

DEGRADATION IN NORTHERN AFRICA



A multi-causal phenomena

Degradation in Northern Africa a multi-causal phenomena

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Abstract- Climate change is the result of complex interactions among natural variability, orbital dynamics, anthropogenic forces, and feedback mechanisms between land and atmosphere. While Milankovitch cycles have historically governed long-term climate shifts, particularly during the Pleistocene, evidence suggests that human influence on landscapes and ecosystems, dating back to prehistory, has played a far more significant role than previously acknowledged. The concept of the Paleo-Anthropocene challenges the notion of a purely “natural” climate, highlighting early human impacts through land use, fire, and niche construction.

In northern Africa, particularly the Sahara, paleoclimatic records reveal that transitions from humid to arid conditions, such as the end of the African Humid Period, were neither uniform nor entirely explained by orbital forcing. The discrepancy between modelled and observed aridification rates suggests that local vegetation loss and land degradation, possibly human-induced, accelerated regime shifts. Archaeological and ecological data further support the idea that *Homo sapiens* have long been a keystone species, shaping ecosystems through migration, agriculture, and pastoralism. These interactions altered soil moisture, precipitation, evaporation, and biodiversity at multiple scales. Modern climate and ecological restoration efforts must therefore be informed by long-term historical and geomorphological context to responsibly navigate the uncertainties of future interventions. Recognizing humanity’s longstanding role in Earth system dynamics opens new possibilities for deliberate, regenerative stewardship of the planet.

Index Terms- Climate change, Milankovitch cycles, Palaeoclimatology, Anthropogenic forcing, African Humid Period (AHP), Regime shifts, Ecosystem degradation, Sahara aridification, Human-environment interaction, Ecological tipping points, Desertification, Climate modelling, Human-induced landscape change

I. INTRODUCTION

The timing, rate and direction of climate change is the cumulative result of natural variability, anthropogenic forcing and the resultant terrestrial-atmospheric feedbacks. Palaeoclimatological records indicate a strong relation between the Earth’s orbital parameters (Milankovitch cycles) and the planetary climate conditions (Pausata et al., 2020). Since the beginning of the Pleistocene 2.6 million years ago, there have been over 20 ice ages driven by orbital changes, which have had significant effects on global climates extending to the equatorial regions (Crucifix, 2012; Herbert et al., 2010). However, climate variations throughout history cannot be explained by Milankovitch cycles alone. The general conclusion of long-term ecological research shows that shifting regimes are always multi-causal (Foley et al., 2013) and the role of anthropogenic forcing in driving continental-scale changes to land cover may have been much more significant than previously understood (Boivin et al., 2016; Hoag & Svenning, 2017; Wright, 2017). The profound potential of humans to reduce vegetal biomass is not restricted to the post-industrial era, but rather dates back far into prehistory, a period some call the Palaeoanthropocene: ‘the time interval before the industrial revolution during which anthropogenic effects on landscape and environment can be recognized, but before the burning of fossil fuels produced a huge crescendo in anthropogenic effects’ (Foley et al., 2013). This hypothesis further claims humans have actively and interdependently co-evolved with their landscapes in the form of ‘niche construction’ in which organisms’ trophic behaviours

correspondingly shape the ecosystems they inhabit (Braje & Erlandson, 2013; Glikson, 2013; Thompson et al., 2021). Decoupling the interplay of human agency in shaping the environment is laden with uncertainty. This all begs the question: What is the ‘natural’ climate and what role does humanity play in shaping planetary functioning over *longue-durée* timescales?

Socio hydrological interactions in the form of land-use change touch upon all green water variables – terrestrial precipitation, evaporation and soil moisture. Land-use change alters precipitation patterns through the modification of the local land–atmosphere coupling and large-scale circulation patterns (Pitman et al., 2012; Runyan et al., 2012; Wang-Erlandsson et al., 2018). As for evaporation – agriculture and pasture expansions (now covering almost half Earth’s ice-free land area) has estimated effects of 2,000–3,000 km³/yr decreases and 800–2,600 km³/yr increases in evaporation – as a result of deforestation and irrigation, respectively (Gordon et al., 2005). Soil moisture functions as the interface between precipitation and evaporation, which implies that changes in soil moisture retention and availability to plants could generate non-linear ecological, biogeochemical and atmospheric changes across scales (Wang-Erlandsson et al., 2022).

In all efforts to restore or regenerate ecosystems we ought to be aware of the root causes and potentially amplifying feedbacks that lead the changing of landscapes and the inherit uncertainties therein. In this light, although greening efforts can have desirable effects for climate mitigation and biodiversity,

afforestation initiatives are still widely criticised. One major criticism that came from global analyses (Taylor & Marconi, 2019) is that those new forests are planned on places which have always supported other ecosystems with their own functioning and biodiversity. This criticism emphasizes the necessity of conducting complementary historical analyses of changing ecosystems including the dynamics of their functioning and the degree of human agency in inducing regime shifts. Moreover, restoration action must assess the feasibility of intentionally inducing ecological regime shifts and the associated (regional and global) impacts of doing so.

II. PALAEOCLIMATOLOGICAL AND GEOMORPHOLOGICAL SIGNS OF DEGRADATION

Degradation is defined here as the negative trend in land condition, including the loss of at least one of the following: biological productivity, ecological integrity, or value to humans (Olsson et al., 2019). Like many other deserts on Earth, the Sahara (which in biofunctionality includes the Sinai Peninsula) have witnessed much wetter conditions in the past. Natural variation in insolation, combined with various other mechanisms, gives rise to alternating arid and humid periods in North Africa, shifting approximately every 20,000 years (DeMenocal & Tierney, 2012; Larrasoana, 2021; Tierney et al., 2017). Precessional cycles (changes in the axial rotation of earth) have to a certain extent paced the hydroclimate of North Africa, but the precise timing and duration of dry/wet periods are not entirely consistent with the rhythm of orbital variation (see Figure 1).

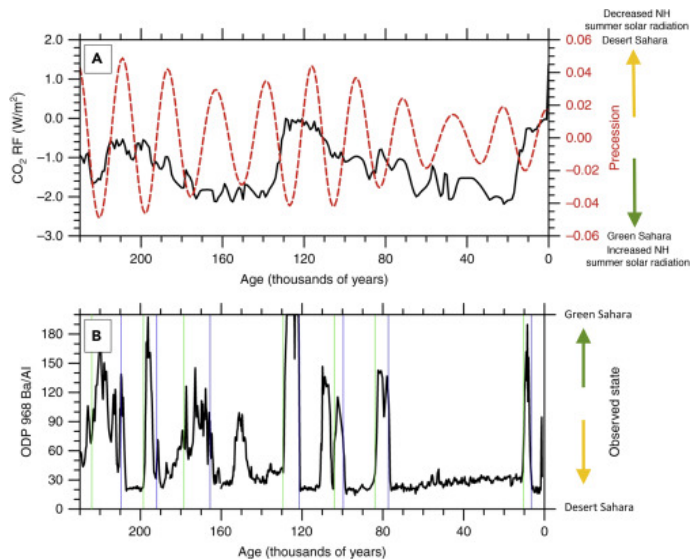


Figure 1. Top image shows a time series of Earth's precessional cycles (red line) and the radiative forcing from changes in CO_2 . Bottom image shows a timeseries of Barium/Aluminium ratio, which is a proxy for wet and dry periods (black line). The start and end of wet periods are indicated by the green and blue vertical lines, respectively. Figure from Pausata et al. (2020) (CC BY 4.0).

The indication that there are additional factors that co-determine the onset of a regime shift makes that the orbital cycles alone cannot be used to predict the state of the climate. Research suggests that the tipping-point behaviour is coupled to the

sensitivity of an area (Pausata et al., 2020), which further suggests that land cover change in the past might be more of a determining factor than has been previously understood.

In place of the hyper-arid landscape the Sahara is today, the region has been periodically lined with a considerable amount of lush green vegetation as well as rivers, lakes, forests, grasses and large mammals roaming between equatorial Africa through northern Africa into the now-arid regions of Central Asia (DeMenocal et al., 2000; Larrasoana et al., 2020; Larrasoana, 2021). The latest African Humid Period (AHP) occurred during the early-to-mid Holocene beginning before 10,000 years ago and ending around 4000 years ago. Whether the termination of the last AHP occurred abruptly or stepwise is still under scientific debate though it is known the process was spatially and temporally variable (Lézine et al., 2011).

The timing and geography of the termination of the AHP is a matter of debate, with some proxy evidence indicating an abrupt transition from wet to dry conditions (Bloszies et al., 2015; Bristow et al., 2018; Collins et al., 2017; DeMenocal et al., 2000; Salzmann & Hoelzmann, 2005) and some that indicate a slower, stepwise transition (Francus et al., 2013; Höpker et al., 2019; Kröpelin et al., 2008; Lézine et al., 2005; Ménot et al., 2020; Neumann, 1989; van der Lubbe et al., 2017).

Climate models consistently underestimate the speed with which many regions of the northern Africa turned arid relative to the proxy record (Claussen et al., 2017). Poor parameterization of climate models accounts for some of the discrepancy (Hopcroft & Valdes, 2021), but the pace of aridification in some portions of northern Africa appears to have exceeded orbital forcing. Figure 2 shows the discrepancy between the expected pattern of termination based on orbital change (if this forcing would be normative), and the measured pattern based on paleoclimate records and sediment cores. The rate of degradation in the northern latitudes was faster, and it begins prior to what would be expected based on orbital forcing alone.

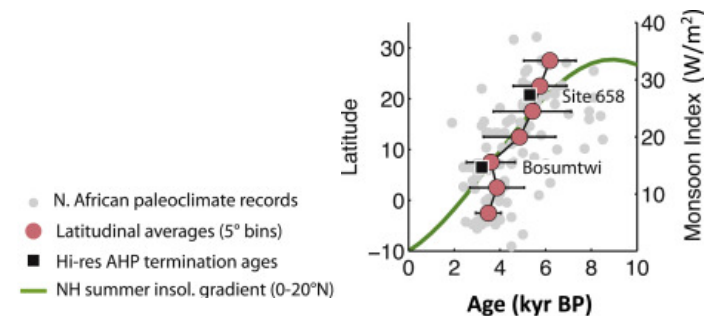


Figure 2. The expected AHP termination associated with orbital forcing is indicated by the green curve. The calibrated ages from paleoclimate records for the ending of AHP is given by the red circles. Figure from Pausata et al. (2020) (CC BY 4.0).

III. HISTORY OF HUMAN SETTLEMENTS AND MOBILITY PATTERNS

The first agriculture-dependent economies and Neolithic cultures likely arose independently in several different locations scattered over the globe (Diamond & Bellwood, 2003), the earliest of which was found to have emerged in the Fertile Crescent (see Figure 3).

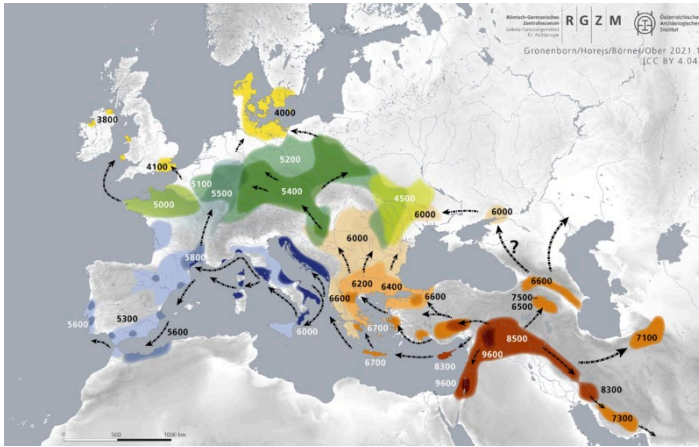


Figure 3 Map showing approximate centres of origin of agriculture and its spread throughout history in western Eurasia (dates in years B.C.) Detlef Gronenborn, Barbara Horejs, Börner, Ober, CC BY 4.0, via Wikimedia Commons.

Major migrations (DeMenocal, 2001) and the development of subsistence practices (Kuper & Kröpelin, 2006) are often driven by climatic and environmental changes. As humans make up an integral part of Earth's System, the question remains whether we might have contributed to the environmental changes that caused us to migrate from our ancestral homelands to new locations. Examples of abandoned settlements can be found in several locations throughout Northern Africa, suggesting environmental conditions changed and were no longer favourable for humans to live in. The ecological dynamics that led up to that point are, however, more challenging to reconstruct (Brooks et al., 2005; Clarke et al., 2016). Many attempts have been made to use computer models to reproduce the exact outcomes as indicated by paleoclimate records, but capturing the interactions between humans, ecosystems and the climate during these climatic shifts remains limited (Hély et al., 2009).

Recent studies suggest that *Homo sapiens* have played a much more important role in facilitating the termination of the last AHP than previously understood (Wright, 2017). Hominin migrations out of Africa beginning around 2 million years ago have been hypothesised to be primarily climate-driven, occurring mainly during warm and wet cycles (Tierney et al., 2017). However, humans have never been passive environmental actors, and there is a growing and significant body of research indicating that the use of technology, such as fire and advanced, cooperative hunting skills, significantly affected landscape composition during the Pleistocene (Boivin et al., 2016; Hoag & Svenning, 2017).

The mastery of fire combined with the cognitive revolution led to greater landscape manipulation skills, which, in turn, led to the

formation of landscapes that were dependent on the presence of humans for their functionality (Scott, 2017). By burning away forests for better hunting grounds, cutting down trees for fuel, building temples and hunting down large animal populations.

Homo sapiens became a keystone species that greatly altered the landscape wherever they roamed (Pinter et al., 2011). Later, the development of pastoralism (which spread from the Fertile Crescent southward after 11,000 BP) introduced a novel trophic feature that is hypothesised to have accelerated orbitally induced de-vegetation and is caused major regime shifts in sensitive ecosystems (Wright, 2017). The effects of animal trampling on ASALs accelerate surface erosion, enhancing albedo (Zerboni and Nicoll, 2019) and recursive effects of an altered 'ecology of fear' as humans protect livestock from predation (Wright, 2017) are argued to have reverberated across the already drying landscape of the Sahara after 8000 years ago. Many archaeological examples indicate the altering effects *Homo sapiens* had on the flora and fauna they came into contact with, leading to extinction, monocultures and a subsequent weakening of local biomes (example of cave paintings shown in Figure 4) thereby making these biotopes more susceptible to climate change.

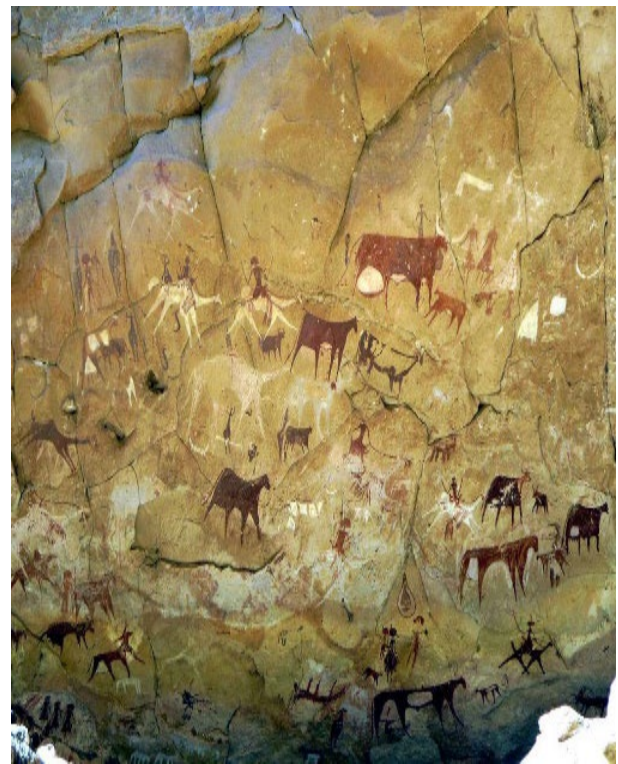


Figure 4. These prehistoric rock paintings were discovered in Manda Guéli Cave in the Ennedi Mountains, Chad, Central Africa. Camels have been painted over earlier images of cattle, perhaps reflecting climatic changes (Simonis et al., 2017)

Therefore, prior to the modern era and burning of fossil fuels driving anthropogenic climate change, human-induced land cover change was an entrenched feature of northern Africa's ecosystems. Humans have been drivers of landscape processes in the region for many millennia. The impact of humans on the

environment has, however, logically increased tremendously from the start of the industrial revolution (Foley et al., 2013).

Recognizing the connections and reciprocity between regional and global scale processes is crucial both in understanding historical climate shifts and managing those of the future (Foley et al., 2005). Taking on a new perspective that, over the course of human history, our interactions with the direct environment have contributed to shaping the global climate to what it is today, opens up opportunities to shape the global climate of the future, but now with intention.

IV. ACKNOWLEDGMENT

“The Weather Makers Foundation” has been established to set the plan for a regenerated Sinai in motion. This document has been created in a series with several other articles that detail the plan on Regenerating the Sinai. These documents are distributed freely.

V. REFERENCES

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