# Lecture 3: Earth's Climate

Smit, A. J.
University of the Western Cape

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**Aims**

This lecture aims to situate human history within Earth's long climatic trajectory, with a particular emphasis on Africa as both evolutionary cradle and laboratory of climatic adaptation. Students are introduced to the interplay of orbital forcing, atmospheric $CO_2$ dynamics, and regional ecological shifts in shaping both global patterns and African-specific developments. By engaging with the archaeological and palaeoclimatic record, the lecture seeks to show how hominin evolution, agricultural transitions, and complex societies were inextricably linked to climate variability. It further aims to highlight the significance of indigenous African crops and adaptive strategies as historical resources for thinking about contemporary and future climate resilience.

**Learning Outcomes**

By the end of the lecture, students should be able to:

1. Outline the major phases of Earth's climatic history over the last 20,000 years and describe their relationship to human dispersal and cultural change.
2. Explain the mechanisms of orbital forcing (Milankovitch cycles) and their role in glacial–interglacial transitions.
3. Assess how climatic variability shaped early hominin evolution and dispersals in Africa from the Miocene through the Pleistocene.
4. Describe the environmental and social conditions underlying the Agricultural Revolution, the African Humid Period, and subsequent aridification.
5. Analyse the connections between crop domestication (millet, sorghum, yams, African rice) and the development of African societies, including the Bantu expansion and the rise of urban centres.
6. Evaluate the impact of climate events such as the Toba eruption, the Medieval Warm Period, and the Little Ice Age on African societies.
7. Critically reflect on how Africa's long-term adaptive strategies — ecological flexibility, diversified livelihoods, and social resilience — can inform responses to modern climate change.

# 1 A Brief History of Earth's Climate and Human Civilisation

Figure 1 shows a brief history of Earth's climate over the last 20,000 years, alongside key events in human history. The timeline precedes the Holocene by several thousand years, starting from the Last Glacial Maximum (LGM) when large ice sheets covered much of North America and northern Europe. The graph illustrates how global temperatures have fluctuated over this period, with significant implications for human societies. The key aspect we need to note is the **Holocene**. The Holocene is the current geological epoch, beginning about 11,700 years ago at the close of the last Ice Age. It marks the interval of relative climatic stability in which human societies developed agriculture, built cities, and formed complex civilizations.

On the left axis of Figure 1 (actually the x-axis due to the orientation we have got here) we have the independent variable, and on the horizontal axis, that is the dependent variable. Here, temperature is the aspect that depends on which point in history we are examining. The graph spans from +4 °C to −4 four °C, relative to the average temperature over the entire depicted period. Now, the main focus is on this central white band, which is key for our discussion.

I explain the content of the scrolling figure below the image.

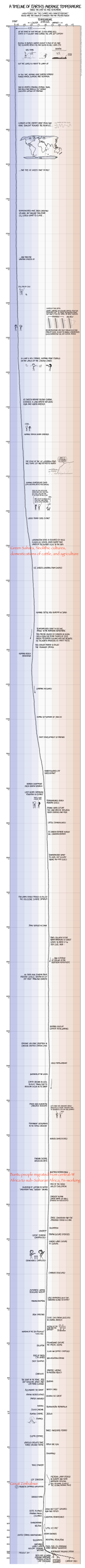


Figure 1: Figure 1. A timeline of human societal development alongside Earth's temperature.

## 1.1 In the beginning

The timeline starts at around 20,000 years ago, and as I scroll down, we move steadily towards the present day. So, about 20,000 years ago, Earth was roughly 4 °C colder than it is today. I must point out that this is quite a Northern Hemisphere-centric perspective. At some point, I should really produce a similar graphic focusing on South Africa or the African continent, so we can localise our interpretations. For the moment, however, do keep in mind that this particular presentation is fundamentally rooted in North American context.

**UPDATE:** I have now created a similar deep-time perspective for Africa (see Section 2), but I must still make a comparable graphic.

At that time, Boston — now a relatively verdant city — was actually buried under about a mile of ice. So, back then, the temperature was still about four °C colder than present, and that is reflected by the dotted line tracing temperature changes. From here on, the graph outlines a chronological procession of climate events and human developments.

## 1.2 Early human migrations and extinctions

Between 19,000 and 19,500 years ago, humans had already dispersed from Africa and were found throughout Eurasia and even in Australia. Notably, when humans arrived in Australia, their sudden presence led, within around a thousand years, to the extinction of all the large mammals — megafauna — in that region. Today, the largest animals in Australia are kangaroos, but prior to human arrival, truly massive creatures inhabited the continent. The arrival of humans is strongly linked to the rapid die-off of these species. This phenomenon is not unique to Australia; similar patterns were happening elsewhere, including South Africa.

Around 19,000 years ago, evidence shows that people began to create paintings, pottery, rope, and other artefacts of material culture.

## 1.3 Climatic shifts and the milankovitch cycle

At approximately 18,500 years ago, there was a slight change in Earth's orbit — a phenomenon known as the Milankovitch cycle. This event caused Earth to absorb a little more heat in its polar regions, which in turn allowed the great ice sheets to begin melting. The process was gradual at first: as the ice sheets retreated, sea levels rose, but temperature increases remained relatively modest. However, atmospheric $CO_2$ concentrations began to creep upwards. This was due to various processes, including the re-mineralisation of materials previously trapped beneath the ice.

As more naturally trapped $CO_2$ entered the atmosphere, warming began to accelerate, though it remained cold by modern standards — still about three °C colder than today.

## 1.4 Human culture and dispersal

By 15,000 years ago, we see the emergence of cave art — the kind that we now admire as cave paintings, though at the time, people might simply have seen it as graffiti. Some of the oldest examples have been found in France.

At around 14,500 years ago, the ice sheets in Alaska shrank to the extent that the land bridge between Asia and North America, the well-known Bering Land Bridge, disappeared. This development made it possible for humans to enter and populate North America for the first time, giving rise to the ancestors of Native Americans. This migration predates the arrival of Europeans on the continent by many thousands of years.

By 13,500 years ago, New York was no longer under ice, and by 13,000 years ago, species such as the woolly rhinoceros became extinct. At 12,500 years ago, significant flooding occurred in what is now Washington state, due primarily to the rapid melting of glaciers.

## 1.5 Rise in $CO_2$ and continuing warming

All the while, $CO_2$ levels continued to rise, driving further increases in temperature. The ice sheets eventually disappeared even from areas such as Chicago.

By 11,500 years ago, people began to settle in the area now called Syria — formerly known as Mesopotamia — within the region known as the Fertile Crescent. This marks a pivotal point, as humans began to establish small communities and, ultimately, towns and cities. The city of Jericho, one of the earliest known urban settlements, arose during this era, when Earth's temperature was still about 1.5 °C colder than present.

## 1.6 Agricultural revolution and the holocene

Moving to 10,000 years ago, as temperatures reached a level still somewhat cooler than modern conditions, the first evidence of farming emerges. People first settled in cities and only then does agriculture appear, in response to the demands of a growing, settled population.

About 9,500 years ago, or more specifically around 9,200 years ago, we see the extinction of the sabre-toothed cat. Horses also disappeared from North America, likely due to human impacts. (A quick aside: there is a facetious reference in the scrolling figure to Pokémon going extinct at this time, which is, of course, entirely fictional.) As temperatures reached levels comparable to those of the 20th century, cattle were domesticated — around 8,500 years ago. By this point, the ice sheet over Canada had entirely vanished.

From roughly 10,000 years ago to the present, Earth's temperature remained, for the most part, within a relatively narrow band — about one degree Celsius higher or lower than today. This stable period is known as the Holocene. It encompasses the entire span during which humans have been able to build cities, develop stable agriculture, and domesticate animals.

## 1.7 Early civilisations and technological developments

By about 7,000 years ago, human settlement is documented in China, which stands as the oldest continuous civilisation in the world. Around 7,500 years ago (5,500 BCE plus the succeeding two thousand years), metal-working begins, along with the invention of the wheel, which, surprisingly, dates to only about 6,000 years ago.

The timeline features several key developments in civilisation — urban life in the Fertile Crescent; Egyptian mummification; the rise of the Indus Valley civilisation; and later, Stonehenge in the UK at about 4,000 years ago. Alphabetic writing appears in Egypt after the development of chariots and further urban expansion.

Written history, iron smelting, and early Greek civilisations also belong to this relatively recent part of our timeline. The peopling of the Pacific and Solomon Islands follows, and then another sequence of events from classical Greece to around 500 BCE, when both Greek and Buddhist traditions were crystallising.

## 1.8 Recent history, the industrial revolution, and climate change

All of the above — essentially everything we know as "civilisation" and "recorded history"—has taken place within this narrow "white band" on the graph, where global temperatures have not deviated by more than about one degree Celsius from present values.

Fast-forwarding to the last few centuries, we reach the invention of the steam engine, which allowed humanity, for the first time, to convert heat energy into mechanical work efficiently — driving the Industrial Revolution. Before this, societies had depended primarily on human and animal labour. Subsequently, developments such as the telegraph and aeroplane emerged, propelling us into the modern era.

Now, as of 2016, we find ourselves not only at the edge of this narrow band but potentially at the threshold of something new. Should we persist with current patterns of fossil fuel combustion — coal, oil, and gas — we are on a trajectory that leads to much warmer global temperatures, with increases possibly in the range of two, three, four, or even five °C above current levels. If, on the other hand, we made a radical change — literally switching off all fossil fuel emissions overnight — we might have a chance to slow the warming, but even then we are now in a climatic regime where no human civilisation has ever previously existed.

## 2 African Climate and Human Evolution: Deep-time Perspectives

Africa's deep-time history reveals an entanglement between changing climates, shifting vegetation regimes, and hominin/human development. From the late Miocene through the Pleistocene and into the Holocene, Africa's climate oscillated between humid and arid extremes, which drove transformations of landscapes from lush forests to expansive savannas and deserts. In turn, our ancestors adapted to these fluctuations through evolutionary change, behavioural innovation, and migration. The drivers and responses eventually culminated in the development of agriculture and complex societies.

Here I will provide a chronological narrative of these processes. I build on "Africa: A Biography of the Continent" by John Reader (1997), and integrate recent findings from paleoecology, archaeobotany, and climate modelling. I will examine how orbital-scale climate forces (e.g., monsoonal shifts and glacial cycles) shaped hominin evolution, how vegetation and hydrology characterised critical phases, the central ecological and cognitive roles of plants in early hominin life, the domestication of indigenous African crops, and the societal transformations spurred by food production. The focus is pan-African, drawing comparative insights from East Africa's Rift Valley to the Sahel, West African forests, and Southern African refugia.

### 2.1 From forests to savannas (Miocene–Pliocene, ~10–3 ma)

During the **Late Miocene (11.63–5.333 Ma)**, Africa's climate embarked on a long-term drying trajectory that permanently altered its ecosystems. Although changes occurred in both hemispheres, the consequences were particularly monumental in Africa (Herbert et al. 2016). Ten million years ago, tropical Africa remained dominated by dense forests and wooded landscapes, but tectonic upheavals (most dramatically the progressive uplift of the East African Rift highlands) combined with global cooling to destabilise these humid biomes. Best estimates suggest atmospheric $CO_2$ concentrations dropped from ~500 to <350 ppm (with significant uncertainty but consistent directionality across multiple proxy compilations) during the **Late Miocene cooling (7–5.4 Ma)** (Herbert et al. 2016, Brown et al. 2022). Concurrently, the land surface temperature dropped by ~7°C (Wen et al. 2023). These reductions catalysed the competitive expansion of $C_4$ grasses (Herbert et al. 2016). Their water-efficient physiology allowed them to outcompete trees under increasingly seasonal rainfall regimes. Mean global surface temperatures, though still several degrees warmer than late-Quaternary glacials, were trending downward from the Miocene Climatic Optimum, while rainfall in East Africa grew more seasonal as tectonic relief reshaped monsoonal circulation and ocean–atmosphere linkages.

By around 8 Ma, the major expansion of $C_4$ grassland biomes was fully underway, a shift that reconfigured hominin foraging grounds and evolutionary possibilities. Strengthened monsoonal seasonality favoured grasses over arboreal cover, and paleoecological records point to the replacement of relatively homogenous tropical forests with a patchwork of contrasting habitats: upland mountains, freshwater lakes, dry savannas, and residual montane forests. This heterogeneity was not a mere background change but a force structuring early hominin adaptations, as resource acquisition strategies had to adjust to spatially fragmented environments. The mammalian fauna from this period indicates that despite regional aridity, water sources and varied habitats supported a rich biodiversity. One punctuating episode in this trajectory was the **Messinian Salinity Crisis (~5.3 Ma)**, when tectonic closure of the Gibraltar Strait led to the partial desiccation of the Mediterranean Sea. This event disrupted atmospheric circulation and likely reduced moisture delivery to northern Africa, intensifying aridity across the continent. The conjunction of falling $CO_2$, global cooling, altered hydrology, and tectonic reshaping thus established the ecological framework in which the earliest members of the hominin clade adapted and diversified and took their first steps toward bipedalism.

The earliest known hominins – *Sahelanthropus tchadensis* (~7 Ma) in Chad and *Orrorin tugenensis* (~6 Ma) in Kenya – date to this late Miocene interval. Paleoenvironmental data suggest these ancestral hominids inhabited wooded or mosaic environments rather than open grassland alone. For example, geological and floral evidence from *Ardipithecus ramidus* (~4.4 Ma) indicates a woodland habitat with closed-canopy forest patches (references). Thus, while the "savanna hypothesis" once postulated that hominins descended from trees as forests gave way to grasslands, the reality is more complex. Early bipeds likely evolved in heterogeneous settings that included both forested and open areas, requiring versatility. Hominin fossil sites from ~7–4 Ma (e.g., in the Rift Valley and central Africa) often show a mix of faunal indicators of wooded savanna and gallery forest, and suggests that our ancestors were adapting to a mosaic landscape rather than a singular savanna biome.

By the early Pliocene — during the **mid-Piacenzian Warm Period (~3.3–3.0 Ma)**—Africa entered a regime of heightened climatic variability superimposed on a background of sustained global warmth. Proxy syntheses (such as boron-isotope reconstructions) place atmospheric $CO_2$ concentrations in the ~300–450 ppm range, albeit with punctuated excursions. Global mean surface temperatures stood ~2–3 °C above pre-industrial baselines, sea level rose by +20–25 m, and ocean–atmosphere circulation supported high primary productivity with sharp seasonal contrasts. On the African continent, hydroclimate was increasingly seasonal and strongly tuned to orbital precession: wetter precession minima alternated with arid maxima, redistributing resources at sub-100 kyr intervals and reshaping the nascent African monsoon system.

This climatic pattern translated into warmer, more productive lake districts and dynamic forest–savanna ecotones, though by ~2.8 Ma cooling intensified with the expansion of Northern Hemisphere ice. The precession-paced oscillation of the West African monsoon persisted, shifting rainfall belts latitudinally; humid phases nourished deep Rift Valley lakes and gallery forests, while intervening dry pulses contracted them, stripping back vegetation and leaving behind open landscapes. Pliocene climate model ensembles leave little ambiguity that $CO_2$ was the primary radiative forcing, giving the African hydroclimate its distinctive rhythm.

The ecological imprint of this structure was the "mosaic" landscape for which the Pliocene is now archetypal. Faunal and floral assemblages indicate a patchwork of savanna, woodland, and wetland habitats, interspersed with forested refugia. In East Africa, rainy seasons could extend for as long as eight months, yielding a gradient of ecological niches — from grasslands to shrublands, wooded zones, and riparian forests — each waxing and waning with orbital pacing. Such environmental heterogeneity did not simply provide a backdrop: it created alternating corridors and barriers, opportunities for niche exploitation alongside constraints on long-term stability. For early hominins, this shifting terrain was at once a laboratory of adaptation and a crucible of survival.

This is the environmental context within which *Australopithecus afarensis* flourished (c. 3.9–2.9 Ma); this species of hominin is well known from the skeleton "Lucy" (c. 3.2 Ma). Persisting for nearly a million years, *A. afarensis* displayed a remarkable behavioural and dietary flexibility that allowed it to sustain viable populations across these shifting landscapes. Its ability to exploit a broad range of resources (forest fruits, woodland tubers, savanna grasses, and lakeshore plants) highlights the adaptive strategies required for survival in early Pliocene Africa.

At the same time, isotopic evidence points to a dietary shift underway: while earlier apes were tied largely to $C_3$ plant foods (forest fruits and leaves), australopiths began incorporating $C_4$ resources (grasses, sedges, and grazing animal tissues) into their diets. *Australopithecus bahrelghazali* (~3.5 Ma, Chad) shows particularly strong $\delta^{13}C$ enrichment, suggesting a heavy reliance on open-habitat foods (Lee-Thorp et al. 2012), a signal that East Africa's grassland expansion was beginning to restructure hominin subsistence. *Australopithecus africanus* (South Africa, after ~3 Ma) likewise demonstrates a broad diet spanning woodland and savanna foods, highlighting regional diversity in both environments and adaptations.

Climatically, the Pliocene did not exhibit a steady “warm and wet” climate but exemplified an era of oscillation. Around 3.6–2.7 Ma, the intensification of Northern Hemisphere glaciation brought more pronounced glacial–interglacial cycles. In East Africa, deep Rift Valley lakes formed during humid pulses only to vanish during arid phases, leaving behind erratic records of expansion and collapse. This “boom–bust” hydrological rhythm imposed repeated selective pressures, rewarding dietary flexibility, mobility, and technological experimentation.

By ~2.8–2.5 Ma, a major global cooling and drying event (sometimes referred to as the “2.8 Ma event”) initiated a new trajectory. African landscapes tilted toward greater aridity, woodlands contracted, and savannas became more extensive. It is in this ecological reorganisation that we see the evolutionary branching of the hominin line. The robust australopiths (*Paranthropus*) evolved powerful jaws and teeth for hard, fibrous foods, while the first members of the genus *Homo* (e.g., *Homo habilis*) appear in the fossil record, associated with the earliest stone tools and a shift toward higher-quality, harder-to-acquire foods such as underground tubers and animal protein.

So, the late Miocene–Pliocene climate trend toward cooler, drier, and more variable conditions transformed Africa’s landscapes from continuous forests to patchwork savanna, woodland, and lakes. Hominins responded by evolving bipedal locomotion (useful for traversing open areas), broadening their diets to include tough C4 plant foods and meat, and developing rudimentary tool use. The ecological role of plants in this phase was obvious: early hominins still relied heavily on plant foods (fruits, leaves, seeds, roots), and the cognitive challenge of locating and processing dispersed plant resources likely honed foraging intelligence. Paleoanthropological evidence suggests that plant foods such as edible roots and tubers may have been fallback resources in dry seasons; some researchers hypothesize that digging for tubers (perhaps with simple wooden tools) could have been an important adaptive strategy in more open, seasonal environments (references). Although such wooden digging sticks do not preserve archaeologically from the Pliocene, the later record (e.g., Middle Stone Age) shows early humans indeed used digging sticks to unearth geophytes. Consequently, by the close of the Pliocene (~2.6 Ma), Africa’s hominins had become animals of the savanna–woodland mosaic, resilient in the face of shifting climates and ready to embark on new evolutionary pathways.

> **i** Foraging Behaviour During the Late Miocene to Pliocene
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> During the early hominin periods, John Reader notes the existence of a mosaic environment of open grassland, wooded savanna, and forests. The mode of living for early hominins like *Sahelanthropus*, *Orrorin*, and *Australopithecus afarensis* was primarily foraging and gathering, likely focusing on plant resources like fruits, leaves, and tubers, as well as insects and other small animals. Reader stresses that the fluctuating climate, oscillating between wetter and drier periods, shaped landscapes and pressured hominins into developing diverse dietary and technological adaptations to exploit these varied resources. This environmental pressure likely fostered a flexible, non-specialised diet that was key to survival across different habitats.

## 2.2 Pleistocene climate oscillations and the evolution of *homo* (2.6 Ma–130 ka)

The **Pleistocene epoch**, beginning ~2.6 Ma with the formal onset of the **Quaternary**, amplified this variability into even sharper oscillations. Global climate fell under the pacing of glacial–interglacial cycles: first the ~41,000-year rhythm of orbital obliquity during the early Pleistocene, and after the Mid-Pleistocene Transition (~1 Ma), the longer ~100,000-year cycles. In Africa these rhythms expressed themselves as alternating pluvial and interpluvial phases: wet intervals in which Rift Valley lakes swelled, rivers spread, and savannas greened, followed by dry episodes when deserts expanded (Sahara, Kalahari) and forests retreated. Overlaid on these were the faster, precession-driven (~20,000-year) monsoonal cycles, which forced tropical rainfall belts into rapid oscillations, producing humid–arid pulses on timescales far shorter than a single glacial cycle. Thus, although much of Africa lay in the tropics, its climate was anything but stable: hominins of the early Pleistocene lived through extremes in hydroclimate that alternated between verdant and desiccated states, conditions broadly analogous to modern East Africa but expressed with heightened amplitude.

Atmospheric $CO_2$ by this stage entered the familiar Quaternary range of ~180–300 ppm, as recorded in later ice-core analogues, and this lower radiative baseline accentuated the contrast between glacial aridity and interglacial greening. In the East African Rift, precession-driven rainfall pulses repeatedly transformed arid basins into freshwater-rich environments, generating high-stands of deep lakes near ~1.9 Ma — the very interval marked by the dispersal of early *Homo* and the acceleration of technological innovation. These hydrological oscillations provided intermittent cornucopias of aquatic and terrestrial resources, only to collapse back into desiccation within a few millennia. In this climatic template, it was not the average condition but the amplitude and tempo of rainfall swings that carried the evolutionary force, shaping hominin ecologies, opportunities for dispersal, and the recurrent need to innovate in the face of shifting resources.

The genus *Homo* diversified and spread during the Pleistocene, displaying leaps in technology and cognition. Many hypotheses have been proposed to link these changes to environment. The classic "savanna hypothesis" argued that a steady trend toward aridity (and the spread of savanna) drove *Homo* adaptations (upright walking, tool-making, larger brains) (references). However, newer research emphasise environmental instability rather than any single habitat as the prime driver. Rick Potts's variability selection hypothesis posits that hominins were selected for flexibility and innovation in response to fluctuating habitats (references). Indeed, a recent analysis of long climate records found that major evolutionary changes align with periods of heightened climate variability in East Africa (references). According to Potts, "unstable climate conditions favored the evolution of the roots of human flexibility in our ancestors," meaning adaptability to change (versus narrow specialisation) was key (references).

The fossil and archaeological record of the early-to-mid Pleistocene supports a narrative of punctuated change correlated with climatic pulses. One of the most significant periods occurred around 1.9–1.8 Ma. At this time, multiple important events coincided: the speciation of *Homo ergaster/erectus* (early *Homo* with a substantially larger brain and body than earlier forms), the first major hominin dispersals out of Africa, and the peak of hominin species diversity (with *Homo*, *Paranthropus*, and late *Australopithecus* contemporaneously present) (references). Paleoenvironmental proxies indicate that this interval was marked by pronounced climate fluctuations in East Africa. Researchers have identified a series of "climate pulses" linked to Earth's precession cycle that caused the repeated appearance and disappearance of deep lakes in the East African Rift System (EARS) (references). Geological evidence shows that around 1.9 Ma, large, ephemeral freshwater lakes suddenly formed in basins along the Rift Valley, transforming arid scrub into productive wetlands (references). These lake high-stands are recorded by deep lake sediments and correspond to times of low dust flux in ocean cores off Africa, indicating wetter regional climate (references). The onset of this wet phase is statistically linked with hominin expansion and innovation. Hominins likely took advantage of the resource-rich lake margins (abundant water, aquatic foods, lush plant growth, and fauna) leading to population growth and the capacity to move into new territories (references). The dispersal of *Homo erectus* beyond Africa (to Eurasia by ~1.8 Ma) may have been enabled by such "window" periods of ameliorated climate, when savannas were greener and deserts like the Sahara reduced, easing migration routes.

The first possible evidence of controlled fire use appears around 1.7–1.0 million years ago (Ma), associated with *Homo erectus* sites. Some of the oldest claims come from Koobi Fora (Kenya) and Chesowanja (Kenya) at ~1.5 Ma, where reddened sediments and burned clay nodules have been reported. Similarly, at Swartkrans (South Africa), bone fragments with thermal alteration dating to ~1–1.5 Ma have been interpreted as fire traces. These finds are debated, because natural bushfires can produce similar signals (references).

The earliest widely accepted evidence comes from Gesher Benot Ya'aqov (Israel), ~780 ka, where archaeologists have identified burned flint microartifacts and charred plant remains in a spatially patterned context. This pushes secure control of fire into the later phase of Homo erectus evolution (references).

> **i Fire Use and Consequences for Feeding**
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> Fire use is transformative in hominin diets. Cooking:
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> - Softens plant tissues (roots, tubers, seeds), making starchy underground storage organs digestible and safe.
> - Detoxifies many otherwise inedible or marginal foods (legumes, bitter roots, some leaves).
> - Tenderises meat and bone marrow, increasing caloric returns and shortening chewing time.
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> The "cooking hypothesis" (Richard Wrangham and colleagues) argues that once fire use became habitual, *Homo erectus* shifted from raw foraging toward a higher-quality diet of cooked foods. This had cascading effects:
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> - Cooking increases caloric yield, reducing the gut's metabolic burden. This fits with anatomical evidence: *H. erectus* had smaller teeth and reduced gut volume compared to australopiths, consistent with reliance on more energy-dense, processed food.
> - More reliable access to calories (via cooking) is thought to have supported encephalisation (brain expansion). Brain size in *H. erectus* rose steadily after ~1.5 Ma, a trajectory that cooking plausibly facilitated.
> - Fire provided not only cooking but also light, warmth, and protection from predators. Campsites structured around hearths suggest new forms of social cohesion, communication, and division of labour.

Following this productive wet pulse, the climate swung back to drier conditions, and many of the Rift lakes shrank or vanished (references). Interestingly, this coincides with what the fossil record shows as a winnowing of hominin diversity after ~1.5 Ma (only *Homo* remains, as *Paranthropus* goes extinct) and the progression of *Homo erectus* toward even larger brain size. One interpretation is that large, erratic climate shifts – pulsed climate variability – created an evolutionary filter. Species unable to cope with extreme swings (too specialised to either wet forests or dry plains) went extinct, whereas the lineage leading to modern humans survived by being generalists. The pulsed climate variability hypothesis specifically argues that these short, intense wet-dry cycles in East Africa were "fundamental to hominin speciation, encephalization and migration" (references). By providing alternating periods of resource abundance and scarcity, the environment may have spurred early *Homo* to develop new foraging strategies (e.g., more meat consumption, cooperative hunting), improved technologies (Acheulean stone handaxes appear by ~1.6 Ma), and possibly social changes, all of which would help buffer against unpredictability.

Throughout the **mid-Pleistocene (~1.2 Ma–130 ka)**, Africa remained locked into oscillatory climates now dominated by 100,000-year glacial–interglacial cycles. The **Early–Middle Pleistocene Transition (~1.2–0.7 Ma)** showed a drastic reorganisation of the climate system: glacial intervals lengthened and intensified, with $CO_2$ minima sinking toward ~180–200 ppm and interglacial peaks recovering only to ~260–280 ppm. Africa's hydrology mirrored these rhythms. During glacials, cooler and drier conditions prevailed: the Sahara and Kalahari expanded, tropical rainforests contracted into refugia, and savanna corridors narrowed to drought-dominated threads. During interglacials, monsoon systems strengthened, deserts retreated, and wetlands and forests expanded. Overlaying this slow 100-kyr pacing were precessional (~20-kyr) oscillations that forced rapid pulses of lake expansion and contraction, embedding high-frequency variability within the broader glacial–interglacial template. What emerges, therefore, is not a simple linear "savannisation" but an alternation of environments — oscillatory wet–dry phases that continually restructured ecologies.

Within this shifting template, hominin evolution marched on. *Homo heidelbergensis* (often regarded as archaic *Homo sapiens* in Africa) arose by ~0.6–0.5 Ma, and archaeological traces suggest adaptations well-suited to climatic instability. At sites such as Olorgesailie in Kenya, stratigraphic sequences between ~500–300 ka record alternating wet and dry phases, mirrored in hominin behaviour: changing prey species, shifts in tool raw materials, and altered landscape use as lake levels rose and fell. Evidence from this period suggests control of fire, large-game hunting, and possibly the construction of simple shelters — technological and social strategies that buffered against environmental unpredictability. By the later Middle Pleistocene, populations show increasingly derived traits, pointing to the emergence of *Homo sapiens* between ~300–200 ka, as reflected in fossils from Jebel Irhoud (Morocco) and Omo-Kibish (Ethiopia).

The timing is significant. Anatomically modern humans appeared in the context of **Marine Isotope Stage 6 (~190–130 ka)**, a protracted glacial marked by hyper-aridity across much of Africa. Global $CO_2$ oscillated largely between ~190–220 ppm, with finer-scale millennial variability now resolved in the EPICA ice-core record. Across Africa, proxies from speleothems and lacustrine deposits indicate widespread contraction of effective moisture: interior basins dried, lakes desiccated, and karst systems ceased growth, all signaling pervasive aridity. Yet the desiccation was not uniform. Along the southern Cape coast, cooler upwelling seas coupled with winter-rain regimes sustained pockets of relative humidity and edible geophyte abundance. Genetic evidence points to a severe demographic bottleneck, with perhaps only a few hundred breeding individuals surviving. Paleoenvironmental and archaeological research suggests survival in ecological refugia, most prominently along the southern African coast, where upwelling systems and diverse littoral resources offered stable sustenance amidst continental desiccation. In this sense, the oscillatory mid-Pleistocene climate was not merely a backdrop but a structuring force: alternating corridors and refuges, constraints and opportunities, that conditioned the evolutionary trajectory of the genus *Homo*.

> **i** Food Crops: ~2 million–300,000 Years Ago (Early to Middle Pleistocene)
>
> The appearance of *Homo erectus* coincided with increased climatic instability and the establishment of glacial-interglacial cycles. Reader mentions that these pressures favoured larger-brained hominins capable of more sophisticated tool use and social cooperation. The mode of living shifted towards more active hunting and gathering. The control of fire, a key technological adaptation mentioned in the text, would have allowed for the cooking of meat and plant foods, increasing digestibility and energy intake. This technological and social evolution enabled *Homo erectus* to exploit a wider range of food sources and led to the first major dispersals from Africa.

## 2.3 Surviving the late pleistocene: modern humans in arid and humid extremes (130–12 ka)

The last phase of the **Pleistocene (~130–12 ka)** was marked by volatile climatic oscillations that repeatedly tested *Homo sapiens*. The termination of MIS 6 around 130 ka ushered in an abrupt warming into **MIS 5e, the Last Interglacial**. Atmospheric $CO_2$ rose toward ~270–280 ppm, and global warmth amplified the strength of the African monsoon. Northern Africa entered a pluvial phase, the so-called Eemian Green Sahara, when tropical rainfall belts surged northward and the present Sahara was transformed into grasslands dotted with lakes and river systems. Proxy records — lacustrine deposits, speleothems, dune chronologies — converge on the picture of a dramatically contracted desert, opening habitable corridors across what is now arid expanse.

This climatic window coincides with the earliest evidence for *Homo sapiens* dispersal beyond Africa. Fossils from Skhul and Qafzeh in Israel (~120 ka) demonstrate that modern humans reached the Levant when it functioned as a biogeographic extension of African savanna. Southern Africa, too, offered stable resource landscapes: coastal plains combined carbohydrate-rich geophytes with abundant marine protein, creating refugial ecotones where human populations could persist and experiment with new foraging strategies. The rainfall regime, however, was dipolar. While the north flourished under MIS 5e rains, the south showed greater variability, with MIS 5a–c marked by oscillations in precipitation that alternately contracted and expanded coastal habitability.

This opportunity was not permanent. By **MIS 4 (~70–60 ka)**, global cooling and lowered $CO_2$ (~190–210 ppm) brought renewed aridity. The Sahara re-expanded, monsoon corridors collapsed, and the Levantine populations that had earlier dispersed outward either disappeared or withdrew. What remained were scattered refugial populations within Africa, many along the southern coast, where a convergence of marine protein, edible geophytes, and relatively buffered rainfall regimes sustained continuity. This oscillatory pattern, already evident throughout the Pleistocene, repeated once more: humid interludes briefly opened corridors that invited dispersal and innovation, only to be snapped shut by the return of aridity. It was within these compressed windows of ecological opportunity and constraint that the hallmarks of behavioural modernity — symbolic expression, diversified technology, and complex sociality — were forged, their development calibrated to the waxing and waning of resource networks under orbital pacing, monsoonal reorganisations, and the fluctuations of $CO_2$.

Into this context of tightening aridity, the Toba eruption (~74 ka) occurred, injecting volcanic aerosols into the stratosphere. While early hypotheses cast Toba as a catastrophic bottleneck event that nearly extinguished Homo sapiens, recent high-resolution proxy records and archaeological data have undermined that view (references). The climatic signal of Toba is now widely regarded as regionally heterogeneous and transient: a volcanic dimming imposed upon an already cooling world rather than a singular global catastrophe. In Africa, the ecological footprint appears to have been structured less by the eruption itself than by differential rainfall sensitivity. Coastal foragers, buffered by marine productivity and underground geophyte stores, weathered short-term disruptions, whereas interior populations, dependent on seasonal rainfall and freshwater lakes, were more vulnerable to moisture failures. This division is visible in paleoenvironmental reconstructions — lake low-stands, enhanced dust fluxes, and speleothem hiatuses — that point to strong aridity inland during MIS 4.

From MIS 4 into MIS 3 (~60–30 ka), atmospheric $CO_2$ rose modestly (~200–240 ppm), and African hydroclimates began to oscillate at higher frequency, paced by Dansgaard–Oeschger variability. Rainfall belts shifted latitudinally with millennial-scale pulses, alternately rehydrating and desiccating corridors. During wetter interstadials, savanna and lake systems expanded, facilitating range extensions and dispersal opportunities; during intervening arid episodes, habitats contracted and corridors pinched off. This rhythm is legible both in Saharan dust records — tracking shifts in aridity — and in East African Rift lake levels, which swung dramatically in phase with northern hemisphere temperature oscillations. Genetic and demographic inferences suggest that human populations tracked these oscillations, expanding during humid phases, then fragmenting or retreating into refugia when aridity returned.

In Africa itself, *Homo sapiens* populations likely contracted to favourable refuges during dry extremes. As noted, one important refuge during the harsh MIS6 glacial (~190–130 ka) appears to have been the southern coastal zone of South Africa (references). Archaeological sites like Pinnacle Point and Blombos Cave on the South African cape have yielded remarkable evidence of modern human habitation dating back to ~164 ka and continuously through ~70 ka (references). These people thrived at a time when much of inland Africa was extremely arid and depopulated. What sustained them was a unique combination of resources in this region:

marine foods and geophytic plant resources. Paleoenvironmental reconstructions of the now-submerged Paleo-Agulhas Plain (the exposed continental shelf during glacial low sea levels) show that it supported a rich fynbos shrubland – part of the Cape Floral Region – which boasts the world's highest diversity of edible geophytes (plants with underground bulbs and tubers) (references). These carbohydrate-rich, starchy plant organs were available year-round and could be reliably harvested with simple digging sticks (references). Additionally, the adjacent Indian Ocean coast provided shellfish, fish, and other seafood, supplying fatty acids and protein. The occupants of Pinnacle Point, as Marean et al. (xxxx) argue, "were feasting on the seafood and carbohydrate-rich plants that proliferated there despite the hostile climate" elsewhere. This resource base may have enabled a small band of modern humans to endure the glacial mega-droughts. Notably, evidence from these sites (such as heat-treated stone tools, shell beads for ornamentation, and pigment use around 164–70 ka) indicates a high level of behavioural and cognitive sophistication (references). The harnessing of diverse plant foods – including not just tubers for food but also wood and plant fibers for tools, and medicinal/technological uses of plants – was likely part and parcel of this cognitive florescence. A striking example is the discovery of 77,000-year-old plant bedding at Sibudu Cave in South Africa: layers of sedges and grasses were deliberately topped with leaves from aromatic, insect-repellent plants (e.g., *Cryptocarya* species) to create a comfortable, hygienic sleeping surface (references). The leaves contain natural insecticides, suggesting these humans had detailed knowledge of plant properties and selected specific foliage to improve living conditions (references). This is an early testament to the cognitive role of plants – not only as food, but as materials for technology (bedding, binding adhesives, etc.) and health (herbal compounds to deter pests).

As the Pleistocene drew to a close, humans faced one more major climatic trial: the **Last Glacial Maximum (LGM, ~21 ka)**. At the LGM, hyper-arid conditions once again prevailed over much of Africa – the Sahara reached its maximum extent, rainforests were fragmented, and even East Africa saw many lakes dry up or become alkaline. Yet by this time (20–15 ka), Homo sapiens had become truly adept at survival across varied ecotones, from the arid Sahara to equatorial forests. In North Africa, hunter-gatherers left rock paintings in what is today the heart of the desert, indicating that pockets of human activity persisted around sparse refugial water sources. In Southern Africa and along coasts, people again concentrated where resources remained, such as along major rivers or productive coastal zones. Around 15,000 years ago, the ice age began to wane and a dramatic transition to warmer, wetter conditions occurred.

## 2.4 ~315,000–200,000 Years ago (early *homo sapiens* emergence during climatic transition)

In Morocco, fossils from Jebel Irhoud dated to ~315,000 years represent some of the earliest known anatomically modern humans. These populations emerged during the major climatic transition around 300,000 years ago, when moisture patterns across Africa were reorganising. The Jebel Irhoud discoveries revealed that early *Homo sapiens* was not confined to a single region but was present across Africa during this important climatic period. The shift in vegetation patterns, with eastern Africa gaining relative abundance and diversity of vegetative resources after 300,000 years ago, may have created new selective pressures that contributed to the emergence of our species. Archaeological evidence shows these early humans were using advanced Middle Stone Age technology, including prepared core techniques and sophisticated hunting strategies. The environmental changes around this time likely facilitated population mixing and cultural exchange across the continent, contributing to the complex evolutionary processes that led to modern humans.

## 2.5 200,000–70,000 Years ago (middle stone age innovation and behavioural modernity)

During this period, African populations developed increasingly sophisticated technologies and symbolic behaviours that mark the emergence of behavioural modernity. At Blombos Cave in South Africa, evidence of ochre processing workshops, engraved designs, and marine shell beads dating to ~100,000-70,000 years ago provides clear evidence of symbolic behaviour. The 73,000-year-old drawing from Blombos Cave represents some of the earliest known graphic designs created by humans. These developments occurred against a backdrop of continued climatic variability, with populations adapting to changing environmental conditions through technological and social innovations. The long tradition of symbolic behaviour spanning over 30,000 years at sites like Blombos Cave and Diepkloof Rock Shelter suggests that these behaviours evolved adaptively, becoming better suited for human perception, cognition, and cultural transmission.

## 2.6 ~74,000 Years ago (toba eruption and population dynamics)

The massive Toba super-volcanic eruption in Indonesia created a global environmental crisis that may have significantly impacted human populations. While early theories suggested this event caused a severe population bottleneck in Africa, more recent research indicates that humans in some regions, particularly coastal South Africa, not only survived but thrived during this period. Archaeological evidence from Pinnacle Point and other South African coastal sites shows continued human occupation and sophisticated technological traditions through the Toba event. The coastal resources, particularly shellfish, were less susceptible to the volcanic winter effects than inland plant and animal resources, providing crucial refugia for human populations. However, genetic evidence suggests that population dynamics during this period were complex, with some populations experiencing stress while others remained stable.

## 2.7 ~70,000–50,000 Years ago (late pleistocene dispersals and cultural complexity)

This period saw both the culmination of symbolic behaviour in Africa and the beginning of major human dispersals out of the continent. The sophisticated cultural traditions evident in the archaeological record — including the refined ochre engravings and shell bead technologies — demonstrate that African populations had developed complex symbolic systems. These cultural innovations likely played important roles in enabling successful dispersals to other continents. Climate conditions during this period, following the Toba event and during Marine Isotope Stage 4 (a cold period from 70,000-60,000 years ago), created both challenges and opportunities for human populations. The end of this cold period coincided with genetic evidence for population expansions and the beginning of successful colonisation of other continents.

> **i** Food Crops: 200,000–50,000 Years Ago (Middle Stone Age)
>
> The focus during this period is on the emergence of early *Homo sapiens* and the development of behavioural modernity. Reader highlights a move towards more sophisticated hunting strategies. Archaeological evidence from coastal South Africa, particularly sites like Pinnacle Point, shows that human populations relied heavily on coastal resources, especially shellfish, as a staple food source. He notes that these resources were less susceptible to the effects of the Toba volcanic winter, providing a vital refugium. The resilience of these populations demonstrates a high degree of adaptability and an understanding of diverse ecosystems, combining hunting and gathering with a reliable marine food source.

## 2.8 15,000–5,000 Years ago (african humid period and cultural transformation)

The African Humid Period represents one of the most dramatic environmental transformations in Africa's recent history. Around 14,700 years ago, changes in Earth's orbital parameters brought monsoon rains deep into northern Africa, transforming the Sahara into a green savanna ecosystem. This period, lasting until about 5,500 years ago, supported vast networks of lakes, rivers, and grasslands where today only desert exists. Lake Mega-Chad covered an estimated 350,000 km$^2$ at its largest extent. The environmental transformation enabled widespread human settlement across regions that are now uninhabitable.

Archaeological evidence reveals complex hunter-gatherer societies that developed sophisticated technologies and possibly domesticated cattle in some regions. At Nabta Playa in southern Egypt, Neolithic cultures flourished with advanced astronomical monuments and evidence of cattle management between 11,000-5,000 years ago. However, recent analysis suggests that early claims of independent cattle domestication in the Sahara may need revision, with evidence pointing toward introduction from the Middle East around 6,300 years ago rather than local domestication. The rock art of this period, found throughout the now-arid Sahara, depicts a rich fauna including elephants, hippos, crocodiles, and giraffes, providing vivid testimony to the dramatic environmental changes.

> **i** Food Crops: 15,000–5,000 Years Ago (African Humid Period)
>
> The African Humid Period saw a dramatic transformation of the Sahara into a green savanna. This allowed for widespread human settlement across regions that are now desert. The mode of living for people in this period was a transition from hunter-gatherer societies to more complex cultures that may have engaged in early forms of cattle management. While Reader revises earlier claims of independent cattle domestication, it notes that Neolithic cultures at sites like Nabta Playa flourished and had access to a wide range of fauna depicted in rock art, including elephants, hippos, and giraffes. The availability of abundant wild game and water sources likely supported the growth of these complex societies.

## 2.9 6,000–4,000 Years ago (end of the humid period and population migrations)

The end of the African Humid Period was not uniform across the continent but occurred in phases from north to south. The transition began around 6,000 years ago and accelerated around 5,500 years ago, with the most severe desiccation occurring around 4,000 years ago. In Egypt, the aridification of the Sahara between 5,000-4,000 years ago created massive environmental stress that likely drove populations toward permanent water sources. The drying was not gradual but occurred in relatively rapid phases over a few hundred years. As grasslands and lakes disappeared, desertification processes accelerated: vegetation loss reduced rainfall generation, light-colored land reflected rather than absorbed sunlight, and soil lost its moisture retention capacity.

This environmental crisis forced large-scale human migrations toward the Nile Valley, fundamentally reshaping the demographic landscape of northeastern Africa. The concentration of populations in the Nile Valley during this period provided the social and economic foundation for the emergence of complex Egyptian civilisation.

## 2.10 5,000–3,000 Years ago (early agricultural expansion and technological transitions)

As the Sahara became increasingly arid, African societies across the continent were developing and expanding agricultural systems based on indigenous crops adapted to local conditions. In West Africa, the domestication of key crops occurred in response to changing environmental conditions. **Pearl millet** was domesticated around 4,500 years ago in the region that is now northern Mali and Mauritania, probably as lakes created by the earlier humid period began to disappear. **African rice** was domesticated in northern Mali, while **yams** were domesticated in the Niger River Basin between eastern Ghana and western Nigeria. In the Sahel region, **sorghum** was domesticated by 3,000 BCE in Sudan.

These agricultural developments were closely tied to climatic changes. As the climate dried and lake networks vanished around 6,000 years ago, local populations began cultivating plants as wild food sources became less reliable. The genetic analysis of these crops shows that domestication was often a gradual process involving continued interbreeding between wild and cultivated varieties, which slowed full domestication but added crucial genetic diversity. This agricultural expansion provided the foundation for population growth and the development of more complex societies across sub-Saharan Africa.

> ℹ Food Crops: 6,000–3,000 Years Ago (End of Humid Period and Agricultural Expansion)
>
> This period sees the dramatic shift toward indigenous agriculture. Reader states that as the Sahara became increasingly arid, populations were forced to develop agricultural systems based on locally adapted crops. He emphasises that the domestication of these crops was a direct response to climatic stress. The transition from a hunter-gatherer to an agricultural mode of living allowed for population growth and the development of more complex, sedentary societies across sub-Saharan Africa (see Section 2.16). The desiccation of the Sahara also drove large-scale migrations towards the Nile Valley, providing the demographic foundation for the emergence of ancient Egyptian civilisation.

## 2.11 3,000–2,000 Years ago (bantu expansion and iron age beginnings)

The expansion of Bantu-speaking peoples from West-Central Africa represents one of the most significant demographic and cultural transformations in African history. Beginning around 5,000 years ago but accelerating around 3,000 years ago, this expansion was closely tied to environmental changes and technological innovations. Climate change around 4,000 years ago created savanna corridors through the Congo rainforest, particularly the Sangha River Interval, which facilitated north-south movement of both people and species.

The Bantu expansion demonstrates how human societies adapted to and took advantage of environmental changes. Savanna-dwelling Bantu speakers showed a clear preference for familiar habitats as they moved southeastward, and their migration was significantly slowed when they encountered rainforest environments — with transitions into rainforest delayed by approximately 300 years compared to movements within savanna habitats. This expansion brought agriculture, livestock herding, and eventually iron-working technology to much of eastern and southern Africa.

> ℹ Food Crops: 3,000–2,000 Years Ago (Bantu Expansion and Iron Age)
>
> The Bantu expansion was driven by a combination of technological innovation and environmental change. Reader notes that Bantu-speaking peoples brought agriculture and livestock herding to much of eastern and southern Africa. Their success was tied to their ability to cultivate crops like sorghum and millet and herd cattle, allowing them to support larger populations and settle new territories. Their expansion was facilitated by the creation of savanna corridors through the Congo rainforest due to climate change, demonstrating how environmental conditions enabled rather than hindered their movements.

## 2.12 2,000–1,000 Years ago (complex societies and climate adaptation)

By 2,000 BCE, the Sahara had become as dry as it is today, with the last major lake drying up around 1,000 BCE. Some researchers suggest these climate refugees from the drying Sahara contributed significantly to the cultural and genetic foundation of ancient Egyptian civilisation. During this period, various African societies developed sophisticated strategies for managing environmental variability and building complex political systems. The rise of Great Zimbabwe (founded around 1000 CE) exemplifies how African societies adapted to challenging climatic conditions through innovative technologies. Located in a climate-sensitive region prone to drought, Great Zimbabwe developed an extensive water management system using "dhaka" pits — large depressions that collected and stored both surface and groundwater. This system could store an estimated 18,000 cubic meters of water, enabling the city to support 10,000-18,000 inhabitants in a semi-arid environment.

The Nok culture in central Nigeria (1500-200 BCE) provides important insights into early Iron Age developments. Contrary to earlier assumptions, the Nok culture began around 1500 BCE as a Neolithic society, with iron technology and elaborate terracotta sculptures appearing only around 900-500 BCE. This demonstrates that complex cultural traditions could develop independently of metallurgy, with iron technology being adopted later to enhance existing social and economic systems.

The Medieval Warm Period (c. 900-1300 CE) created favourable conditions for several African polities. In West Africa, the Mali Empire flourished during this time, leveraging trans-Saharan trade routes that benefited from relatively stable climatic conditions. The empire's wealth, famously displayed during Mansa Musa's pilgrimage to Mecca in 1324-1325, was built on controlling gold-producing regions and managing trade networks that connected sub-Saharan Africa with Mediterranean and Middle Eastern markets. These trade routes were possible because the Sahara, while still a desert, was more manageable for caravan travel during the Medieval Warm Period than during subsequent cooler periods.

> **i Food Crops: 2,000–1,000 Years Ago (Complex Societies)**
>
> Reader mentions the rise of complex societies like Great Zimbabwe, which developed innovative water management systems to support its large population in a semi-arid environment. This indicates that while agriculture and herding were the primary modes of living, advanced engineering was required to manage the environmental constraints of a climate-sensitive region.

## 2.13 1,300–1,850 CE (little ice age impacts and societal responses)

The Little Ice Age brought significant challenges to African societies through altered precipitation patterns and temperature changes. In southern Africa, the abandonment of Mapungubwe around 1290 CE and the simultaneous rise of Great Zimbabwe coincided with the beginning of drier conditions associated with the Little Ice Age. Temperature decreased by about 1°C across much of the continent. The impacts were particularly severe in equatorial East Africa, where widespread drought and desiccation occurred from the late 1700s to about 1830.

Lake systems across the continent experienced dramatic changes: Lake Naivasha was reduced to a puddle, Lake Chad was desiccated, Lake Malawi became so low that people could traverse dry land where deep water normally existed, and Lake Rukwa completely dried up. These drought events were "more severe than any recorded drought of the twentieth century". In West Africa, particularly the Sahel, the Little Ice Age was characterised by a progressive drying trend between 1250 and 1850 CE, with major drought events punctuating the period, the most severe occurring around 1600 CE.

The climatic stresses of the Little Ice Age forced African societies to develop new adaptive strategies. Some communities shifted their settlement patterns, moving to areas with more reliable water sources. Others diversified their economic activities, combining pastoralism, agriculture, and trade to reduce vulnerability to environmental shocks. The end of the Little Ice Age around 1850 CE brought relief to some regions, but also contributed to population growth and increased competition for resources, setting the stage for the social upheavals of the late 19th century.

**ℹ Food Crops: 1,300–1,850 CE (Little Ice Age)**

The Little Ice Age brought significant challenges to African societies through altered precipitation patterns and widespread droughts. The text notes that communities adapted by diversifying their economic activities, combining pastoralism, agriculture, and trade to reduce vulnerability. This period highlights the importance of maintaining multiple livelihood strategies — a theme the text returns to in its conclusion — as a way to build resilience against climate shocks.

## 2.14 1,850–1,960 CE (colonial period and imposed economic transformation)

The Industrial Revolution in Europe and North America was intimately connected to African resource extraction. Coal powered British imperial expansion, while African colonies supplied raw materials to European factories. This extraction-based economic model made African territories more vulnerable to climate shocks by reducing economic diversification and eliminating traditional adaptive strategies.

## 2.15 1,960–2,025 CE (independence, development challenges, and modern climate change)

The post-independence period has been marked by efforts to rebuild African economies while confronting accelerating climate change. Recent data show the average rate of warming in Africa was +0.3°C per decade during 1991-2022, compared to +0.2°C per decade between 1961-1990.

In South Africa, temperatures have increased by 1.5°C since the 1960s, twice the global average warming rate. Rainfall patterns have become more erratic, with hot and cold extremes increasing. Climate models project continued warming throughout the 21st century, with low mitigation scenarios leading to warming well in excess of 3°C posing much higher risks than high mitigation futures limiting warming below 2°C.

Despite these challenges, recent research reveals that African societies have maintained remarkable adaptive capacity. A continent-wide study of livelihood strategies over the past 10,000 years shows that successful adaptation has consistently involved diversifying economic activities rather than relying on single strategies. Communities that combined herding, farming, fishing, and foraging showed greater resilience to climate variability than those focused on intensive single-sector approaches. These historical lessons are increasingly relevant as Africa faces unprecedented climate challenges while building modern economies.

## 2.16 Food crops and their role in social and political responses for african societies

The agricultural developments discussed, particularly the domestication of drought-tolerant crops, had extensive social and political consequences for African societies. The shift from foraging to farming fundamentally reshaped human social organisation and lead to the rise of food surpluses, the establishment of social hierarchies, and the development of more complex and stratified societies.

### 2.16.1 Pearl millet (*cenchrus americanus*)

Figure 2: Figure 2: Pearl Millet (*Cenchrus americanus*)[1].

- Domesticated around 4,500 years ago in northern Mali and Mauritania. Pearl millet is one of the most drought-tolerant cereals in the world. As a C4 grass, it has high photosynthetic efficiency and requires minimal water. It can produce a significant grain yield with as little as 250 mm of annual precipitation and has an extensive root system to access water deep in the soil. It is also highly tolerant of high temperatures, with optimum growth temperatures of 33-35°C and the ability to withstand temperatures up to 42°C. This tolerance to heat and aridity is a key adaptation.
- The domestication of pearl millet allowed people to remain in and expand into the increasingly arid regions of the Sahel after the end of the African Humid Period. Instead of being forced to migrate to river valleys, communities could establish permanent settlements in semi-arid zones. This agricultural stability provided a foundation for population growth and the development of more complex societies, as labour could be invested in activities beyond daily foraging.

[1] Source: A.S. Rao/ICRISAT, https://www.cgiar.org/innovations/high-iron-pearl-millet-for-better-health/

#### 2.16.2 African rice (*oryza glaberrima*)

Figure 3: Figure 3: African Rice (*Oryza glaberrima*) Editor (2024).

- Domesticated in northern Mali. Unlike its Asian counterpart, African rice is highly adapted to the unique, variable conditions of West Africa. It is known for its tolerance to a range of stresses, including drought, flooding, and iron toxicity in soils. This resilience means it can thrive in both rain-fed upland areas and seasonally flooded lowlands.
- The ability of African rice to cope with both droughts and floods provided a much-needed degree of food security in an environment characterised by unpredictable wet and dry cycles. Its competitiveness against weeds also reduced the labour required for cultivation. The cultivation of African rice enabled communities in West Africa, especially in the Niger River Basin, to develop agricultural systems that were resilient to climatic fluctuations, and which supported the growth of urban centers and more complex social structures.

### 2.16.3 Yams (*dioscorea* spp.)

Figure 4: Figure 4: Yams (*Dioscorea* spp.)[2].

- Domesticated in the Niger River Basin. Yams are a high-carbohydrate tuber that can be stored for long periods. Yams are a staple root crop that thrives in the humid tropics. They are particularly resilient to pests and diseases and, most importantly, can fill the "hunger gap" during lean or drought periods because the tubers can be stored for extended periods. This storage capacity provides critical food security.
- The domestication of yams in the Niger River Basin provided a reliable, storable high-carbohydrate food source. This reduced the pressure of seasonal food scarcity, and enabled communities to build up a food surplus. This surplus allowed for population growth and the specialisation of labour, and so moving beyond subsistence farming. The development of permanent settlements and the ability to weather periods of environmental stress were direct consequences of the reliable food source provided by yams.

[2]Source: REUTERS/Temilade Adelaja.

### 2.16.4 Sorghum (*sorghum bicolor*)

Figure 5: Figure 5: Sorghum (*Sorghum bicolor*)[3].

- A cereal domesticated in Sudan by 3,000 BCE. As a C4 plant, sorghum is well-known for its exceptional tolerance to drought, high salinity, and high temperatures. It can grow on marginal lands with low nutrient input and is often considered a "star crop" for combating hunger in the face of climate change. Its deep roots and ability to reduce water loss through leaf-rolling mechanisms make it highly resilient to water stress.
- Sorghum cultivation was central to the development of agricultural societies in the Sahel and eastern Africa. Its ability to grow in arid and semi-arid regions meant that populations could expand beyond river valleys and into drier savannas, supporting the large-scale migrations and demographic changes, such as the Bantu expansion. Its reliability in harsh climates made it a cornerstone of food production and a key factor in the sustained growth of many early African societies.

**Food surplus and sedentism**

The transition from a nomadic, hunter-gatherer lifestyle to a sedentary, agricultural one was driven by the **reliability of new food sources**. Crops like sorghum and pearl millet, which can be stored for long periods, allowed communities to accumulate a food surplus. This surplus provided a buffer against environmental shocks, such as drought, and enabled populations to grow. With a stable food supply, people no longer had to constantly move in search of sustenance, leading to the establishment of **permanent settlements**. This shift to sedentism created a new dynamic where communities could invest in more durable infrastructure, such as granaries for storage or, in the case of Great Zimbabwe, complex water management systems.

**Specialisation and social stratification**

A stable food supply meant that not everyone had to be involved in food production. This allowed for **labour specialisation**. Some individuals could become full-time potters, blacksmiths, or weavers, while others focused on activities like leadership or ritual. This specialisation gave rise to social hierarchies. Leaders emerged who managed the distribution of the food surplus, organised labour for large-scale projects, and

[3] Source: Cambridge University Botanic Garden, https://www.botanic.cam.ac.uk/learning/trails/dyestrail/sorghumbicolor/

controlled trade networks. The Nok culture in Nigeria, with its elaborate terracotta sculptures , is a prime example of a society where complex cultural traditions and specialised craftsmanship developed before the widespread adoption of iron technology.

**Population growth and expansion**

The combination of a reliable food source and sedentism led to significant **population growth**. Larger populations required more sophisticated political structures to manage conflicts and organise communities. The Bantu expansion, discussed in the text, is a great illustration of this. The Bantu-speaking peoples, armed with agricultural knowledge and later, iron technology, were able to expand across the continent, replacing or integrating with existing hunter-gatherer populations. Their agricultural lifestyle allowed them to support higher population densities, giving them a distinct advantage.

## 2.17 Lessons from deep-time adaptation

African history reveals that successful climate adaptation has consistently involved flexibility, diversity, and innovation rather than rigid adherence to single strategies. From the earliest hominins navigating Miocene climate transitions to modern communities facing 21st-century warming, the key to survival has been maintaining multiple livelihood options and strong social networks for sharing resources and knowledge. The archaeological and isotopic evidence shows that communities mixing pastoralism, cultivation, hunting-gathering, and fishing were making context-specific choices that enhanced their resilience to unpredictable conditions.

This deep-time perspective challenges modern development approaches that often privilege intensive agriculture or single-sector economic growth. Instead, Africa's 10,000-year history of climate adaptation suggests that maintaining diverse, flexible livelihood systems — combined with strong social networks and adaptive institutions — provides the most robust foundation for weathering environmental uncertainty. As Africa continues to lead global population growth while contributing minimally to historical greenhouse gas emissions (only 3.8% of global emissions despite hosting 17% of world population), these historical lessons offer valuable guidance for building climate-resilient societies in an uncertain future.

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