settlements and urban sustainability

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We propose a dedicated research effort on the determinants of settlement persistence in the ancient world, with the potential to significantly advance the scientific understanding of urban sustainability today. Settlements (cities, towns, villages) are locations with two key attributes: They frame human interactions and activities in space, and they are where people dwell or live. Sustainability, in this case, focuses on the capacity of structures and functions of a settlement system (geography, demography, institutions) to provide for continuity of safe habitation. The 7,000-y-old experience of urbanism, as revealed by archaeology and history, includes many instances of settlements and settlement systems enduring, adapting to, or generating environmental, institutional, and technological changes. The field of urban sustainability lacks a firm scientific foundation for understanding the long durée, relying instead on narratives of collapse informed by limited case studies. We argue for the development of a new interdisciplinary research effort to establish scientific understanding of settlement and settlement system persistence. Such an effort would build upon the many fields that study human settlements to develop new theories and databases from the extensive documentation of ancient and premodern urban systems. A scientific foundation will generate novel insights to advance the field of urban sustainability.

urbanism | cities | sustainability | persistence | archaeology

The entire modern economic–political order is only a few centuries old. Will today’s cities last another 500 y? 1,000 y? What factors affect the persistence of cities and settlements over the long haul? Why do some cities last far longer than others? While answering these questions could contribute productively to sustainability science, they cannot be satisfactorily answered by existing research in this field. The archaeological and historical records, on the other hand, are replete with instances of urban systems that lasted much longer than the entire history of modern capitalism or the international system of nation states. Fig. 1 shows the persistence of a few major settlements around the world. While some of these have impressive longevity, in fact, archaeologists and historians know next to nothing systematic about how long settlements lasted, or what factors promoted persistence or collapse. We propose a dedicated research effort on the temporal persistence of past settlements

to significantly extend our scientific understanding of urban sustainability.

Persistence over long periods—crucial to sustainability—has been neglected in sustainability science. Twenty-five years ago, Costanza and Patten observed that “the basic idea of sustainability is quite straightforward: a sustainable system is one which survives or persists. . . Sustainability, at its base, always concerns temporality, and in particular, longevity” (ref. 1, pp. 193–194). As sustainability science has matured it has tended to be confined in its temporal scope. In a recent synthesis, Clark and Harley (2) call for sustainability science to expand its temporal range, “to focus more on the long-term, large-scale patterns.” We argue that three attributes of the archaeological and historical records allow them to address this challenge. First, the long temporal records of these fields (Fig. 1) generate patterns over a scale unattainable through standard research on

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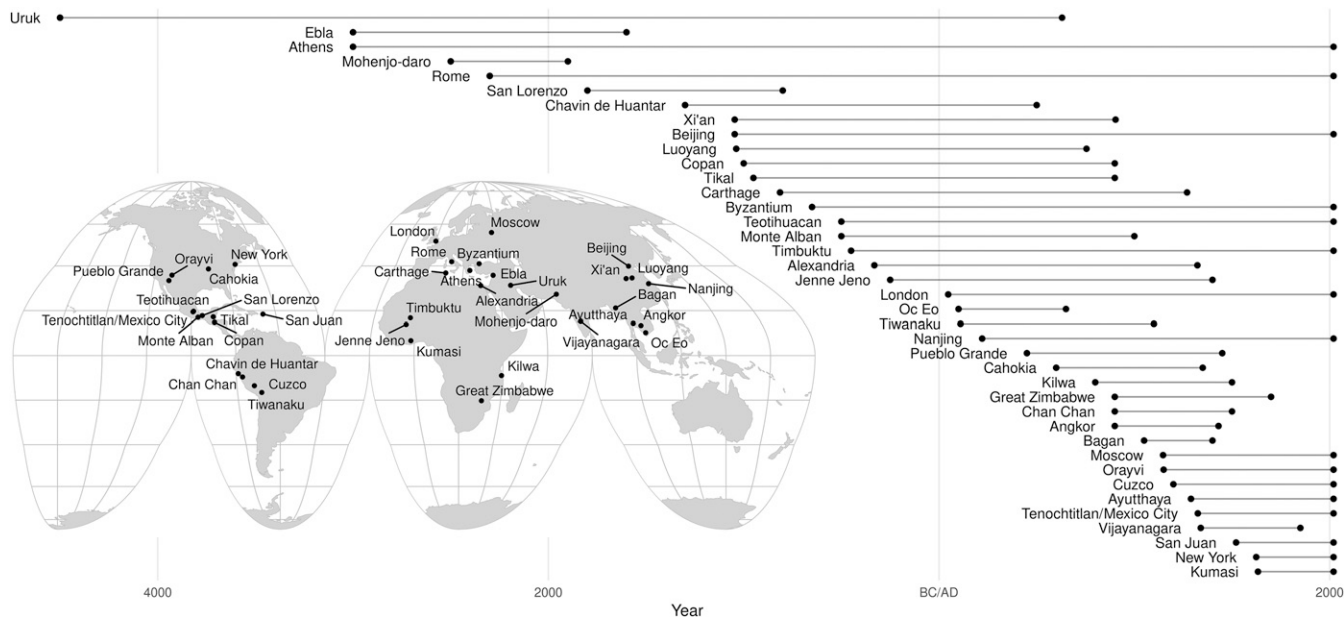


Fig. 1. Persistence (length of occupation) of a sample of premodern settlements. The figure shows the total length of continuous settlement. This is an illustrative sample; it is not random or systematic. See SI Appendix, Fig. 1, for sources of these data and discussion.

contemporary sustainability. Second, the potential datasets from these fields encompass thousands of cities and settlements, with variable end states. Third, methodological and conceptual advances now allow archaeologists and historians to address the patterns and changes of institutions in the past, permitting new insights on the long-term effects of institutions on settlements.

There have unquestionably been dramatic changes in energy and technology in recent centuries that make insights from early cities irrelevant for some of the sustainability challenges faced by societies today. For example, from the perspective of energetics—the total amount of energy harvested and used by a society—Imperial Rome, Aztec Tenochtitlan, Ming Dynasty Beijing, and Tudor London were all at a similar level far below that of modern cities (3, 4). The many significant differences between past and present cities, however, are also balanced by some key similarities (Table 1). The lack of systematic quantitative research on urban sustainability in the deep past prevents any solid conclusions about the relative strengths of such similarities and differences. There are, however, reasons to believe that there may be closer parallels between ancient and modern cities than have been widely recognized. For example, settlement scaling theory (5)—which is built on a foundation of human sociality, transport costs, and the benefits of social interactions—has been shown to predict salient aspects of urban structure and function based on empirical city size data from both contemporary and premodern urban systems (6, 7). The clear implication is that cities today and in the distant past are linked by fundamental generative processes.

It is a truism in the social sciences that “the past matters.” However, when asking how the past matters for urban sustainability science, two key questions must be addressed. First, are there sufficient points of similarity to allow the past and present to be compared in a rigorous fashion? Second, can relevant data from the past be generated and assembled to permit adequate scientific analyses of key questions? The research program we propose in this paper is designed to investigate these questions. Our focus is on the persistence or longevity of cities and other settlements. For any ancient settlement to survive for long periods, its residents must have found ways to solve social dilemmas in the realms of coordination, cooperation, and collective action. We suggest that the role of institutions in promoting urban growth, decline, and longevity may be comparable at different scales and contexts, allowing productive comparisons of ancient and modern urban trajectories. History, identity, and institutions matter for urban sustainability today (1, 8, 9), and they probably mattered for urban persistence in the past. However, until systematic quantitative data are generated for past cities and settlements, the value or relevance of early cities in this domain will remain unknown.

What Is Settlement Persistence?

We propose that urban sustainability science can be strengthened by expanding the focus of analysis from the modern notion of cities to all human settlements. Settlements—which include cities, towns, and villages—are locations with two key attributes: They concentrate social, economic, and cultural interactions and activities

Table 1. Major persistence-related similarities and differences between ancient and modern cities

Major similarities	Major differences
1) Human behavior and sociality	1) Energy sources and consumption
2) Social interactions and their outcomes	2) Transportation and communication technology
3) The effects of population size and density	3) Industrialization and workplace changes
4) The role of institutions	4) Participation in the capitalist world economy

in physical space, and they are where people dwell or live. From this perspective, cities are a type of settlement, but the dynamics we explore characterize all settlements, not just cities (10). Justification for this claim comes from research that reveals features traditionally thought of as “urban” in fact characterize villages and nonurban settlements, including empirical studies of neighborhood organization (11), and the quantitative outcomes of scaling analysis (12).

In the most basic terms, settlement persistence represents a measure of the length of continuous use of a well-defined area or place of human occupation. We identify four types of settlement persistence. 1) Persistence of occupation refers to continuous use of a place through time, irrespective of its size, function, or institutions. 2) Persistence of demographic scale means that a settlement is occupied through time, with a population above some threshold. Small groups of squatters living in the ruins of a destroyed city would count for persistence of occupation (type 1), but not of demographic scale (type 2). 3) Persistence of institutions describes situations where key social institutions continue to operate through time. 4) Persistence of cultural practices describes a situation of continuity in a particular ethnic or cultural group occupying a settlement.

Remarkably little is known about the nature of settlement persistence or its variability in early times. How long did settlements last within particular regions? Although archaeologists and historians have raw data on this, the information has not been synthesized or analyzed (13), largely because many steps are needed to transform primary field findings into data in a format suitable for the analysis of persistence and other topics (*Discussion*). Once data have been assembled for specific regions, a second question concerns variability between regions: Do settlements generally last considerably longer in some regions compared to others? This perspective enables the key question for sustainability analysis: What factors account for variation in persistence, both within and among regions?

If we are to extract useful insights from settlement persistence in the past, we need to find statistically robust patterns both in the longevity of settlements and in the attributes that can play an explanatory role in such longevity. We need to go beyond simply marveling at the fact that certain settlements lasted for 1,000 or 2,000 y, especially since nominal continuity may be more a function of modern historical labeling rather than a valid indicator of the true persistence of demographic or institutional formations. A precise definition of persistence—beyond the general observations above—needs to be developed, followed by indices devised to measure persistence. Settlements exist as part of a system, and these larger settlement systems must be delineated. Next, mean and median longevities can be estimated, along with the SD. Only after this empirical exercise is completed can the duration of any one settlement or settlement system be placed into urban comparative analysis (perhaps measuring novelty by SDs from the settlement system mean). At present, this statistically simple analysis is not possible for most of the urban systems of the past.

We present two datasets that illustrate some of the major features of past settlement persistence. Fig. 2 shows the distribution of estimated settlement longevity from two large survey areas: the Basin of Mexico, home to the large cities of Teotihuacan and Tenochtitlan (14), and central Italy surrounding Rome (15). Despite the dramatic differences in the nature of these locations environmentally and culturally, there are some intriguing parallels. The mean and median lengths that settlements persisted in both

systems are similar, and both distributions show a substantial left skew with relatively few settlements in the long tail far beyond the central tendency. Such general similarities in the distributional form suggest that it may be profitable to further explore the kinds of common processes that could generate such distributions across these two very different settings and beyond (16).

The question of persistence is central to the study of any system. For a system to be recognized as such, it must be separable from its environment and identifiable in space and over time (17). Sometimes systems persist for very long intervals, and sometimes they are more evanescent. Research on systemic persistence (including resilience, sustainability, and various social scientific themes) provides conceptual and methodological foundations for a specific effort centered on settlement persistence. The persistence of social systems and institutions through time has received only limited attention in the social sciences. The persistence of empires and polities has been modeled quantitatively (18, 19), and economists have analyzed the persistence of institutions over periods up to a few centuries (20, 21). Similarly, ecologists and theoretical biologists have addressed the persistence of organisms and ecosystems over time (22, 23), and species and ecosystems over the deep time of evolutionary history (24, 25).

The study of settlement persistence reflects the idea that “history matters.” Thus, path dependence (and its generative mechanisms of increasing returns, self-reinforcement, positive feedbacks, and lock-in) represents a core concept clarifying how particular social arrangements and practices can have durable impacts on settlement dynamics long after their initial rationale has faded (26, 27). Tainter (28) and Morris (29) convincingly argue that for societies to endure they must solve a series of cascading problems, some of which are unintended consequences of previous problem-solving successes. Are there organizational features or path dependencies common to societies that endure? Settlement systems embody a socio-spatial dialectic where social processes and environmental phenomena are mutually constitutive and evolve together when adaptation occurs. Reexamination of archaeological and historical data—together with the development of new conceptual framing to study settlement persistence—promises to be revelatory about the fundamental drivers of settlement formation, adaptation, reorganization, and collapse.

Why Is Settlement Persistence Important?

As recently as 2006, an urban planner could claim, “The modern city is virtually indestructible” (ref. 30, p. 142). However, today, the fates of cities around the world look far less stable. Cities and towns are shrinking in many areas (31), and climate-induced rising sea levels will require drastic action for coastal cities (32) leading to calls of impending doom. Societal collapse has captured the popular imagination at least since the publication of the still popular *The Decline and Fall of the Roman Empire* by Gibbon in 1776 (33). More recently the work of Jared Diamond (34) focused attention on the factors that led to the “collapse” of seemingly robust and well-entrenched societies. Impressive ruins around the world bear witness to cities and societies that are no longer among us (although the descendants of the people who lived in these societies certainly are). Collapse narratives invoke hubris, overreach, pestilence, violence, war, mismanagement of natural resources, famine, decay of social cohesion, and rising inequality. Collapse is tragedy performed on a grand scale; no wonder it commands our attention.

However, while the popular imagination obsesses about societal collapse (34, 35), the empirical record shows the limitations

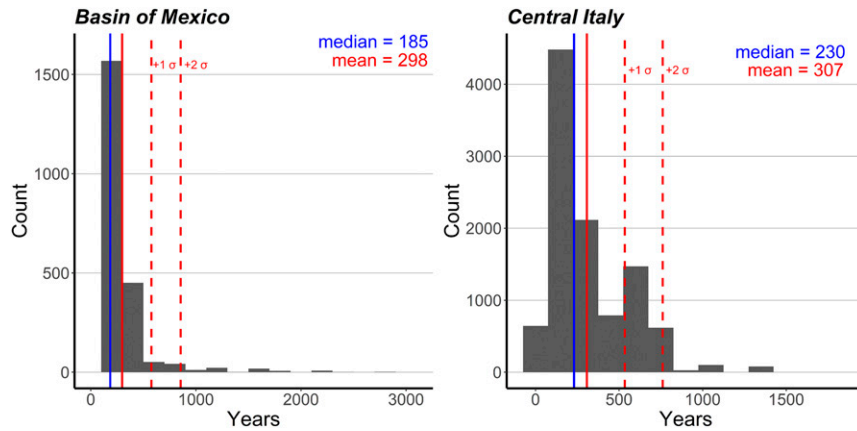


Fig. 2. Histograms showing the distribution of settlement occupation spans for large samples of settlements in the Basin of Mexico (Left) and central Italy (Right). For each histogram, the median value is shown in blue and the mean and 1 and 2 SDs above the mean are shown in red. See [SI Appendix, Fig. 2](#), for sources of these data and discussion.

of this emphasis. Both persistence and failure, in the face of changing environmental, demographic, political, and cultural settings, were common in the ancient world. If Tikal and other ancient Maya cities persisted as settlements for nearly 2,000 y—and as capitals with kings for many centuries—“collapse” hardly seems an adequate description of their fates; they persisted far longer than all but a few contemporary settlements. While much has been written about the fall of the Roman Empire, Roman urbanization lasted over 1,000 y, adapting and persisting through political upheaval, climate change, invasions, and pandemics (36, 37). Indeed, many cities recoup their size and influence after a “collapse” event (Fig. 3). Persistence is not limited to urban settlements either; for example, the largest sedentary villages in the Hohokam region in the northern Sonoran Desert lasted for 1,000 y (38). The irrigation channels built by the Hohokam people influenced the development of irrigation systems long after their settlements were abandoned (38) and continue to shape urbanization in Phoenix today.

Settlement persistence, as a phenomenon and a concept, is closely related to resilience, and resilience theory provides part of our rationale for the scientific importance of persistence. Resilience theory is focused on the persistence of relationships among ecosystem components when challenged by disturbances (39, 40). The proposed research agenda builds upon resilience theory, focusing on system relationships, system processes, and function (23). Ecology has focused on similar questions that, like the proposed research, require long-term data from history and paleoecology. Relevant issues include an understanding of emergence through time (41) and the operation of time lags, or cross-scale dynamics (42). Resilience theory and urban ecology have primarily informed urban sustainability science conceptually (39, 43, 44), or through small-*n* or case studies (45, 46). Empirical research with the necessary breadth—regional, continental, and global spatial scales (47)—and time depth (8) is still insufficiently developed in ecology.

Settlements are complex systems whose dynamics are shaped by multiple interacting factors. As Nobel Prize-winning economist Paul Romer has highlighted, cities are simultaneously biological, social, economic, physical, and cultural environments (48). Reducing the dimensionality of these systems is crucial for identifying the key entities, system variables, processes, and scales with which to assess, measure, and explain settlement persistence. We

propose three key categories of drivers of settlement persistence: geography, demography, and institutions (Fig. 4). Each of these three factors influences the four types of persistence listed above (persistence of occupation, of demographic scale, of institutions, and of culture):

- 1) Geography—the structure and dynamics of terrain, climate, and ecosystems in urban hinterlands—sets a strong constraint on any persistent human dwelling place. A geographic approach asks whether certain locations are more likely to attract and sustain human populations, how these affordances vary over time and space, and whether the legacies of past modifications to the landscape constrain the development of subsequent settlements (26, 49). Recognition of the mutually constitutive relationship between social life and physical environment helps avoid the pitfalls of environmental determinism while still recognizing the dynamic role played by local geographies.
- 2) Demography—the growth and decay of populations within settlements and the flow of migrants between them—is the most basic dimension of settlement persistence. A demographic approach to persistence might focus on questions of continuity of populations: How many people lived in a certain place for a certain time? Do larger cities last longer than smaller ones? Are there population thresholds beyond which persistence becomes more or less likely?
- 3) Institutions—the rules, norms, and shared strategies that shape decision-making (50)—provide an explanation for many patterns of persistence and failure, in line with work by economic historians. Institutions are the means by which people create infrastructure (such as roads and irrigation systems) as well as the rules and norms for settlements and their resource use in a given environment. An institutional approach might ask what kinds of institutional arrangements favor persistence across cultures, whether institutions that enhance settlement persistence are favored by cultural group selection, and the extent to which a city’s norms and institutions can survive past the end of its physical settlement.

The specific processes included in these three categories interact to shape a settlement’s long-term trajectory. For example, the intersection of two of the drivers discussed above—demography and institutions—can define several settlement trajectories. Some

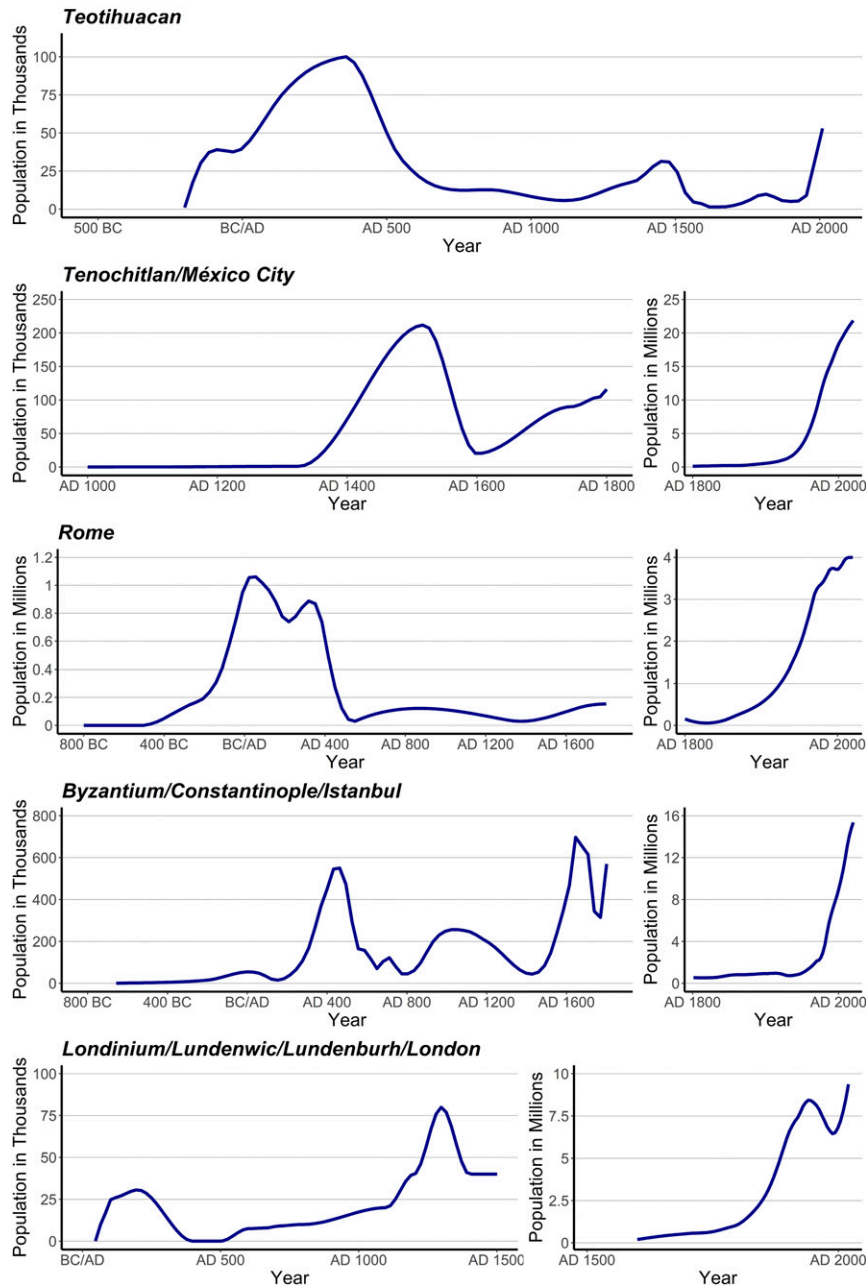


Fig. 3. Size trajectories of five long-lasting cities. See *SI Appendix, Fig. 3*, for sources of these data and discussion.

settlements exhibit long-time continuity in both demography and institutions. A second trajectory describes places occupied for long periods while institutions have changed. Long-lived cities such as Rome, Mexico City, or Cairo fit this pattern (Fig. 3). In other cases, settlements have risen and fallen, all within an encompassing institutional context that persists. Imperial capitals in early China fit this pattern particularly well (51). A final trajectory is the collapse scenario: The settlement and its institutions come to an end at the same time. The interactions between these categories of drivers and the four types of persistence identified above were likely complex and in need of research.

The three categories of drivers singled out above have been identified by historical social scientists as crucial for understanding recent societal and urban changes on the scale of decades and, occasionally, centuries (20, 52–54). For this reason,

we hypothesize that they were also crucial causal factors in the persistence of settlements in ancient times. For contributing to urban sustainability science, institutions stand out as a key set of driving forces. The few studies of institutional contributions to the persistence or success of cities or societies are limited to the western political–economic tradition (20, 55). Will the world institutional context continue in its present configuration one or more centuries into the future? Or might the future situation be quite different? This uncertainty gives a special impetus to research that can examine institutions and their impact over long periods of time, and in divergent cultural/societal traditions. As important as institutions might be for explaining settlement persistence, however, the archaeological identification of past institutions is still in its infancy (56), and much work remains to be done on their operationalization.

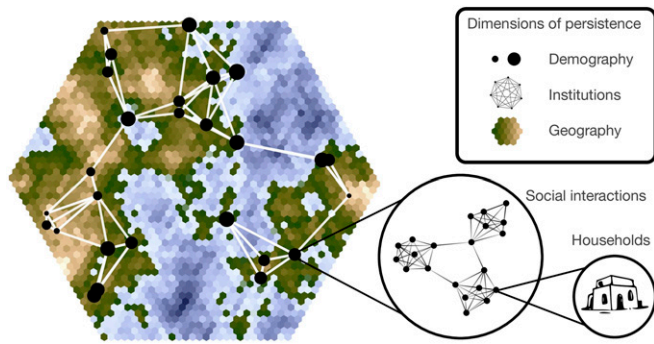


Fig. 4. Three hypothesized major causes or determinants of settlement persistence: settlement size (demography), institutions, and geography. These play out at different spatial and social scales, from households to networks to landscapes.

The Challenge and Promise of Archaeological and Historical Data

We first consider some of the advantages of archaeological and historical data for analyses of sustainability issues; then we discuss difficulties in generating and working with such data. The primary strength of archaeological data is the ability to monitor changes over long spans of time (57–59) (Figs. 1–3). A second strength of archaeology derives from use of data at large spatial scales. Regional survey projects typically record all identifiable sites within entire regions (60) (Fig. 2). Due to the technological constraints in antiquity, such regions often approximate the effective resource catchment—the effective “world” of most potential resources—for the sites that they contain.

Archaeological data in the form of settlement surveys can provide a near-complete sample of ancient settlements in a region. Archaeologists have previously used these datasets to reconstruct topics ranging from patterns of urbanization or polity formation to regional exchange systems (61). However, analyses of these datasets remain underutilized and often focus on very specific regional questions. Survey data have particular potential for the analysis of the three factors of settlement persistence that we highlight across settlements and regions. Archaeologists have a long history of relating settlement patterns to a region’s geography. Demographic information can be gleaned from settlement size. Institutions can be studied in the form of public or civic structure types (market, palace, or temple forms), portable material culture (coins, religious paraphernalia), and textual records. Rigorous assessment of these different dimensions will provide the basis for undertaking a comprehensive analysis of settlement persistence between settlements and across regions.

Large archaeological datasets can be built up in two ways, either through regional programs of fieldwork, which require high initial outlays of time and money but generate internally consistent data, or through collating data from multiple sources (often from rescue or salvage work), which requires extensive efforts to standardize among sources. In both cases, fieldwork generates raw data in terms of artifact counts and spatial information, but it often takes years to analyze and process the remains and all of the information from a survey or excavation. Archaeological projects are increasingly making their quantitative data available in repositories, but even so, data formats are not at all standardized (62). While methodological problems of data granularity and coding are common to many disciplines, archaeological data have a particularly long journey from fieldwork to database, leaving

basic questions—such as the comparability of urban sustainability in the present and past—unanswered. The primary obstacle to using archaeological and historical data to analyze aspects of urban sustainability is that such data have only recently begun to be processed and assembled in formats that permit systematic quantitative analysis.

In response to the potential benefits of assembling and synthesizing data to address larger questions in a quantitative fashion, archaeologists are now developing ways to synthesize data from diverse sources (62, 63). The growth of the Coalition for Archaeological Synthesis and the creation of a new Center for Collaborative Synthesis in Archaeology at the University of Colorado are responses to both the potential benefits of such research and the methodological recalcitrance of archaeological data. In a study of how archaeologists who work on paleoclimates interact with the Intergovernmental Panel on Climate Change, Kohler and Rockman (64) conclude that archaeologists will have to improve their analytical methods and data quality in order to contribute significantly to paleoclimatic research. This observation applies equally to many domains of archaeological knowledge, and it informs our proposal.

Archaeologists and historians are increasingly publishing papers on sustainable development and urban sustainability in the past (65–69). None of these studies, however, present systematic quantitative data on early human communities or their responses to social or environmental stresses. They are narrative accounts, often with adequate concepts and goals, but based on limited data. They do not contain the kinds of rigorous quantitative analysis necessary to contribute significantly to sustainability science today. The data assembly obstacle mentioned above is largely to blame for this situation.

Developing a Research Agenda

Many would agree with the premise that ancient settlements and their long settlement histories are important and underutilized datasets in the study of urban sustainability, in large part due to the problems that the authors discuss. We call for the development of a new interdisciplinary research effort focused on the persistence of settlements. Such an effort would build upon a number of fields to derive general principles and insights that can advance scientific understanding of urban sustainability. We clarify that we are not calling for the development of a new scientific field but rather an effort where the accumulated insights of various fields are integrated in order to guide the interpretation of existing empirical regularities and the collection of new data.

Using new databases built from the extensive documentation of past settlements by archaeologists, historians, geographers, and economists, interdisciplinary teams could test and construct theory and build settlement persistence models that will support urban sustainability science. There are many reasons why systematic archaeological data have yet to be arrayed to address questions in urban sustainability. Much work needs to be done regarding data standardization, mining, and analyses for the empirical study of settlement persistence to support model building and testing.

However, data—even enormous amounts—without associated theory to interrogate and make sense of it, do not generate predictive insights. For archaeological and historical data to speak to contemporary challenges of urban sustainability, such data must be examined with new analytical perspectives, posing new questions—informed by general sustainability science—on the experiences of past settlement life. By proposing four types of

settlement persistence through time (occupation, demographic scale, institutions, and culture), we have begun to tease out the variation in the empirical record of settlement persistence in the past. We still have little idea just how long past cities and settlements lasted, beyond anecdotal data (Fig. 1) and a few cases (Fig. 2). The proposed research exercise, which presupposes the configuration of research teams willing to engage in deep dialogue across disciplines and even epistemological perspectives, should pose new questions common to settlement systems of different eras, and propose answers whose explanatory reach spans eras and geographies.

Although it is perhaps not possible or productive to generate predictions on how long contemporary urban area of system might persist, we think it is feasible—and even compelling—to identify those institutional, demographic, and geographical features of cities and urban systems in the past that contributed to the successful resolution of collective action problems to facilitate persistence and longevity. Just as the study of socioeconomic

development in the recent past increasingly illuminates and informs policymaking on development today (20, 70, 71), the lessons to be learned from research on past settlement persistence could be relevant to determining those aspects of contemporary urbanism that facilitate, or hinder, the ongoing process of adaptation and persistence.

Data Availability. The code and data used to generate Figs. 1, 2, and 3 have been deposited in GitHub (<https://github.com/mpeoples2008/PopPersistenceFigures>). All other study data are included in the article and/or supporting information. Previously published data were used for this work (citations for previously published data are contained in the supporting information).

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