Climate change: The great civilisation destroyer?

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War and unrest, and the collapse of many mighty empires, often followed changes in local climes. Is this more than a coincidence?

1200 BC. The most beautiful woman in the world, Helen, is abducted by Paris of Troy. A Greek fleet of more than a thousand ships sets off in pursuit. After a long war, heroes like Achilles lead the Greeks to victory over Troy.

At least, this is the story told by the poet Homer around four centuries later. Yet Homer was not only writing about events long before his time, he was also describing a long-lost civilisation. Achilles and his compatriots were part of the first great Greek civilisation, a warlike culture centred on the city of Mycenae that thrived from around 1600 BC.

By 1100 BC, not long after the Trojan war, many of its cities and settlements had been destroyed or abandoned. The survivors reverted to a simpler rural lifestyle. Trade ground to a halt, and skills such as writing were lost. The script the Mycenaeans had used, Linear B, was not read again until 1952.

The region slowly recovered after around 800 BC. The Greeks adopted the Phoenician script, and the great city states of Athens and Sparta rose to power. "The collapse was one of the most important events in history, because it gave birth to two major cultures," says anthropologist Brandon Drake. "It's like the phoenix from the ashes." Classical Greece, as this second period of civilisation is known, far outshone its predecessor. Its glory days lasted only a couple of centuries, but the ideas of its citizens were immensely influential. Their legacy is still all around us, from the maths we learn in school to the idea of democracy.

But what caused the collapse of Mycenaean Greece, and thus had a huge impact on the course of world history? A change in the climate, according to the latest evidence. What's more, Mycenaean Greece is just one of a growing list of civilisations whose fate is being linked to the vagaries of climate. It seems big swings in the climate, handled badly, brought down whole societies, while smaller changes led to unrest and wars.

The notion that climate change toppled entire civilisations has been around for more than a century, but it was only in the 1990s that it gained a firm footing as researchers began to work out exactly how the climate had changed, using clues buried in lake beds or petrified in stalactites. Harvey Weiss of Yale University set the ball rolling with his studies of the collapse of one of the earliest empires: that of the Akkadians.

It began in the Fertile Crescent of the Middle East, a belt of rich farmland where an advanced regional culture had developed over many centuries. In 2334 BC, Sargon was born in the city state of Akkad. He started out as a gardener, was put in charge of clearing irrigation canals, and went on to seize power. Not content with that, he conquered many neighbouring city states, too. The empire Sargon founded thrived for nearly a century after his death before it collapsed.

Excavating in what is now Syria, Weiss found dust deposits suggesting that the region's climate suddenly became drier around 2200 BC. The drought would have led to famine, he argued, explaining why major cities were abandoned at this time (Science, vol 261, p 995). A piece of contemporary writing, called The Curse of Akkad, does describe a great famine (*box next page*):

Weiss's work was influential, but there wasn't much evidence. In 2000, climatologist Peter deMenocal of Columbia University in New York found more. His team showed, based on modern records going back to 1700, that the flow of the region's two great rivers, the Tigris and the

Euphrates, is linked to conditions in the north Atlantic: cooler waters reduce rainfall by altering the paths of weather systems. Next, they discovered that the north Atlantic cooled just before the Akkadian empire fell apart (Science, vol 288, p 2198). "To our surprise we got this big whopping signal at the time of the Akkadian collapse."

> *For the first time since cities were built and founded,*
> *The great agricultural tracts produced no grain,*
> *The inundated tracts produced no fish,*
> *The irrigated orchards produced neither syrup nor wine,*
> *The gathered clouds did not rain, the masgurum did not grow.*
> *At that time, one shekel's worth of oil was only one-half quart,*
> *One shekel's worth of grain was only one-half quart. …*
> *These sold at such prices in the markets of all the cities!*
> *He who slept on the roof, died on the roof,*
> *He who slept in the house, had no burial,*

It soon became clear that major changes in the climate coincided with the untimely ends of several other civilisations (see map). Of these, the Maya became the poster child for climate-induced decline. Mayan society arose in Mexico and Central America around 2000 BC. Its farmers grew maize, squashes and beans, and it was the only American civilisation to produce a written language. The Maya endured for millennia, reaching a peak between AD 250 and 800, when they built cities and huge stepped pyramids.

Then the Maya civilisation collapsed. Many of its incredible structures were swallowed up by the jungle after being abandoned. Not all was lost, though - Mayan people and elements of their culture survive to the present day.

Numerous studies have shown that there were several prolonged droughts around the time of the civilisation's decline. In 2003, Gerald Haug of the Swiss Federal Institute of Technology in Zurich found it was worse than that. His year-by-year reconstruction based on lake sediments shows that rainfall was abundant from 550 to 750, perhaps leading to a rise in population and thus to the peak of monument-building around 721. But over the next century there were not only periods of particularly severe drought, each lasting years, but also less rain than normal in the intervening years (Science, vol 299, p 1731). Monument construction ended during this prolonged dry period, around 830, although a few cities continued on for many centuries.

Even as the evidence grew, there was something of a backlash against the idea that changing climates shaped the fate of civilisations. "Many in the archaeological community are really reticent to accept a role of climate in human history," says deMenocal.

Much of this reluctance is for historical reasons. In the 18th and 19th centuries, anthropologists argued that a society's environment shaped its character, an idea known as environmental determinism. They claimed that the warm, predictable climates of the tropics bred indolence, while cold European climates produced intelligence and a strong work ethic. These ideas were often used to justify racism and exploitation.

Understandably, modern anthropologists resist anything resembling environmental determinism. "It's a very delicate issue," says Ulf Büntgen, also at the Swiss Federal Institute of Technology, whose work suggests the decline of the Western Roman Empire was linked to a period of highly variable weather. "The field is evolving really slowly, because people are afraid to make bold statements."

Yet this resistance is not really warranted, deMenocal says. No one today is claiming that climate determines people's characters, only that it sets limits on what is feasible. When the climate becomes less favourable, less food can be grown. Such changes can also cause plagues of locusts or other pests, and epidemics among people weakened by starvation. When it is no longer feasible to maintain a certain population level and way of life, the result can be collapse. "Climate isn't a determinant, but it is an important factor," says Drake, who is at the University of New Mexico in Albuquerque. "It enables or disables."

Some view even this notion as too simplistic. Karl Butzer of the University of Texas at Austin, who has studied the collapse of civilisations, thinks the role of climate has been exaggerated. It is the way societies handle crises that decides their fate, he says. "Things break through institutional failure." When it comes to the Akkadians, for instance, Butzer says not all records support the idea of a megadrought.

In the case of the Maya, though, the evidence is strong. Earlier this year, Eelco Rohling of the University of Southampton, UK, used lake sediments and isotope ratios in stalactites to work out how rainfall had changed. He concluded that annual rainfall fell 40 per cent over the prolonged dry period, drying up open water sources (Science, vol 335, p 956). This would have seriously affected the Maya, he says, because the water table lay far underground and was effectively out of reach.

So after a century of plentiful rain, the Maya were suddenly confronted with a century of low rainfall. It is not clear how they could have avoided famine and population decline in these circumstances. Even today, our ability to defy hostile climes is limited. Saudi Arabia managed to become self-sufficient in wheat by tapping water reservoirs deep beneath its deserts and subsidising farmers, but is now discouraging farming to preserve what is left of the water. In dry regions where plenty of water is available for irrigation, the build-up of salts in the soil is a serious problem, just as it was for some ancient civilisations. And if modern farmers are still at the mercy of the climate despite all our knowledge and technology, what chance did ancient farmers have?

Greek Dark Ages

While many archaeologists remain unconvinced, the list of possible examples continues to grow. The Mycenaeans are the latest addition. The reason for their downfall has been the subject of much debate, with one of the most popular explanations being a series of invasions and attacks by the mysterious "Sea Peoples". In 2010, though, a study of river deposits in Syria suggested there was a prolonged dry period between 1200 and 850 BC - right at the time of the so-called Greek Dark Ages. Earlier this year, Drake analysed several climate records and concluded that there was a cooling of the Mediterranean at this time, reducing evaporation and rainfall over a huge area.

What's more, several other cultures around the Mediterranean, including the Hittite Empire and the "New Kingdom" of Egypt, collapsed around the same time as the Mycenaeans - a phenomenon known as the late Bronze Age collapse. Were all these civilisations unable to cope with the changing climate? Or were the invading Sea Peoples the real problem? The story could be complex: civilisations weakened by hunger may have become much more vulnerable to invaders, who may themselves have been driven to migrate by the changing climate. Or the collapse of one civilisation could have had knock-on effects on its trading partners.

Climate change on an even greater scale might be behind another striking coincidence. Around 900, as the Mayan civilisation was declining in South America, the Tang dynasty began losing its grip on China. At its height, the Tang ruled over 50 million subjects. Woodblock printing meant that written words, particularly poetry, were widely accessible. But the dynasty fell after local governors usurped its authority.

Since the two civilisations were not trading partners, there was clearly no knock-on effect. A study of lake sediments in China by Haug suggests that this region experienced a prolonged dry period at the same time as that in Central America. He thinks a shift in the tropical rain belt was to blame, causing civilisations to fall apart on either side of the Pacific (Nature, vol 445, p 74).

Critics, however, point to examples of climate change that did not lead to collapse. "There was a documented drought and even famines during the period of the Aztec Empire," says archaeologist Gary Feinman of the Field Museum in Chicago. "These episodes caused hardships and possibly even famines, but no overall collapse."

Realising that case studies of collapses were not enough to settle the debate, in 2005 David Zhang of Hong Kong University began to look for larger patterns. He began with the history of the Chinese dynasties. From 2500 BC until the 20th century, a series of powerful empires like the Tang controlled China. All were eventually toppled by civil unrest or invasions.

When Zhang compared climate records for the last 1200 years to the timeline of China's dynastic wars, the match was striking. Most of the dynastic transitions and periods of social unrest took place when temperatures were a few tenths of a degree colder. Warmer periods were more stable and peaceful (Chinese Science Bulletin, vol 50, p 137).

The Thirty Years war

Zhang gradually built up a more detailed picture showing that harvests fell when the climate was cold, as did population levels, while wars were more common. Of 15 bouts of warfare he studied, 12 took place in cooler times. He then looked at records of war across Europe, Asia and north Africa between 1400 and 1900. Once again, there were more wars when the temperatures were lower. Cooler periods also saw more deaths and declines in the population.

These studies suggest that the effects of climate on societies can be profound. The problem is proving it. So what if wars and collapses often coincide with shifts in the climate? It doesn't prove one caused the other. "That's always been the beef," says deMenocal. "It's a completely valid point."

Trying to move beyond mere correlations, Zhang began studying the history of Europe from 1500 to 1800 AD. In the mid-1600s, Europe was plunged into the General Crisis, which coincided with a cooler period called the Little Ice Age. The Thirty Years war was fought then, and many other wars. Zhang analysed detailed records covering everything from population and migration to agricultural yields, wars, famines and epidemics in a bid to identify causal relationships. So, for instance, did climate change affect agricultural production and thus food prices? That in turn might lead to famine - revealed by a reduction in the average height of people - epidemics and a decline in population. High food prices might also lead to migration and social unrest, and even wars.

He then did a statistical analysis known as a Granger causality test, which showed that the proposed causes consistently occurred before the proposed effects, and that each cause was followed by the same effect. The Granger test isn't conclusive proof of causality, but short of rerunning history under different climes, it is about the best evidence there can be (Proceedings of the National Academy of Sciences, vol 108, p 17296).

The paper hasn't bowled over the critics. Butzer, for instance, claims it is based on unreliable demographic data. Yet others are impressed. "It's a really remarkable study," deMenocal says. "It does seem like they did their homework." He adds that such a detailed breakdown is only possible for recent history, because older civilisations left fewer records.

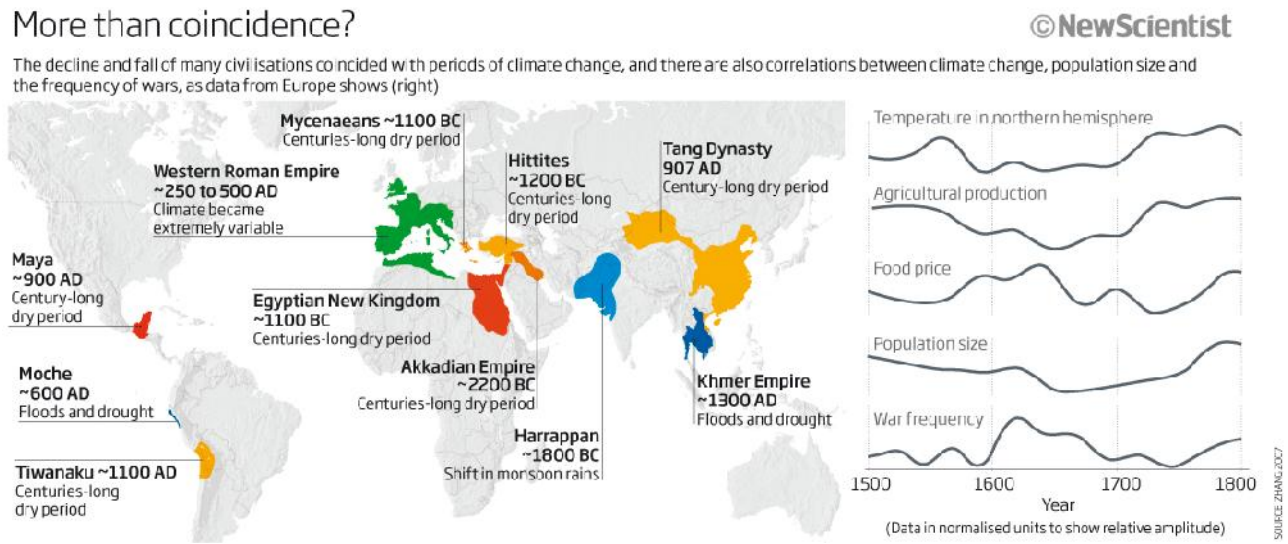
So while further studies should reveal much more about how the climate changed in the past, the debate about how great an effect these changes had on societies is going to rumble on for many more decades. Let's assume, though, that changing climates did play a major role. What does that mean for us?

On the face of it, things don't look so bad. It was often cooling that hurt past civilisations. What's more, studies of the past century have found little or no link between conflict and climate change. "Industrialised societies have been more robust against changing climatic conditions," says Jürgen Scheffran of the University of Hamburg, who studies the effects of climate change.

On the other hand, we are triggering the most extreme change for millions of years, and what seems to matter is food production rather than temperature. Production is expected to increase at first as as the planet warms but then begin to decline as warming exceeds 3 ┗C. This point may not be that far away - it is possible that global average temperature will rise by 4 ┗C as early as 2060Movie Camera. We've already seen regional food production hit by extreme heatwaves like the one in Russia in 2010. Such extreme heat was not expected until much later this century.

And our society's interconnectedness is not always a strength. It can transmit shocks - the 2010 heatwave sent food prices soaring worldwide, and the drought in the US this year is having a similar effect. The growing complexity of modern society may make us more vulnerable to collapse rather than less.

We do have one enormous advantage, though - unlike the Mycenaeans and the Mayas, we know what's coming. We can prepare for what is to come and also slow the rate of change if we act soon. So far, though, we are doing neither.



The Khmer

The Khmer empire, centred in what is now Cambodia, began in 802 AD. It built the astounding temple of Angkor Wat, dedicated to the god Vishnu, in the 12th century.

We now know that Angkor Wat was not, as long thought, a lone structure. It was the heart of a teeming city covering 1000 square kilometres, surrounded by even larger suburbs. Before the Industrial Revolution, Angkor was perhaps the world's largest city. But it was sacked and abandoned in 1431 apart from the temple, which by then had been taken over by Buddhists.

What made the Khmer abandon their metropolis? According to Brendan Buckley of Columbia University in New York, changes to the monsoon were a contributing factor. Buckley used tree rings to produce a yearly record of monsoon rainfall from 1250 to 2008. He found that the monsoon was weak in the mid to late 1300s. This was followed by a short but harsh drought in the early 1400s, just before Angkor fell. There were also a few years when the monsoons returned with a vengeance, causing severe floods.

Like many south Asian societies, the Khmer relied on the monsoon to water their crops. Canals and reservoirs channelled water to farms and homes in Angkor. Many are now filled with sand and gravel, carried in by floods, and Buckley showed the deposits in at least one canal date to the time of the collapse. This damage would have made it even harder to manage the water supply, at a time when it was already limited and unpredictable.

The Moche

Between 300 and 500 AD, a people called the Moche thrived and established cities along the coast of Peru. Their farmers built a network of irrigation canals, and grew maize and lima beans. Their capital boasts the largest adobe structure in the Americas, the Huaca del Sol.

Some of the people were giants for their time, reaching 180 centimetres, and may have had a ceremonial role as "kneeling warriors" who were ultimately sacrificed to the gods. After 560, however, the Moche civilisation began to decline. By the time they abandoned the coastal cities around 600 and moved inland, their irrigation channels had been overrun by sand dunes.

The decline may have been triggered by changes in climate. Studies of ice cores suggest that an especially intense El Niño cycle around this time produced intense rainfall and floods, followed by a long and severe drought.