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Floodplain Catastrophes and Climate Change: Lessons from the Rise and Fall of Riverine Societies

PROFESSOR MARK G. MACKLIN
The Centre of Catchment and Coastal Research and River Basin Dynamics and Hydrology Research Group, Institute of Geography and Earth Sciences, Aberystwyth University

The concept of a benign or stable climate during the last 11, 500 years (Holocene) has been recently challenged by growing evidence that there have been numerous periods of rapid climate change, many of which lasted several centuries and had worldwide hydrological impacts. Examination of ~50 globally distributed palaeoclimate records reveals as many as six episodes of significant rapid climate change starting at around 7000 (9000–8000 cal yr B.P.), 4000 (6000–5000 cal yr B.P.), 2200 (4200–3800 cal yr B.P.) and 1500 BC (3500–2500 cal yr B.P.), and also at 750 (1200–1000 cal yr B.P.) and 1350 AD (600–150 cal yr B.P.). Most of these climate change events were characterized by polar cooling, tropical aridity, and major atmospheric circulation changes, although in the most recent interval at 1350 AD (600–150 cal yr B.P.), polar cooling was accompanied by increased moisture in some parts of the tropics.These phases of increased climatic variability have been at scales significant to humans and ecosystems and were frequently associated with catastrophic droughts or floods. Extreme hydrological events often appear to have coincided with major disruptions of riverine societies and well known examples include the collapse of the Akkadian Empire of Mesopotamia (the world's first 'hydraulic' empire) at the end of the 3rd millennium BC and the Moche civilization of northern Peru during the latter part of the 6th century AD. Both of these societies relied on irrigation of dryland floodplains for food production. Significantly, these events appear to mirror what is presently happening to global climate and the hydrological cycle as the result of anthropogenically caused increases in green house gases. We are not the first society to face the threat of environmental catastrophe resulting from rapid changes in catchment hydrology and river regime, but because of the world's rapidly growing population and its depletion of natural resources, we are now uniquely vulnerable to the effects of increased climatic variability.

Studying and understanding how past societies perceived, adjusted to and, in some instances, attempted to manage rapidly changing water resources might provide invaluable lessons for our current global crisis. However, this can only be done if we avoid the intellectual pitfall of seeing these events solely from an overly simplistic environmental deterministic viewpoint. The first complex urban societies in both the Old and New World all owed their development to local rivers that provided water for irrigation and growing crops. The responses of human societies to environmental change in the past, including the pre-industrial river (hydraulic) civilizations, are likely to have been highly complex and the 'smoking guns' of cultural and social change, migration and site abandonment preserved in the archaeological record and seemingly synchronous with rapidly changing environmental conditions, do not necessarily reflect society 'collapse' in response to singular or a series of extreme hydrological events. In this keynote address the long-term interaction between people and dynamic river environments are explored and critically reviewed in the context of two of probably the best documented periods of rapid Holocene climate change that occurred at c. 2250-1850 BC (4200–3800 cal yr B.P.) and c. AD 800 and 1350 (1150-600 cal yr B.P.). Both these events were of global significance and coincided with major cultural transitions and demographic changes. The first of these episodes of pronounced climate variability- the so called 4200 cal yr B.P. climate event – occurred towards the end of the 3rd Millennium BC and happened at or around the same time as major cultural and demographic changes in the world's first three urban civilizations – the Old Kingdom of Egypt, the Akkadian Empire of Mesopotamia and the Indus Valley Civilization. Using examples from my recent research in the Dongola reach of the River Nile in northern Sudan, I evaluate relationships between human settlement and varying river hydrology, channel form and location by matching changes in settlement patterns with radiometrically dated phases of river activity.

The second episode of pronounced climatic variability considered is the interval between AD 800 and 1350 popularly known as the Medieval Warm Period, but since climatic conditions during this interval were neither continuously warm nor optimum for human and animal populations, the name Medieval Climatic Anomaly (MCA) is preferred and used in this lecture. The MCA was a time of prolonged droughts and warm temperatures in many parts of the world, most notably in western North America and Central America. But in other regions, including Western Europe and the Mediterranean it was characterised by major floods. Because the MCA occurred in the relatively recent past, archaeological and historical records are sufficiently detailed to provide the information required to demonstrate synchrony with rapid climate shifts and to determine whether these changes are consistent with predicted responses to environmental stress and resource shortages.

The Holocene hydrology of the Nile is controlled by the intensity and geographical extent of the monsoon, related to the movement of the Inter-Tropical Convergence Zone north and south of the equator. The past and present flow of the Nile is therefore an excellent barometer of global climate change. With no major tributaries downstream of Wadi Hawar the flow of the Nile in northern Sudan and Egypt is entirely dependent on rainfall in the headwaters of the Blue Nile in Ethiopia and the White Nile in equatorial Africa. This places human communities in the lower part of the Nile Valley that rely on river water for irrigation especially vulnerable to rapid climate change.

Our research in the Dongola reach of the River Nile in northern Sudan, in conjunction with Dr Derek Welsby and his colleagues at the British Museum, began in the mid 1990s and was prompted by the observation that archaeological sites in this region were preferentially located along former river channels of Nile that in some cases are now more than 10 km from the present river. These former courses of the Nile were named the Alfreda, Hawawiya and Seleim channels by Derek Welsby and of particular archaeological interest were the concentration of sites along their margins belonging to the Kerma culture that date from the period c. 2500-1500 BC. The Kerma kingdom in Upper Nubia was a powerful independent state that arose in competition with Egypt with its wealth based on gold and floodwater farming of large tracts of fertile alluvial floodplains. However, precisely when these channels had been active and, most importantly, when they had dried up were unknown. Fortunately, the valley floor of the Dongola reach of the River Nile is 'pockmarked' with many hundreds of rectangular- or circular-shaped pits, many of which have been dug through Nile alluvium down to the underlying Nubian sandstone bedrock 4-6 m below present ground level. Diesel-powered pumps have been installed at the bottom of these pits to suck out groundwater to irrigate land for growing crops. These exposures have allowed us to reconstruct in great detail the three dimensional form of former channels as well as to sample alluvium and interbedded windblown material for dating using newly developed Optical Stimulated Luminescence techniques that allow us to establish when sediment was last transported either by flowing water or by the wind.

Both archaeological and sediment dating evidence indicates that Nile flows gradually switched from the Hawawiya (central) to the Alfreda (eastern) channel between the later Neolithic c. 4500-3500 BC and the beginning of the Kerma period at c. 2500 BC. This process, marked by the eastward shift of settlement and the focusing of sites within a progressively narrowing strip either side of the Alfreda channel, seems to have accelerated at or shortly after the well documented period of rapid climate change that began at 4200 cal yr B.P., which coincided with the collapse of the Egyptian Old Kingdom polity at c. 2200 BC. For the Kerma kingdom this climatic crisis appears not to have a catastrophic impact on local communities in Upper Nubia as seen in the Dongola reach of the River Nile where people shifted their settlements to the better watered parts of the floodplain that received more reliable seasonal flows. The Kerma kingdom continued to flourish for more than 500 years until ending abruptly at c. 1550 BC with its defeat by the Egyptians at the beginning of the New Kingdom. What emerged in our 2008 field season from sedimentological and dating studies of a hand-dug 2.5 m deep pit beneath the bed of the former Alfreda Nile channel is that regular seasonal flows ceased shortly before c. 1400 BC, coinciding almost exactly with the end of the Kerma culture. (Slide 14) Sediments in this channel comprises alternating beds of orange coloured blown sands, showing when the channel was dry and grey river silts indicating periods of Nile flooding. At the base of the pit are blown sands within which there are two thin layers of silt deposited by major Nile floods sometime between 1410-910 and 910-770 BC. In the middle part of the section dated to between 770-540 BC river silts are thicker indicating a return to seasonal flows in the Alfreda channel or a period characterised by exceptionally large floods in the main Nile. These are covered by blown sand that show the Alfreda channel again stopped flowing at c. 540 BC with the last two Nile floods recorded at around 240 BC and AD 330.

What distinguishes our research from similar studies elsewhere in the Nile Valley, and from those in Mesopotamia and in the Indus Valley, has been the dating of river channel and floodplain sediments (using luminescence techniques) that adjoin archaeological sites whose occupation span the late 3rd - early 2nd Millennium BC This enables for the first time changes in settlement patterns and culture to be precisely matched with radiometrically dated phases of river activity, particularly when channels were abandoned and ceased to flow. Unexpectedly and contrary to previous research on early agricultural societies in the Nile Valley dependent on floodwater farming, the Kerma culture continued to flourish during the environmental crisis centred at around 2000 BC with the number of settlements actually increasing in the period 2050-1750 BC. This goes against much that has recently been written on the impact of the 4.2 ka climate event on the Egyptian Old Kingdom, the Akkadian Empire and the Indus Valley Civilization and suggests that causal links in these regions between cultural change at this time and climatic variability may need to be re-evaluated. The end of the Kerma culture did occur suddenly but more than 500 years later coinciding within 100 years or so of the drying up of the Alfreda Nile shortly before 1400 BC. Both in Upper Nubia and elsewhere in the tropics c. 1500 BC is marked by pronounced aridity and the end of the Kerma culture at this time represents one of the best documented and dated examples of a climate change induced floodplain 'catastrophe' in the Old World. The presence and continuity of the Kerma culture for more than 1000 years followed by its demise in less than a century is noteworthy in any context. One scenario is that failing Nile floods in Upper Nubia resulted in the abandonment of large tracts of agricultural land weakening the Kerma kingdom and making it vulnerable to conquest by Egypt.

The MCA was marked by a wide range of changes in climate globally, including relative warmth over the North Atlantic/European sector and much of the extra-tropical Northern Hemisphere. The MCA is also the most recent natural counterpart to modern warmth and can therefore be used to test natural versus anthropogenic climate forcing in relation to the occurrence of extreme hydrological events and their impact of on riverine societies more generally. Some of the best documented examples of this come from North America especially in the American West where prehistoric agricultural communities during this period were badly affected by a series of devastating droughts and floods. One or more of three intense and persistent droughts impacted many North American cultures in the early-11th, middle-12th and late-13th century, including the Anasazi people in the Four Corners region of the western United States. The impacts of prolonged drought on these dryland agriculturalists that depended on rain-fed maize as a dietary staple can be assessed in remarkable detail because of tree-ring based climate reconstructions and tree-ring dated habitation sites. These show population crashes at around AD 1150 with abandonment of the region by AD 1300 coinciding with multi-decadal droughts during the middle-12th and late-13th century.

At around the same time irrigation agriculturists known as the Hohokam who farmed the valley bottomlands of the Gila catchment of south-central Arizona (within which the present day cities of Phoenix and Tucson are located) were affected by a series of catastrophic floods between AD 1020-1160. Prior to the middle-11th century river channels in the region were aggrading and created ideal conditions for the emergence and development of floodwater farming. Stratigraphic and ^{14}C evidence indicate that dramatic cultural reorganizations seen in the Hohokam archaeological record between AD 1050 and 1150 in the form of significant social change and population rearrangement coincided with a regional episode of channel down cutting and widening that left canal head gates high above the channel flow, making it impossible to restore the previously existing canal system. This new organization sustained itself until around AD 1400-1450, coinciding with another phase of channel erosion, when the Hohokam floodwater farming system finally collapsed, and villages and canals were abandoned. These floodplains were not farmed again for more than 400 years until the pioneer Jack Swilling visited the region in 1867 and saw from the old Hohokam ruins the potential for irrigation-based agriculture. The following year Swilling had a series of canals built following the line of the ancient Native American system, which prompted his friend Lord Darrell Duppa to name the settlement 'Phoenix' on the basis of its 'rebirth' on the ancient Hohokam site.

In Europe the MCA was also a period of rapid cultural, social and demographic development as well as time of dramatic river channel and floodplain change. However, unlike the examples of human-river environment interaction considered so far, anthropogenic activity was equally significant as climate change as an agent of floodplain transformation and in many catchments it was more important. An almost ubiquitous impact of the agricultural revolution of Middle Ages in Europe was the accelerated input of soil and sediment into river systems, and rapid and widespread floodplain sedimentation with rates commonly 10 times higher than in the pre-Medieval period. This resulted in the formation, primarily through the infilling of channels and lower-lying back-water wetlands, of the tabular-shaped floodplains that we see today in many European river catchments. A reduction in the amount of floodwater conveyed by river channels and stored on floodplains also led to an increase in overbank flooding. Similar order-of-magnitude increases in catchment erosion and sedimentation occurred following the introduction of European agricultural practices during the 19th century in both America and Australia. This huge increase in agricultural production in the Middle Ages created arguably Western and Northern Europe's first manmade environmental disaster with catastrophic erosion and flooding associated with the Great Famine of 1315-1317. This was followed by the exceptional storms and floods of July 27th and 28th 1342 in north-central Europe that exceeded all subsequent records. These late medieval floodplain catastrophes, unlike those that were occurring at around this time in North America, arose in part from the progressive deterioration of land under human use resulting from forest clearance at an unprecedented scale from the 9th to the 13th century. Some areas stripped by sheet erosion and gullying during the exceptionally severe weather events of the 1310s and 1340s were never farmed again. Ironically it took a greater humanitarian calamity - the Black Death of 1348-1350 - to lift land-use pressure and prevent further environmental damage.

My conclusion is that we can ill afford to ignore any lessons the natural environment has taught societies; not least because complex modern societies are likely to be more vulnerable to environmental impacts than were pre-industrial communities in the past. However, establishing causal relationships between, for example, river dynamics and cultural and demographic change is not a straightforward task and identifying possible natural environmental triggers of societal change is especially problematic. The solution may be to stress the inseparable nature of environmental and cultural influences, and view the physical environment as a delimiter of possible action rather than as a prescriptive agency. Nevertheless, the study of prehistoric and historical river societies do offer some rather sober warnings about the ability or not to adapt to climatic and environmental change. Today environmental and river catchment managers see adaptation as a means of minimising the adverse impacts of anthropogenic climate change. Adaptation, for example, 'by making space for water' is seen as something that is manageable and, by implication, predictable. But the long view of the archaeological record shows that adaptation has in the past been associated with great social upheaval that could not have been foreseen by those who were undertaking the adaptation. Past adaptation has occurred out of necessity, after damages have already been incurred and the view of adaptation as a means of neutralizing the impact of environmental change is a naïve one, particularly when such change is abrupt in nature as is typically the case in many riverine contexts. There is growing evidence from studies of floodplain environments from around the world for linked environmental and social change. The long list of riverine societies that have passed into history, who failed to adapt to the upheavals triggered by environmental change, suggests that it would be probably wise for us to plan for a worst case scenario!