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Author

Boivin, Nicole, Crowther, Alison

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Mobilizing the past to shape a better Anthropocene

Nicole Boivin[1,2,3,4*] and Alison Crowther[1,2]

[1] Department of Archaeology, Max Planck Institute for the Science of Human History, Jena, Germany

[2] School of Social Science, The University of Queensland, St Lucia, Australia

[3] Department of Anthropology and Archaeology, University of Calgary, Calgary, Canada.

[4] Department of Anthropology, National Museum of Natural History, Smithsonian Institution, Washington, DC, USA.

* Corresponding author: boivin@shh.mpg.de

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Abstract

As our planet emerges into a new epoch in which humans dominate the Earth System, it is imperative that societies initiate a new phase of responsible environmental stewardship. Here we argue that information from the past has a valuable role to play in enhancing the sustainability and resilience of our societies. We highlight the ways that past data can be mobilized for a variety of efforts, from supporting conservation to increasing agricultural sustainability and food security. At a practical level, solutions from the past often do not require fossil fuels, can be locally run and managed, and have been tested over the long-term.

Past failures reveal non-viable solutions and expose vulnerabilities. To more effectively leverage increasing knowledge about the past, we advocate greater cross-disciplinary collaboration, systematic engagement with stakeholders and policy-makers, and approaches that bring together the best of the past with the cutting-edge technologies and solutions of tomorrow.

Main

The past decades have seen human-caused land cover change, habitat fragmentation, extinction, and global warming approach and potentially surpass critical threshold points[1]. *Homo sapiens* now plays a dominant role in shaping the Earth system, suggesting that our planet has entered a new geological epoch, the Anthropocene[2]. Maintenance of the Earth's current ecological trajectory threatens not only countless other species but also critical ecosystem services that support human societies[3]. While we may not be the first organism to have generated such disruption – oxygen-emitting cyanobacteria, for example, may have precipitated mass extinction and global cooling as a result of the Great Oxygenation Event ~2.4-2.35 billion years ago[4,5] – we are certainly the first species capable of conscious recognition of our impact. Indeed, human cognition and its cultural manifestation is not only what led us to our current impasse, but also what can help us find our way out[6]. Our species possesses – and can act on – vast, and growing, cultural knowledge accumulated across long time spans and manifested in diverse reservoirs.

One key reservoir of information pertinent to the ecological challenges we face today is the past. Along with language, art, and symbolism, another distinctive feature of our species is cultural memory. From traditional repositories like oral history, texts, and monuments, to the application of contemporary scientific methodologies like history, archaeology, and palaeoecology, knowledge of the past is accumulated by human societies in diverse ways. Accessing the past allows us to maintain cultural traditions over long time frames, but also to learn and change. In the Anthropocene, the past provides insights into how we emerged as a planet-transforming species. More important in many ways is that it also holds information we can draw upon to shape a better Anthropocene[7]. Not only is the past key to assessing the nature and scale of our impacts today, it also offers a repertoire of cultural and technological practices and solutions to address those impacts, whose success and legacies we can evaluate in ways that are impossible in the absence of a historical perspective.

In this Review, we examine how information about the past, particularly from archaeology but also related disciplines like history and palaeoecology, offers valuable knowledge that we can draw upon to more effectively shape our planet's future, and create a 'good Anthropocene'[6]. Building on previous endeavours[8-14], we look at how knowledge regarding the past can help to support present-day efforts in areas ranging from conservation to food security and sustainable cities (Figures 1 and 2), promoting both social and ecological resilience (defined as the capacity of a system to absorb disturbance and re-organize while undergoing change, enabling retention of function, structure, identity, and feedbacks[15]). We do not endorse anti-technology perspectives nor naïve embrace of the 'ecologically noble savage' concept[16]. Indeed, we strongly advocate technological, science-based solutions to the environmental challenges of the Anthropocene – the current, still unformalised[7,17,18] and chronologically ill-defined[7,18-20] geological age, in which human activity has come to take on a profound role in shaping the global environment[2,17,20]. We also take the view that past human environmental impacts, while dwarfed by the sheer scale of anthropogenic Earth System transformation today, were substantial, often destructive, and unlikely to have left any pre-industrial ecosystems in a pristine state[18,21]. In looking to the past, our perspective is that contemporary environmental solutions must draw on the full range of available evidence and knowledge; information about the past can and should play an important role in shaping a better Anthropocene.

Supporting biodiversity and conservation efforts

Human-caused biodiversity loss[22,23], including the extinction of a broad range of species[24], began long ago[21,25], and is one of the most important challenges of the Anthropocene. Globally, biodiversity loss across virtually all ecosystems threatens the maintenance of critical ecosystem services[26]. Accordingly, ecosystem conservation and restoration are priority issues, demanding effective conservation policies and close collaboration between scientists, policy-makers, and stake-holders. Increasingly, as researchers have recognized the importance of a long-term perspective to effective ecosystem management and conservation[27-33], archaeologists have found themselves playing a role in conservation efforts, with the aim of drawing on the human past to design more effective conservation and restoration strategies, policies, and agendas[7,14,31,34-41].

For conservationists, a critical archaeological and palaeoecological contribution is the clarification of ecological baselines (Figure 3). Work in restoration ecology requires understanding of the degree of change that has occurred from baseline conditions, the natural, climate-driven shape of ecosystems prior to human intervention[42,43]. With insufficient long-term data, baselines can be artefacts of unrecognized pre-industrial change[32,37,39]. For example, archaeological studies have shown how prehistoric human exploitation shaped the distribution, behavior, and population dynamics of species like northern fur seals[44] and sea otters[45], providing guidance for Pacific coast conservation programmes. At the same time, archaeological research can also show that it may not be possible or even desirable to return to pre-human baselines. Decades of archaeological investigation have revealed that many valued landscapes and biotic assemblages have developed as a consequence of past human activity[27]. For example, the rare Garry oak ecosystem of Vancouver Island in Canada was shown by palaeoecological and archaeological data to have had a long history of Indigenous management[46]. Accordingly, conservationists are increasingly embracing novel ecosystems[47] and recognizing that ecosystems created via long-term human management are equally valid targets for conservation[46].

Archaeological data can also be critical to species extirpation and re-introduction efforts[48], shedding crucial light on former species ranges and whether species are invasive or native[21,35,49]. Ancient DNA from archaeological and museum specimens has revealed genetic bottlenecks, alterations to genetic diversity, and lineage replacements in diverse species, with major conservation implications[50-52]. Such archaeogenetic data have also been drawn upon to help show why re-introductions fail, for example in the case of otter re-introductions on the Oregon coast that were probably sourced from inappropriate populations[53]. Archaeological data can support the re-establishment of breeding populations by providing ecological and dietary information useful to conservators[54,55]. Archaeology has also contributed to efforts to identify sustainable harvesting rates and practices[31,39,56-58], and predict climate change impacts to species and populations[35,59,60]. Also of considerable value to conservation efforts is archaeology's engagement with indigenous and local communities, which has led to crucial recognition of the value of traditional ecological knowledge, customary practices, community values, and cultural heritage sites to ecological conservation efforts[61-63].

Effective fire management

Fire management in the Anthropocene faces numerous challenges. While combustion of fossil biomass and the clearing and burning of forests are the primary causes of anthropogenic greenhouse effects, fire is also a key process in many ecosystems, enhancing biodiversity and shaping nutrient and energy flows[64-69]. Humans were potentially using fire by 1.5 Mya[70,71], and it is clear from archaeological, historical, and ethnographic records that societies have been shaping fire regimens globally for millennia through forest clearance, promotion of grazing, plant dispersal, alteration of ignition patterns, and active suppression of fires[64,72-78].

The need to consider anthropogenic fire as part of the baseline processes shaping most of the world's fire prone ecosystems is accordingly recognised[31,64]. Prehistoric and Indigenous fire practices that gave rise to fire resilient communities and landscapes, supported taxa that are now threatened, enhanced biodiversity and ecosystem services, and gave rise to valued cultural landscapes[63,64,73,76,77,79] are of increasing interest to forest and land managers[40,80] (Figure 2). It is recognized that colonial era fire suppression policies in many regions, particularly in the tropical savannas, severely disrupted traditional land management practices, increasing wildfire severity and extent[75,77,81-83]. In Australia, this has led to dramatic declines in small mammals in the last decades[84] as well as increased erosion[85]. Traditional Australian Aboriginal burning practices, which increase habitat heterogeneity and pyrodiversity, and mediate the deleterious effects of climate variability[64,72,76,86], are increasingly recognized as a viable contemporary approach to fire management[72,80,87]. Such long-developed, place-based fire knowledge and practice provide a wealth of tried and tested information that is now seen as key to designing local fire management plans as well as granting legitimacy to fire management institutions[82].

Climate change impacts on fire are expected to further intensify the need for better understanding of past data and anthropogenic land management[78,88]. It is suggested that future climate change will create an unprecedently fire-prone environment[89], exacerbated by the trend towards large, uncontrolled fires[65,69,81]. Managing climate, fire, carbon, and economic feedbacks will demand that humans use fire while neither degrading biodiversity and ecosystems nor threatening human health and well-being[78], goals that indigenous knowledge systems and historical data will play a key role in helping meet[69,78,90-92].

Sustainable agriculture

The emergence of agriculture was arguably one of the most important cultural transitions in the history of *Homo sapiens*. As a result of this fundamental shift beginning ~10 kya, humans today control a vast and disproportionate share of the planet's resources[93,94]. As our species' population has increased, however, effectively feeding it has become a major challenge. While the Green Revolution massively improved global food production[95], it is increasingly clear that modern agricultural land-use practices have traded short-term increases in food production for long-term losses in ecosystem services, including many that are important to agriculture[3,96,97]. Ancient agricultural practices offer an important source of knowledge for addressing the challenges of 21st century agriculture, which must achieve massive cuts in greenhouse gas emissions, reduce biodiversity and habitat losses, decrease water withdrawals, and phase out water pollution from agricultural chemicals if it is to meet the world's future food security and sustainability needs[96].

Many past societies engaged in agricultural intensification[13,98], in some cases drawing on methods that supported centuries or millennia of agricultural land use, including in fragile environments[10,99,100]. The past suggests diverse trajectories to intensification, and offers a time depth enabling insights into the sustainability, resilience, and vulnerability of agricultural systems[13,98,101-104]. While ancient technology is not necessarily green technology[10], many past approaches offer environmental benefits while also being more appropriate for developing world contexts where mechanization and access to fossil fuels and capital is more limited[10,98].

There has been notable interest in the productivity and potential agroecological benefits of some of the most visible remnants of past agriculture and aquaculture, such as ancient irrigation systems[105-108], terracing[107,109], raised [98,110-113] and other forms of field systems[114-116], and traps, ponds and weirs[117]. For example, the raised field agriculture once practiced across South and Central America, but widely abandoned following the Spanish conquest, is thought to have provided better drainage, soil aeration, moisture retention, and fertility than is commonly found in agriculture in the region today[98,111,118], as well as to have conserved water[98] and reduced the need for landscape burning[119]. The perceived advantages of prehistoric practices have led to attempts to rehabilitate ancient agricultural infrastructure – for example in the Peruvian Andes, where a series of projects over the last decades has brought some pre-Hispanic terraces back into use[109]. Lessons learned in early attempts suggest the importance of buy-in from local communities and careful attention to markets[12,105,109,115,120], as well as 'soft' factors like socio-economic organisation[98,100] and 'stewardship memory'[63,115,121] to successful archaeology-inspired agroecology.

As understanding of ancient agriculture has improved, initially less obvious aspects of past farming have attracted increasing interest. For example, long-term resilience appears to have been linked in many parts of the ancient world to agricultural landscapes hosting diverse crops, species, and habitats[11,122], the opposite of the monocultures typical of industrial agriculture today. In the eastern Amazon beginning 4500 years ago, for example, complex agroforestry, combining cultivation of multiple annual crops with progressive enrichment of edible forest species and the exploitation of aquatic resources, supported long-term food security and limited forest clearance in the pre-Columbian era[123]. Researchers today are increasingly promoting the benefits of such mixed agroecosystems, and calling for the conservation of the 'bio-cultural refugia' or 'bio-cultural heritage' that communities have created over the long-term in different parts of the world[10,13,63,122,124]. Additionally, the importance of biodiversity hotspots or remnants within broader agricultural landscapes – such as field and pasture margins, forest fringes, hedges, stone walls, and gravel pits or quarries – many of which were established thousands of years ago in regions like Europe, is of growing interest[125].

Reviving ancient crops

Also useful has been exploration of the kinds of crops used in the past. While several thousand plant species have undergone some form of domestication[126], agriculture today has become reliant on an increasingly limited range of crop plants – just 20 plant species provide ~90% of the world's calories[126,127] – leaving global supply systems deeply exposed to the threat of pathogens, pests, and climate change. Archaeologists today are contributing to exploring the utility of a variety of extant but presently under-cultivated crops[128], as well as a diverse array of 'lost crops' now extinct except in wild form[129]. A key example of the former are millets, naturally drought and heat tolerant cereals that promoted appreciable levels of resilience in diverse regions of the ancient world[11,130], and that could potentially help alleviate ecological degradation, reduce crop risk, and increase productivity if returned to wider cultivation today[11]. Lost crops include species like goosefoot and erect knotweed that were domesticated by Indigenous North Americans; their experimental cultivation by archaeologists suggests some vie with closely-related crop relatives like buckwheat and quinoa in terms of productivity[129,131]. Archaeology has a role to play not only in identifying more nutritious, suitable, sustainable, and resilient crops, but also in agrigenomic crop improvement[132] and attempts to accelerate the domestication of new crops[133].

Soil sustainability

Soil lies at the base of all human subsistence systems[134-136], and soil retention and improvement were key foci of human activity in many regions of the world for thousands of years. Of growing archaeological interest is evidence for past, often profound anthropogenic modification of original soil horizons across multiple parts of the world, leading to the creation of Archaeological Dark Earths (ADEs) such as the Terra Preta del Índio in the Amazon[137,138] and plaggen soils of northwest Europe[139,140]. Whether in the Amazon[137,138], Andes[141], Africa[142], New Zealand[143,144], or Australia[145], these human-modified soils share in common a number of features, including their high organic matter content, improved capacity to hold nutrients and moisture, and remarkable carbon sequestration properties[137,138,145,146]. They have attracted considerable attention for their agricultural and climate change mitigation potential, leading to the development of modern biochar technology[147-150] (Figure 2). Recent archaeological research has focused on understanding the structure and genesis of ADEs[137,138,151-153], with the aim of supporting the establishment of a new generation of anthropic soils[154], as well as stimulating other applications such as in the area of sustainable sanitation and bio-waste management[149,155]. Terra preta appear to be the outcome of long-term anthropogenic enrichment of soils through the addition of charcoal and other organic waste (e.g., domestic refuse, bone, excrement) and frequent small-scale burning[137,138,156]. Other ancient methods of anthropic soil enrichment are also capturing research attention, including the intentional addition of algae in Maya gardens[157,158] and seaweed in topsoils around the Baltic Sea[159], as well as the unintentional enrichment of African savannah soils through prehistoric animal penning[160,161]. Soil retention and conservation, through terracing and bio-fertilisation[162], are key ancient technologies of interest in modern soil sustainability studies[101,135,136,157,158,163]. Archaeological time scales enable assessment of the long-term impacts of specific technologies and practices on soil quality, including soil degradation[135,136].

Assessing and mitigating pollution

While the scale of pollution today is unprecedented and severely threatens global ecosystems and human health[164], environmental pollution is not a new phenomenon. Archaeological and related records show evidence for the long-term occurrence of pollution as well as its impact on past populations and environments[165-171]. While the study of past pollution has numerous contemporary applications, a critical one is the establishment of natural baselines[172-174]. For example, data from a high-resolution Alpine ice core coupled with historical evidence for a decline in lead smelting during the European Black Death (~1349-1353 CE) revealed that true minimum natural lead levels in the atmosphere are overestimated by government and industry standards, demanding serious reevaluations of current environmental, industrial, and public health policies[154]. Greenhouse gas emissions from agriculture and stock-keeping may also have been higher in the past than appreciated[175-177]. Studies of the impact and legacy of ancient heavy metal pollution are also helping to understand processes of pollution product breakdown, persistence, biogeochemical cycling, and bioaccumulation across diverse time spans and in different environments[169,178-182]. For example, analysis of ancient copper mining in Cyprus and Jordan has shed light on processes of bioaccumulation and biomagnification of heavy metals and sulfur in certain plant and animal parts and species, with implications for their role as biomonitors of environmental quality[170,178,179,183,184].

Building sustainable cities

More than half of the Earth's ~7.5 billion people currently live in cities[185], yet most existing forms of urbanism are morphologically, functionally, and environmentally unsustainable under current conditions[186]. While urban studies have focused almost exclusively on modern western cities[187], urbanization has been a global process for millennia, offering a diversity of urban models, as well as unique opportunities to assess their longevity, resilience, and environmental impacts. One key area of recent archaeological interest has been the low-density, agrarian-based urbanism that characterized many ancient tropical cities[188], for example in Mesoamerica[187], Southeast Asia[189], and the Amazon[190]. A critical feature of these early examples of urbanization was the practice of intensive agriculture within the city itself. For instance, Maya cities featured an urban sprawl of dispersed households with domesticated gardens interfingered with built space and agricultural fields[187,191]. These proximate food staple sources[121] likely contributed to the longevity of many Maya cities[121,187,192]. Mixed agro-urban settlements were not unique to the tropics; Byzantine Constantinople, for example, featured urban and near urban agriculture that contributed greatly to food security even during multi-year sieges[121]. These early dispersed agrarian cities offer more sustainable, food secure models of urbanism that are less dependent on fossil fuel and more resilient to food supply shocks resulting from, for example, pandemics, conflict or climate change[191]. They serve as useful models for those discussing urban and peri-urban agriculture as a solution to present-day sustainability challenges[124,191,193].

Another important feature of early agrarian-based cities appears to have been smallholder cultivation. Maya and Aztec cities are thought to have featured a high degree of local control, enabling households and communities to make decisions about their activities, supporting longevity, resilience, and food security[187]. Effective water management was an additional key resilience-building tool. Ancient cities often developed remarkable technologies to ensure water security, through both centralized and decentralized approaches; some were major achievements of engineering, and numerous ancient water solutions offer sustainable, cost-efficient, and environmentally-friendly water technologies for the present and future[121,194-198].

Resilience in the face of climate change

Anthropogenic climate change is the defining issue of our time, and is leading to momentous impacts on physical and biological systems globally[199]. Archaeologists have long been interested in climate as a critical factor in contextualizing past human behavior[200-202], suggesting considerable scope for engagement with attempts to address the major and growing challenges of climate warming today[8,203,204]. Archaeological data provide a critical long-term perspective that is absent from contemporary experience and measurements of climate change[203,205,206], and an opportunity to explore past societal responses to diverse climate change scenarios, including collapse[188,207-210]. At the same time, challenges of resolution, preservation and curation, correlation versus causation, and interpretation offer recognized limitations[211-213].

At a basic level, archaeological sites incorporate climatic signals that can be relevant to understanding climate systems. For example, insights from Peruvian archaeology helped drive recognition of Holocene change in El Niño-Southern Oscillation (ENSO), leading to insights into how El Niño will behave under conditions of global climate change[202]. Historical and archaeological data have been key to reconstructing the climatic and environmental shifts associated with the Medieval Climatic Optimum and Little Ice Age[214,215]. Nonetheless, the real power of archaeology lies in its ability to shed light on human responses to climate change and the conditions that promoted or hindered societal resilience in the face of climate change impacts like drought[13,200,211,216]. These have highlighted the role of, for example, existing vulnerabilities like conflict, inequality, and food shortages in worsening climate impacts, as well as the problems inherent in overly rigid systems and infrastructure[13,130,204-206,217]. Such data can be critical to improving climate-change models[218]. They may also show that solutions to climate change available in the past are not necessarily available today[216,219,220].

Ancient technologies for addressing water shortages or managing water in arid environments are also of exceptional contemporary interest[10,108,221,222]. For example, the often millennia-old qanat water management systems found across the Middle East, North Africa, and South Asia – much like the *piquois* developed by the Nazca of Peru[223] – offer a practical solution to problems of water supply in arid environments as a result of their low evaporation rates, and relatively low cost and technological demands[221] (Figure 2). Qanat systems do not deplete water supplies, and do not require a source of power or fuel to operate, leading many to be resuscitated to provide sustainable water in the present[13,221]. The extensive tank-based irrigation systems developed over two millennia ago in the Dry Zone of Sri Lanka likewise provide critical infrastructure that still deliver an important buffer against the effects of climatic fluctuations today[108,224].

Discussion

Our overview of some of the key ways the past is being drawn upon to support the creation of a better Anthropocene enables a number of clear conclusions. Firstly, disciplines like archaeology that study the past have a critical role to play in shaping the future[7,9-11,206]. The past provides a long-term record that gives historical perspective to present day challenges and processes[7,9,13,225]. Secondly, the past also offers critical solutions[9-11,187]. Many of these do not require fossil fuels, pollute far less, are more sustainable and cheaper, can be locally run and managed, and have been tested, often over centuries or even millennia. Thirdly, ancient practices and technologies are accordingly often far more appropriate than modern ones for developing countries[10]. While not all past solutions were sustainable, many appear to be more so than today's. Many were abandoned not because they were unsustainable, but because other factors intervened that eroded social or political stability, including war, conflict, natural disasters, social inequality, disease, colonialism, and genocide. Fourthly, and critically, the past has a role to play in protecting and managing ecosystems and biodiversity[14,36,37]. Past data help to evaluate and establish more accurate and appropriate baselines across multiple disciplines from ecology to pollution studies. Archaeology has a vital role to play in informed conservation, land management, and agroecology[7,10,11,13,122,124]. Fifthly, archaeology and related disciplines are critical to identifying the factors that support resilience. Remains from the past often provide a unique source of information about the long-term effects of deliberate practices and unintentional impacts that are invaluable for developing productive and sustainable strategies[10,13,122,124,130,136]. They have highlighted the role of inequality and injustice in fostering vulnerability to the unique challenges of the Anthropocene[130,204].

The relevance of the past to addressing the challenges of the Anthropocene today is illustrated in Figure 4, which outlines a key set of capabilities the past brings to the table. At the same time, a number of caveats must be raised. For one, not all technologies and practices in the past were sustainable. The past reveals failures as well as successes. While societies through time have shown remarkable resilience and developed extraordinary solutions, they have also caused extinctions, fragmented landscapes, deforested and degraded ecosystems, and endured inequality, collapse, and failure[18,21,130,226-230]. We must refrain from romanticizing the past, and from searching for simple panaceas. We must establish the actual sustainability of past technologies and practices, which is sometimes far from clear and deeply contested[12,103,104]. This should be a major focus of archaeological research. We must also establish the potential applicability of ancient solutions in contemporary contexts, in which different levels of urbanization, globalization, and ecological degradation, as well as population size, for example, might confound their relevance. A solution that works in one time and place might not work in another.

Additionally, we should be wary of prioritizing technological and material solutions. Data on the past also shed light on the critical role of social, political, and cultural factors in driving or diminishing resilience in a number of past societies[13,130,203,204,231]. Factors like decentralization and local governance appear to have been critical to responding to diverse challenges and engendering resilience[124,187,198,221]. Poor governance, inequality, and inflexibility appear to have exposed ancient populations to increased vulnerabilities in the face of climate shocks, natural disasters, pandemics, and drought[12,13,130,201,205,232]. The archaeological record highlights that neither technology nor even ecologically sustainable practice can shield societies from systemic vulnerabilities.

Moving forward, we suggest the following recommendations on the basis of our Review. Firstly, the study of how archaeology can contribute to shaping a better future is increasing[231] but still not a regular feature of mainstream archaeology[9,203,225]. It should be. As it continues to move away from its privileged antiquarian origins, the discipline should focus more on systematic research to assess past solutions, practices, and sustainability[9,201,206,225,233]. This research should be multidisciplinary[34,37,225,234], drawing archaeologists into close engagement with urban researchers, ecologists, agronomists, soil scientists, chemists, geneticists, anthropologists, and sociologists, amongst others. It should move beyond mere lip service or incorporation of trendy terms towards increasing genuine engagement with the problems faced by societies now and in the future. Such engagement with real world problems might do much to address the notable diversity challenges faced by the discipline[235,236] whose paucity of BAME (black, Asian, and minority ethnic) enrollment[236] and continued colonial legacies[237,238] do little to address the air of privilege and exoticism that it retains.

Secondly, archaeologists should also engage beyond academia, not only with those who can shape policy, but also those on the Anthropocene front lines, including farmers, rangers, conservationists, local communities, and Indigenous peoples[9,13,34,62,63,239]. Transforming concepts into meaningful action is not easy[13] but lessons have already been learned, for example by early co-ventures between archaeologists and farmers to revive abandoned landesque capital, not all of which met with success[12,105,120,240]. Solutions from the past cannot simply be transposed intact into very different social, techno-economic, environmental, or climatic contexts[12,13,76,98,221]. Community-based measures have inevitably proven the most successful[12,62,63].

Thirdly, lines of engagement must also be increased in the opposite direction. It is not only up to archaeologists, historians, palaeontologists, palaeoecologists, and others from historical disciplines to advocate for the value of the past. Researchers in other disciplines, as well as policy-makers, must educate themselves, and begin to more carefully consider the relevance of historical data to present and future challenges. Archaeology in particular is often misunderstood, with many unwilling to let go of outdated views of the discipline more reflective of childhood fascination than contemporary reality. The onus is often placed on researchers in the historical disciplines to reach across disciplinary lines, but institutions, organizations, research projects, and committees tasked with creating policy or addressing future challenges must also reach out to archaeologists, palaeoecologists, historians, and others. The decision of the Anthropocene Working Group[18] and the National Academy of Sciences Leopoldina's Corona and Society Working Group[241] to invite researchers from the historical disciplines amongst their participants provide examples of the benefits and challenges of this kind of engagement. Ultimately, however, breaking down structural barriers to cross-disciplinary engagement, such as fragmented government heritage management policies that limit capacities to address the intersection of archaeology and climate[203], will also be critical to enabling greater engagement of archaeology with the challenges of the Anthropocene.

It is also clear that we need to do more to protect cultural heritage[9,100], and to further broaden our definitions of heritage[63,121]. Researchers and cultural heritage managers must be more active and vocal about threats to valuable inherited landesque capital, including the ancient qanats, terrace systems, reservoirs, cisterns, field systems, and irrigation systems that past societies invested so much labour in creating and that can continue to benefit societies today, as both active systems and as models. But societies must also recognize the value of anthropogenic soils and forests, of biodiverse agricultural fields, and other landscapes and ecosystems that often have been sustainably managed or farmed for millennia[61,63,191,242]. At the same time, we must not fail to recognize the extraordinary contribution and potential of modern technologies and developments. We must work towards solutions that bring together the best of the past, present, and future, integrating traditional and modern approaches to find the best way forward[106].

Addressing the formidable challenges of the Anthropocene demands cross-disciplinary engagement, action beyond academia, creativity, and wide disciplinary support for such efforts. Archaeology, with its vast and growing store of knowledge about the past has a responsibility to help humanity draw on all available data to create a better, greener, more sustainable, and more equal future. The past may be a foreign country[243], but it is one we can visit and learn from.

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Correspondence should be addressed to NB.

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NB and AC conceived and wrote the paper.

Competing Interests

The authors declare no competing interests.

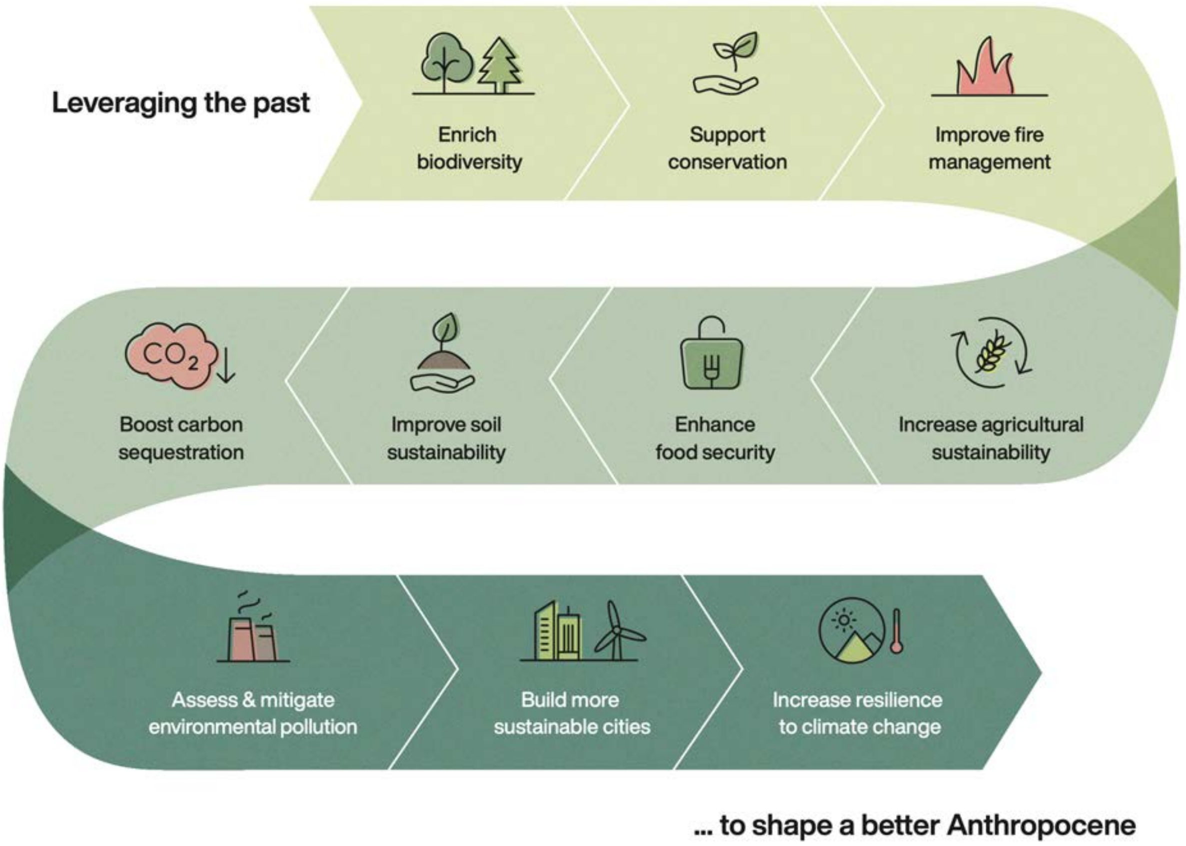

Figure 1. A summary of key ways that historical data can enhance the resilience of societies today and into the future. Information from disciplines like archaeology, history, historical ecology, and palaeoecology has an important role to play in shaping sustainable solutions to the challenges of the Anthropocene.

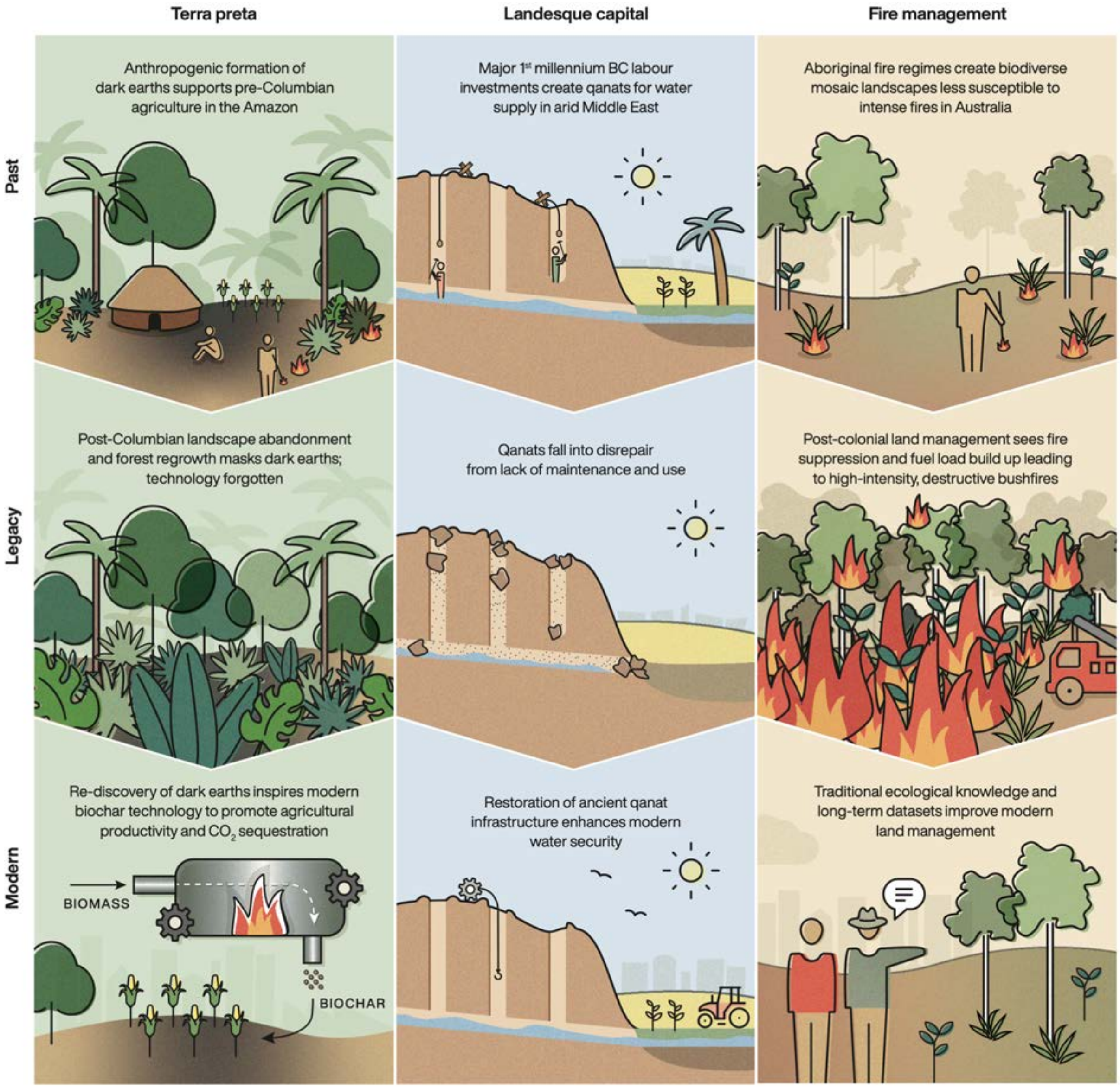

Figure 2. Application of past practices and solutions to modern-day challenges. Around the world today, we can find myriad examples of how past cultural and technological practices and solutions are being revived today to address pressing environmental and land management challenges. Examples include (left to right) mobilization of ancient terra preta (anthropogenic dark earth) technology, revitalization of landesque capital (long-term landscape investments), and adoption of traditional fire management regimes.

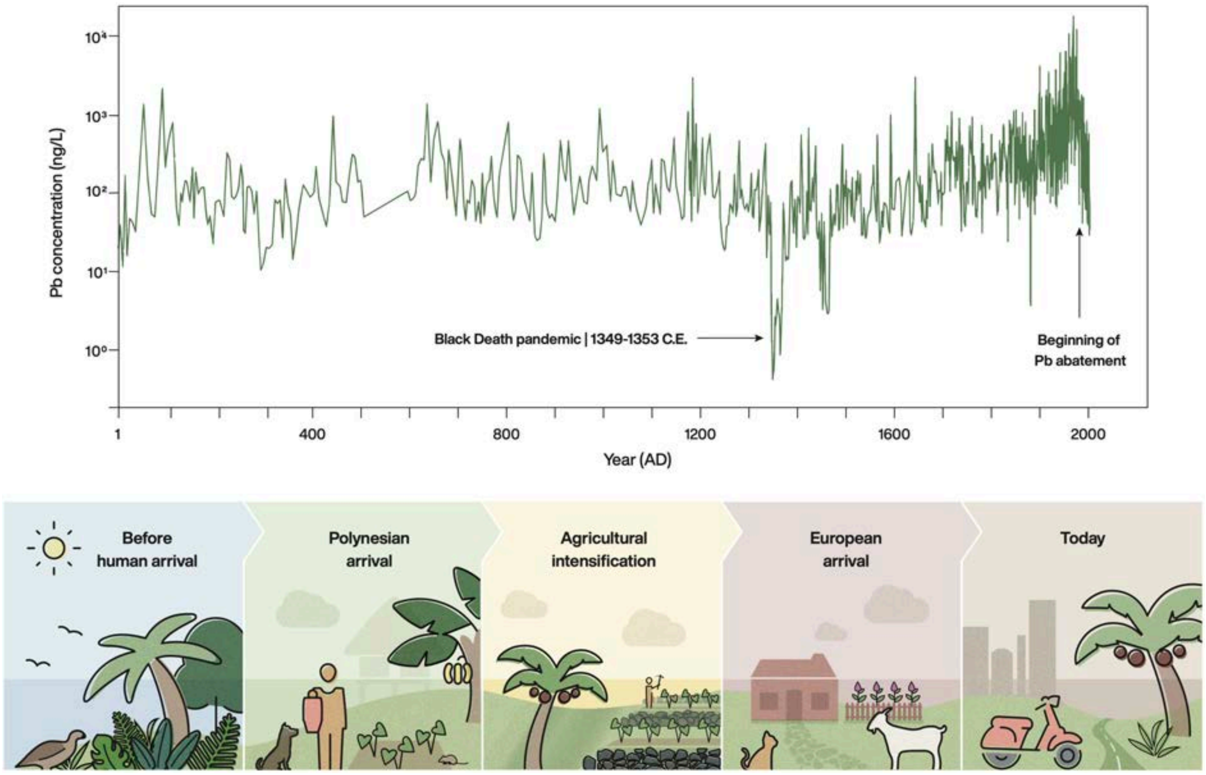

Figure 3. Using past data to create modern baselines. Researchers increasingly recognize the importance of drawing on archaeological and other historical data to generate more informed baselines for guiding environmental policies and conservation strategies. Examples include: Top: Reconstruction of historical lead (Pb) levels from a high-resolution Alpine ice core, showing correlation between a drop in atmospheric lead levels with historical and archaeological evidence for the cessation of smelting during the European Black Death; used to set natural atmospheric lead baseline for industrial pollution standards (modified from ref. 154). Bottom: Shifting baseline showing successive stages of human transformation of tropical Polynesian island ecosystems, including species extinctions (e.g., seabirds, flightless birds), exotic plant and animal introductions, vegetation clearance, and landscape change, as revealed by archaeological datasets.

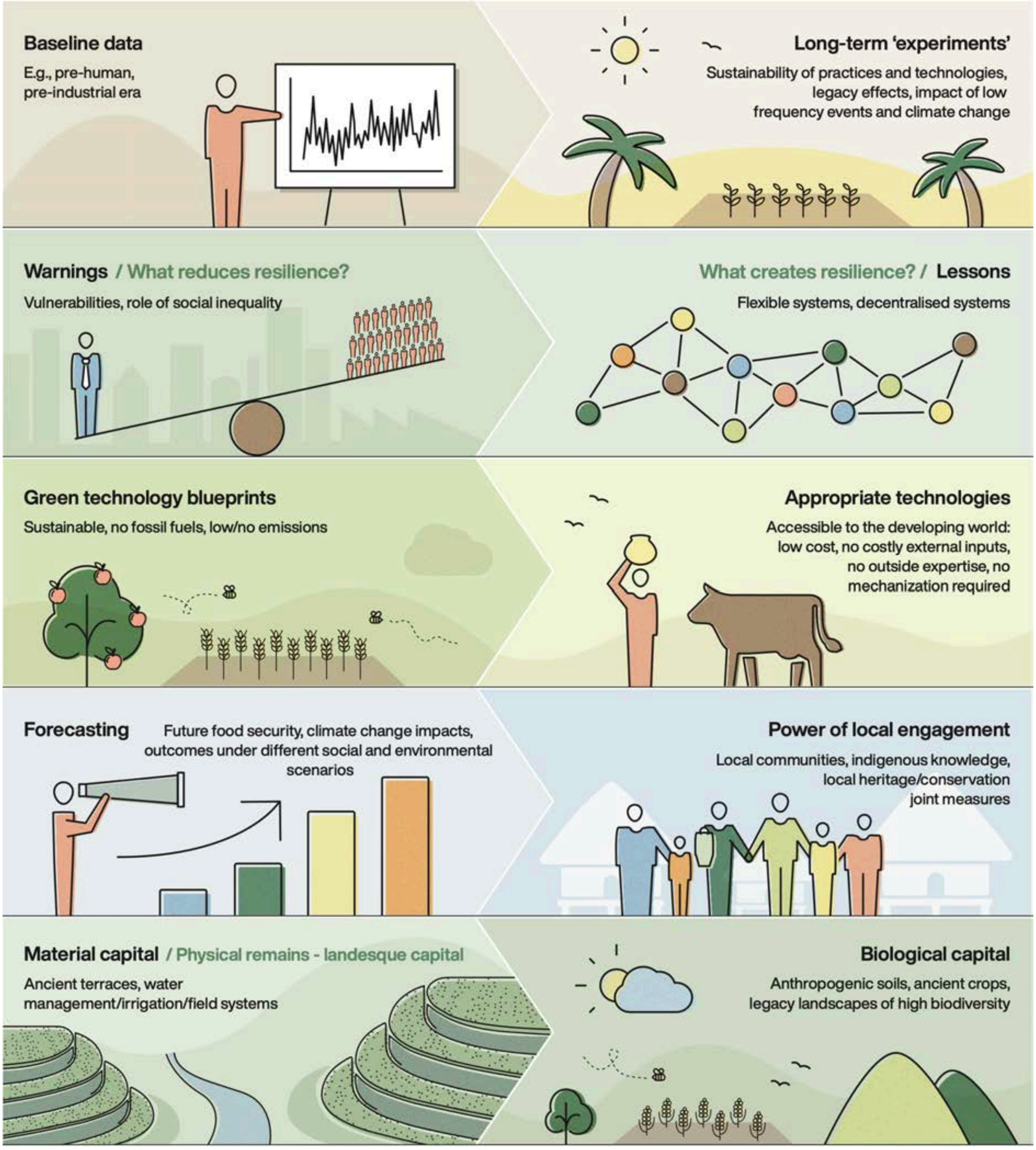

Figure 4. Summary of key deliverables the past offers in addressing the challenges of the Anthropocene. The past provides important lessons and insights, as well as crucial data that can be instrumentalized to improve research, planning, policy making, and forecasting, and create more resilient and sustainable communities into the future.