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Úrsula Oswald Spring
John Grin
Czeslaw Mesjasz
Patricia Kameri-Mbote
Navnita Chadha Behera
Béchir Chourou
Heinz Krummenacher
(Eds.)

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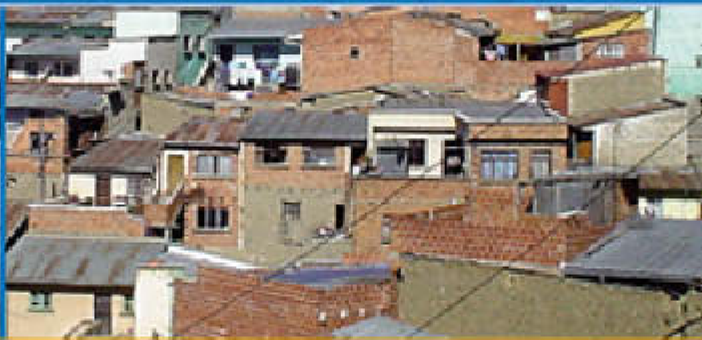


Facing Global Environmental Change

Environmental, Human, Energy, Food, Health and Water Security Concepts

Springer

Contents

5 Natural Climatic Variations in the Holocene: Past Impacts on Cultural History, Human Welfare and Crisis

Wolf Dieter Blümel

5.1 Introduction: Climate Change – Past and Future[1]

Since the late 20^{th} century, research efforts have increasingly focused on past, present, and future climatic changes, and on global environmental change. Their consequences for humankind are still uncertain, but they pose many dangers for human beings, societies and states, including for security. Scientists and non-governmental organizations are concerned as to how humankind could be affected by climatic mutations and could mitigate and adapt to some impacts. This refers to a change of paradigms: The last decades were characterized by a certain ignorance of natural determinations on cultural development (Issar/Zohar 2004).

This chapter reviews how even minor climatic fluctuations might have triggered sensitive environmental changes, and how they affected human activities and civilizations either positively or negatively. Highly industrialized societies are not protected from these natural challenges, but all societies are dependent on solid food and water supplies. Finally it will be discussed whether a retrospective view of (pre-)historic climate events may be helpful for predicting future developments.

During earth history the climate has never been constant – no matter what time scale is used or for whatever reasons. This chapter deals with the young Quaternary period, i.e. the past 20,000 years. It includes parts of the last glaciations, especially the *Last Glacial Maximum* (LGM), and especially the so-called *Holocene* of the past ten thousand years. This period is most important for the cultural development of humankind.

The Holocene as the post-glacial warm period has been perceived as the most stable climatic period of the past 130,000 years. Based on this unusual climatic stability during the past 10,000 years, many researchers and laymen assumed that the present global warming – indicated e.g. by the retreat of the glaciers since 1850 – has been caused by anthropogenic effects. Thus, global warming was interpreted as a catastrophe for humankind.

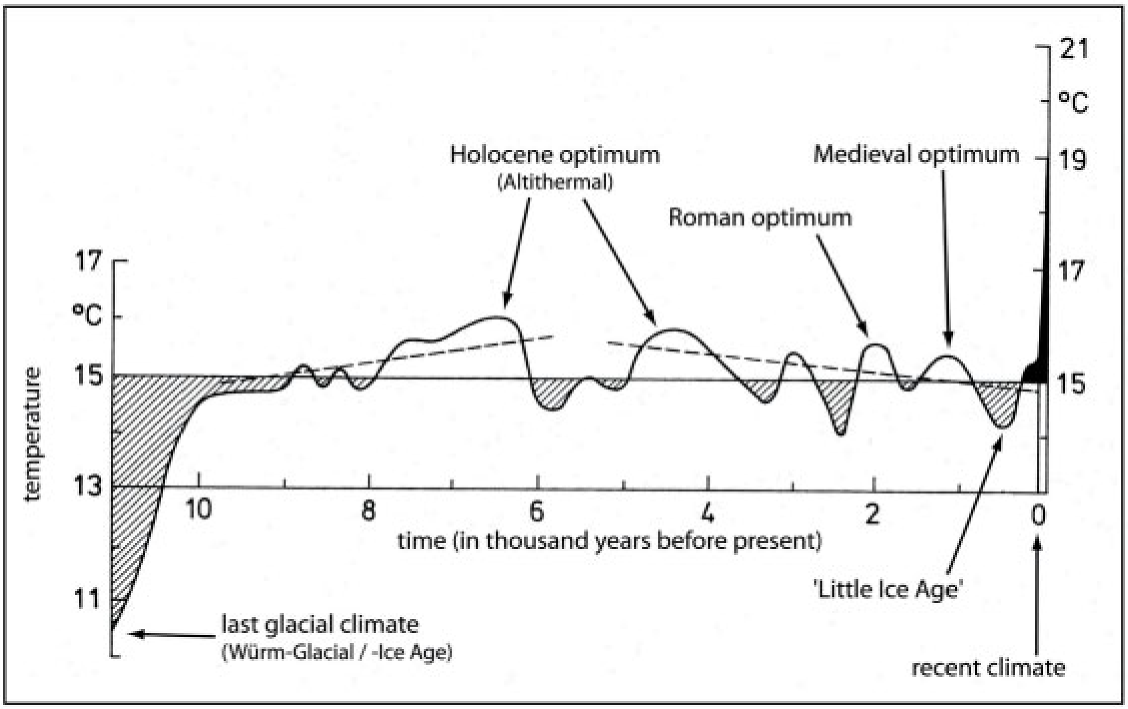
A series of natural climatic fluctuations could be reconstructed (see figure 5.1), using archives like pollen, moors, fossil soils, lake sediments, archaeological remnants, artefacts, etc. In prehistoric and historic times, warming was normally accompanied with various advantages for humankind. Warming increased the agricultural effectiveness and extended the arable land to higher latitudes or higher up into the mountains. Simultaneously, air humidity was also enhanced and the tropical monsoons brought more rainfall for larger areas in dry regions. With regard to climate history the following trends may be briefly summarized:

- climatic variations belong to the natural system and have different, partly complex causes;
- in the past periods of warming these mostly led to welfare and cultural progress;
- atmospheric cooling usually coincided with famine, drought, disasters, and cultural decline.

The following chronological references offer selected examples for these linkages and permit some conclusions on future developments. This chapter distinguishes between *climatic optima* and *pessima*. 'Climatic optima' are periods with mostly favourable conditions for human societies; while 'climatic pes-

1 This chapter partly relies on earlier German publications by Blümel (2002, 2006) and it is based on a lecture presented to a workshop. It does not aim at representative and comprehensive insights on the manifold aspects of the topic. It reflects the lead editor's invitation to offer an overview regarding past climate impacts on human welfare and on crises. It has been revised taking many valuable recommendations of anonymous reviewers from other disciplines into account.

Figure 5.1: Reconstruction of the Holocene climatic fluctuations. **Source**: Adapted from Schönwiese (1995) with permission by the author.



sima' are cooler periods with unfavourable, and often precarious living conditions.

Table 5.1: Stratigraphic Table of the Late Glacial and Holocene. **Source:** Blümel (2006: 18) adapted from the National Atlas of the Federal Republic of Germany 2003.

Stratigraphy	Stadial and inter-stadial period	Calendar years before present (cal BP)
Holocene (post glacial period)	Subatlantic	2,800 – 0
	Subboreal	5,100 – 2,800
	Atlantic	8,200 – 5,100
	Boreal	9,800 – 8,200
	Preboreal	11,590 – 9,800
Late Glacial Period	Younger Dryas	12,680 – 11,590
	Alleröd	13,370 – 12,680
	Elder Dryas	13,535 – 13,370
	Bölling	13,670 – 13,535
	Oldest Dryas	13,810 – 13,670
	Meiendorf	14,446 – 13,810
Last Glacial Maximum > 14446		

Reconstructing past climates resembles a difficult jigsaw puzzle: Meteorological measuring started in the 18th century. All climatic information on older periods must be gained from different indicators and archives. Those 'archives' can be e.g. descriptions, paintings, registered dates like grain prices, wine qualities, or crop quantities – they can be interpreted and 'translated' in climatic terms. Going further back into the past fossil soils, pollen and macro-biotic relicts, dendro-ecological or ice-core analysis, lake deposits, eolian sediments, or other geomorphological remnants deliver indirect climatic records. Only several such indicators can contribute to a more precise estimate of past conditions. Absolute datings (radio carbon) or archaeological findings may help to fix the time period concerned.

The author's scientific interest has focused on hot and polar deserts, landscape development and paleoecology. It was attempted to control, if even minor climatic variations or fluctuations have been expressed in peripheral and extreme regions of the globe. One additional method to identify climatic fluctuations is the behaviour of regional populations. Crop failure, starving, migrations, abandoning of settlements, etc. can be compared with references in so-called 'correlated or contemporary sediments' to obtain more reliable information on the attributes, impacts, and geographical range of climatic variations. Those (minor) fluctuations in the Holocene (table 5.1) have been overlooked for a long time in the previous paleo-climatic discussions.

5.2 Pleistocene Immigration – America's Early Inhabitants

During the Late Stone Age, periods of migration and distribution of human groups were directly influenced by paleo-climatic conditions. The global average temperature was about 11°C, or 4 to 5°C lower than today. In higher latitudes, huge ice domes covered the continents. In so-called peri-glacial areas in the middle latitudes, like in Central Europe, the annual average temperature was several °C below zero and the land was covered with tundra and cold steppe vegetation.

During the *last glacial maximum* (LGM) the sea level was about 130 metres lower. The bottom of shallow ocean floors dried up in some parts of the world. Thus, people could move even by foot between islands of the Asian archipelago and even to Australia. For the population in both Americas the drying of the Bering Strait between Siberia and Alaska had been crucial: bout 25,000 years before the present (BP), main stream theories assume that Mongolian groups immigrated to North America – the posterior 'indigenous' Indian population*).[2] Anthropologists investigated the population and settlement history of South America. They were surprised that the Monte Verde culture in southern Chile originated already 13,000 years BP (Blümel 2002).[3] How could this fast distribution be explained across huge distances, irrespective of immense obstacles like rain forests, mountain barriers, and rivers?

Paleo-geography offers an answer: The global atmospheric conditions in those periods of glacial maximum and late glacial periods were much cooler and had lower humidity. The vegetation cover all over the globe totally differed from today. In Middle and South America, the rainforest in the Amazon Basin had disappeared and remained only in small island-like patches (figure 5.2; Veit 2007; Whitmore 1993, 1990). Areas in between were savannahs, steppes or even deserts. Thus, the collector and hunter populations could migrate and spread rather quickly. These open landscapes offered abundant prey and vegetable food. Thus, this cool and precarious climate had favoured the early migration processes.

This example illustrates how climatic change really occurred: The margins of ecosystems shifted to a distinct alteration or even to a complete transformation of pre-existing ecosystems (for later developments in the Sahara see Kröpelin/Kuper 2007; Pachur/Altmann 2006; part 5.4.1 below). These integrative and structured natural systems work simultaneously as human habitats. Changes in natural conditions had automatically influenced the land-use pattern and mode, as well as productivity, etc.

Figure 5.2: Refuges of the Amazonian rainforest during the last glaciation, compared with the present situation. **Source:** Adapted from Haffer (1969) and Veit (2007) with permission of both authors.

5.3 North Atlantic Current: The First European Crisis

The transition from the conditions of the Ice Age to the next interglacial period (*Holocene*) was accompanied by periods of warming and cooling. The most effective intersection – the '*Younger Dryas Event*' about 13,000–11,560 yBP (years before present; table 5.1) – was caused by the outburst of huge quantities of melting water from North-America's collapsing ice shields into the Atlantic Ocean. This light sweet water

2 Other theories of the migration to America by boat (e.g. by Thor Heyerdahl, Norway and by Santiago Genovéz, Mexico) are neglected here. It is shown how climate variations affected and altered the global vegetation cover – the main source of human food.

3 See: G. Forster: "Wandertrieb im Blut", in: *Der Spiegel*, No. 3 (1997): 152–153.

interfered with the thermohaline convection and interrupted the North Atlantic Current (Gulf Stream) and its heating effect for the north Atlantic surroundings. Thus, large parts of Europe returned to a cold periglacial climate. Living conditions of the stone-age populations deteriorated, because woodlands disappeared again and the food supply with game, fruits and firewood became scarce. People had to move to more pleasant landscapes, i.e. to South-eastern Europe. The last impact of the ending glaciation in North-America occurred 8200 yBP, at the end of the Boreal period (table 5.1). Melting water once more affected the Gulf Current and led to a remarkable cooling in the North Atlantic, and possibly to a disturbance of the thermohaline circulation (Weiss/Bradley 2001). Many researchers are still looking for the geographical range and the ecological effects of the Younger Dryas, and the 8200 BC event. Those 'natural experiments' may teach what will happen if the Gulf Current is disturbed: Contemporary global warming with its melting of glaciers and Arctic sea ice has caused fears of a weakening or collapse of the North Atlantic Current. The present discussion on the future of the Gulf Current has been controversial (Bryden/Longworth/Cunningham 2005: 655; Lund/Lynch-Stieglitz/Curry 2006; Rahmstorf 2000; Rahmstorf/Schellnhuber 2006).[4]

5.4 Holocene Climatic Fluctuations During the Past Ten Millennia

According to the reconstruction of the Holocene climatic 'swing', some simplified and obvious correlations between climatic milieu and human welfare or crisis will be discussed. The aim is to signal the importance of the climatic environment for human behaviour in general. Favourable climatic conditions may support welfare, cultural rise, and social stability. On the other side: Fixed political or societal organizations may experience chaos, collapse or launch migrations. Looking back may give some picture of what will possibly happen in parts of the world if the global climatic change proceeds.

5.4.1 Postglacial 'Megathermal' - Global Welfare and the Neolithic Revolution

Caused by astronomic parameters like the inclination of the earth's axis and its gyroscoping, barging rotation (precession), the so-called postglacial thermal optimum ('*megathermal*' or '*altithermal*') occurred. Between 10,000 and 5000 yBP a global climatic change took place. It was the warmest period since the *late glacial maximum* (LGM) until now, with increased rainfall in dry lands (shrinking of deserts, expansion of savannahs and woodlands). The Saharian desert nearly disappeared (Claussen/Kubatzki/Brovkin/Ganopolski 1999; Claussen/Gayler 1997) and changed into a grassland and bush savannahs with lakes, periodic rivers and lots of game like antelopes, elephants or crocodiles (Kröpelin/Kuper 2007; Pachur/Altmann 2006). Numerous artefacts and fossils documented an abundant environment. The domestication of different animals and pastoral nomadic life emerged. The metamorphosis of the Saharian ecosystem is an impressive and amazing example for the ecological consequences of climatic variations.

This climatic optimum with regard to temperature, rainfall, and seasonal conditions led to the 'neolithic revolution' or a settled way of life: Agriculture developed in the Near East (and maybe simultaneously in other regions). Jericho is one of the oldest towns (9000 BP) and counterpart of Çatal Höyük in Anatolia (Issar/Zohar 2004 and chap. 6 below). From the 'fertile crescent' (Mesopotamia and adjacent regions) settlements spread to Europe (Müller-Beck 1983; Waterbolk 1968; Issar/Zohar 2004: 557ff). Impressive megalithic cultures settled also in higher latitudes (e.g. in Scotland, Orkney Islands) referring to optimal agricultural conditions and abundant food production to create stone circles like the Ring of Bodgar, Stonehenge, or large megalithic tombs. Astronomic functions and calendars that were integrated into these monuments point to the importance and the perception of the climatic framework within the Neolithic civilization.

It is obvious to recognize the Megathermal period of the Holocene as the mystic 'paradise', or the 'garden of Eden' or the famous 'golden era'. It seems to have been a time of easy living and of a surplus of 'human energy'. All this can be explained by a high and reliable landscape potential, caused by optimal climatic parameters. The impressive megalithic monuments correspond with the social and economic opportunities of those times. This mega-architecture seems to belong to advanced civilizations, and it evi-

4 Susanne Donner: "Viele Modelle – eine Tendenz: Ergebnisse aus Klimasimulationen unterscheiden sich nur im Ausmaß des Klimawandels"; at: <http://www.wissenschaft.de/wissenschaft/hintergrund/271519.html?Page=2> (3 November 2006).

dently evolved in favourable warm climates. Similar conclusions may also be allowed for later climatically optimal periods, e.g. concerning the famous Gothic architecture in Europe or the Maya sites in Yucatán, Mexico (see fig. 5.9, 5.10, 5.11).

5.4.2 Cooling Climate - The End of Paradise

The 'end of paradise' occurred immediately. A famous witness of a climatic jump was the well-known 5,300 years old snow-mummy named 'Ötzi'. This member of the Neolithic groups living in the North Italian Alps (South Tirol) was found on a ice free yoke in the Austrian Ötztal Alps. Ötzi probably died in a blizzard, remained permanently buried, and became mummified in the hard snow until 1991 (Blümel 2002). During the altithermal period of the Holocene, the glaciation of the Alps was less expanded than today. The tree line reached 200-300 metres further up. Neolithic summer camps (seasonal grazing) have been found in the high alpine region (e.g. close to the village of Obergurgl in North Tirol). Ötzi's death documents the rapid end of the postglacial Altithermal in Central Europe. The beginning of the following cold Bronze Age was an extreme time of deterioration and of agricultural crisis (crop failure) in Europe, accompanied by frequent famines and loss of population ('Piora-oscillation', Schönwiese 1995). The atmospheric cooling that was accompanied by strongly diminished precipitation ended the 'green Sahara' and the desert expanded again (see 5.5.1). Similar processes could also be reconstructed in eastern Chinese drylands: up to 3400 yBP, these regions have been humid woodlands. Documents prove that in about 2200 yBP the northeast showed a dry climate with steppes and desert conditions (Tarasov/Wagner/Guiyun 2007). Concerning the Mediterranean, Issar/Zohar (2004: 101) stated:

> In detail the proxy-data from the Soreq Cave show that a warm and dry period starting around 3500 BCE and lasting a few decades to a century, a cold and extremely humid climate followed, continuing until 3300 BCE. Then came an extreme dry period, peaking around 3200 BCE, followed again around 3000 BCE by a cool and humid period that lasted, with some interruptions, for about seven centuries.

This statement makes clear that contemporary climatic variations express their individual dynamics and features within the different regions and landscapes of the globe. Another example from Mesopotamia also stresses this aspect:

> By 3500 BC, urban Late Uruk society flourished in southern Mesopotamia ..... But these colonies and the expansion of Late Uruk society collapsed suddenly at about 3200-3000 BC. ... Now there are hints in the palaeoclimatic record that it may also be related to a short (less than 200 years) but severe drought (Weiss/Bradley 2001).

Have these two examples been an incidental parallel to Ötzi's death?

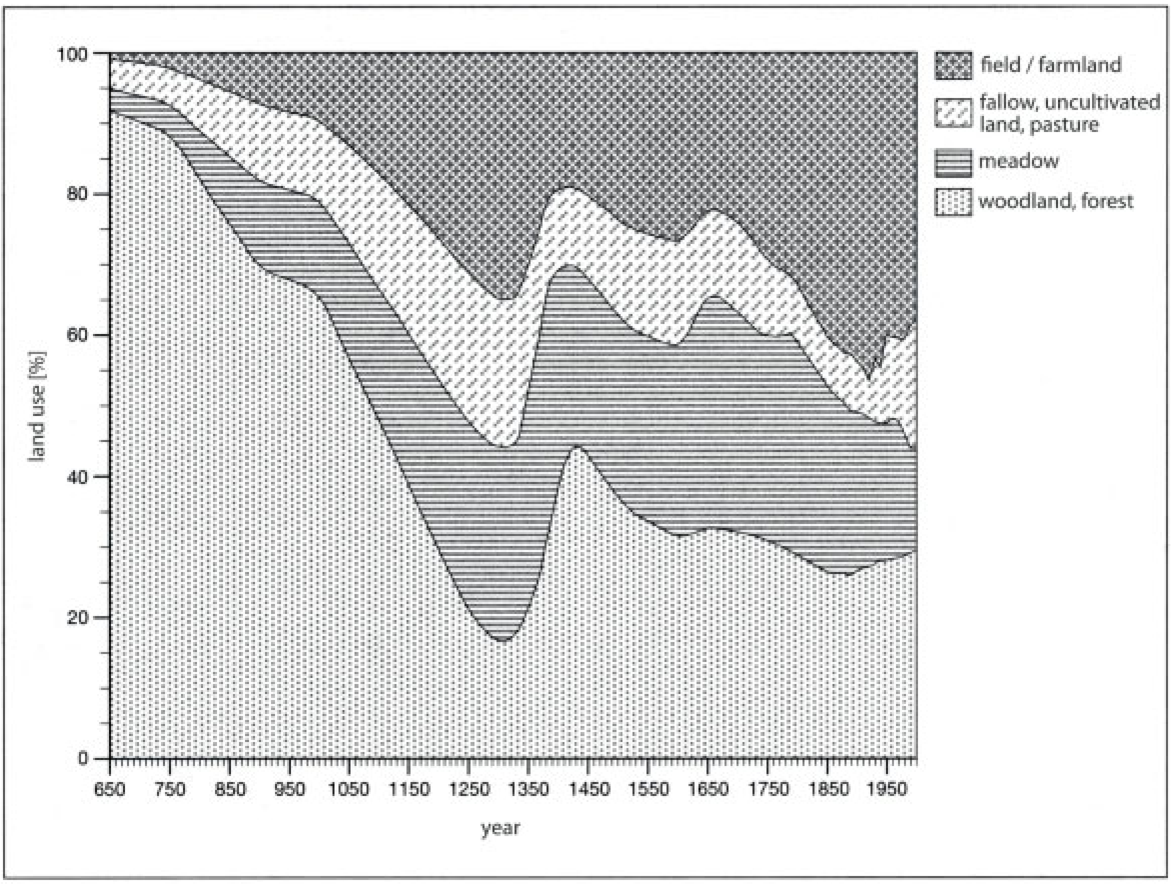
5.4.3 Celtic Culture and Roman Empire: A New Warm Period

The Celtic period (during the Iron Age) started around 700 or 600 BC with the Hallstatt culture and was supported by an appreciable improvement of the climate. Since the 7^{th} century BC the population was growing, the society became complex and hierarchically structured. Centralization occurred steadily and towns emerged. Widespread connections in trade and cultural exchange flourished (e.g. with Greece and other Mediterranean regions). Since the 4^{th} century BC, climatic deterioration stopped this cultural development and Celtic society collapsed. Large migrations started to Southern Europe, the Balkans, and Asia Minor.

A revival of Celtic culture took place in the La Tène era. During the following times the Roman Empire expanded and occupied Celtic and Teutonic territories. Roman cities were founded in *Germania*, supported by an abundant agricultural production. The impressive architectural remnants point to welfare, civilization, and surplus. The administration of these northern territories was facilitated as the Alps could be crossed even in winter. Indicators hint to stable climatic conditions with only low variability – the so-called *Roman climatic optimum*. The warmer climate allowed the growth of grapes even in Britain. Successful trade could be maintained from north to south. More humid conditions supported intensive west-east trading and cultural exchange along the Silk Road to China. Yang, Braeuning, Shi, and Chen (2004) reconstructed a warm and humid period in the arid zones of northwest China between 2200 and 1800 yBP.

The rise and fall of the Roman Empire was evidently accompanied and partly steered by climatic circumstances, which are also reflected in other parts of the world. It can be regarded as a model for expansion and growth, supported by favourable climatic conditions (Lamb 1982, 1989; Schönwiese 1995). To mention only one military aspect: A huge army oper-

Figure 5.3: Development of the land use expansion in Germany since the European peoples' migration. The medieval climatic optimum caused an increase in population and a wave of foundations of towns. Woodlands were cleared and transformed into fields, pasture and fallow. During the 13th century woodlands declined below 20 per cent of the total area. With the beginning of the next climatic crisis after about 1330 (Little Ice Age) the agricultural land shrank and forests spread again. **Source**: Adapted from Bork/Bork/Dalchow/Faust/Piorr/Schatz (1998) with permission of the authors.



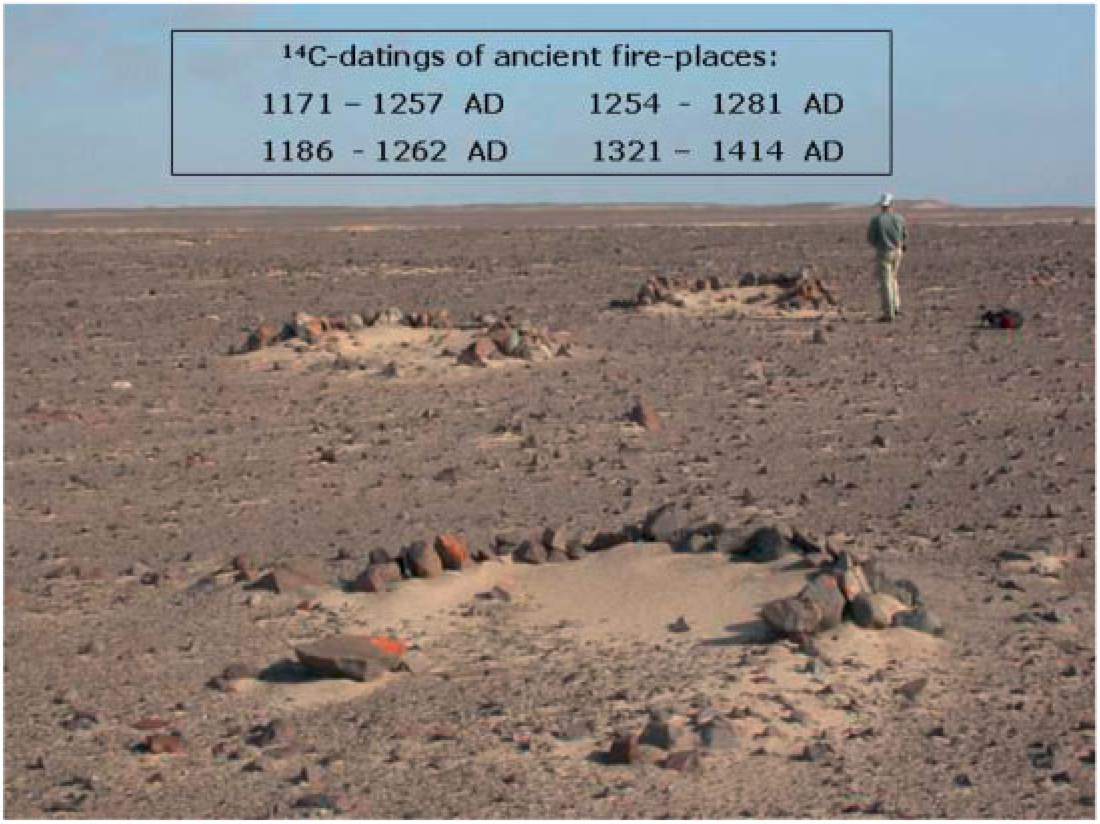
ating distant from home must be supported by the occupied lands. Insufficient crops and livestock slow down or prevent military gains. The fall may have been accelerated by disturbances, social crises, and migration movements that were triggered by precarious circumstances. (For a detailed discussion of the Roman fate see: Gibbon 1776-1788, 1983; Huntington 1915, 2001; Lamb 1982, 1989; Brown 2001, Bradley/Jones 1992).

5.4.4 The Climatic Crisis: European Peoples' Migration

Between antiquity and the Middle Ages an evident climatic crisis took place. Climate deteriorations triggered population movements. The most well-known consequence was the European mass migration from the 3rd to the 6th century. The beginning of this 'mysterious' process – fraught with consequences – can be explained with crop failure and famines caused by the worsening (or cooling) of the climate. Especially tribes living in Northern or North-western Europe were affected. Malnutrition and social unrest may have been responsible for the mass migrations and conflicts in Europe which contributed to the collapse of the Roman Empire. The famous 'Silk Road' was abandoned due to water shortage and lack of supplies. Increasing aridity in the Asiatic steppes may have been one climatically determined cause for the advances of the Huns (Brown 2001).

The lack of impressive architectural sites was a typical outcome of hardship: There was no surplus or time for demanding cultural activities under those circumstances. On the contrary, destruction and chaos determined life more than development. Social turbulence, collapse of social structures, migrations, and

Figure 5.4: The hyper-arid Skeleton Coast Desert (Namibia): Numerous stone settings of wooden-made wind-shelters, charcoal, bone-remnants of antelopes or lions and ostrich-pearls refer to a former savannah-ecosystem in the present desert. **Source:** photo by Blümel (2006).



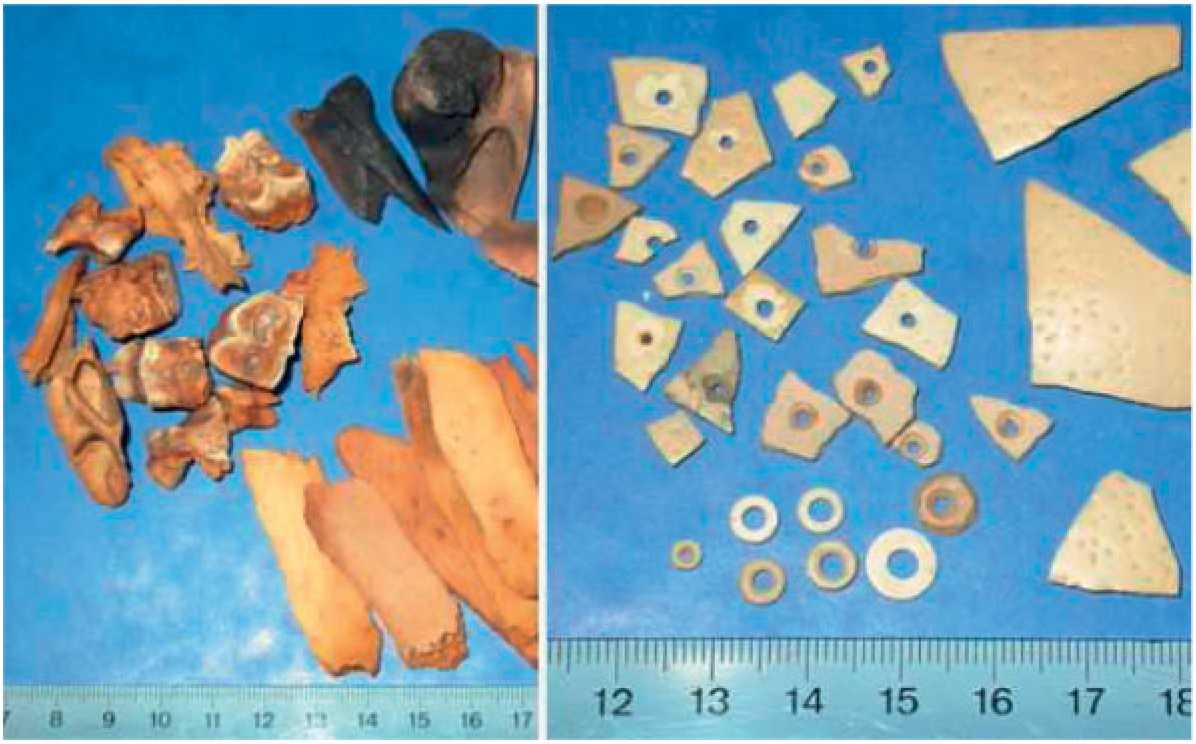
conflicts determined the way of life. The scenario of the European migration of people could point to a scenario for regional processes that may be triggered by future climatic changes, especially in less developed countries.

5.4.5 Medieval Warming: Population Growth and Urban Life

Based on the hypothesis that climatic warming contributed to cultural development, a persuasive proof can be found in the European middle and higher latitudes (Bradley/Jones 1992; Brown 2001, Glaser 2001; Hsü 2000; Lamb 1982, 1989). The medieval times (between 1000 and 1330 AD) are marked by a warming and climatic stability, which resulted in high agricultural productivity and a surplus of food, and thus caused an immense population growth. In Central Europe, thousands of cities and villages were founded, establishing the present settlement network. Agricultural production spread out again into the low mountains, more than 200 metres higher than today. Labour-sharing, manufacturing, trading, and services developed, supported by the productive rural surrounding. With regard to future effects of climatic change the stable weather and seasonal conditions were important as a guaranty for abundant crops. Thus large wooden areas had to be cleared. The woods dropped to less than 18 per cent of the German surface (Bork/Bork/Dalchow/Faust/Piorr/Schatz 1998; figure 5.3)

The fascinating Gothic architecture symbolizes until today the prosperity and surplus of those times. The medieval period is another example for the dynamic of climatic optima: Reliable and high agricultural productivity was the indispensable prerequisite for creating social and political structures, and it led to a distinct diversity of techniques and cultural development. This climatic framework has been the basis of welfare during all times, irrespective of the systems of rule. The medieval warming also benefited higher latitudes: Grain production was possible in Scandinavia north of the 65° latitude; vineyards grew in Southern Scotland. The polar pack ice retreated considera-

Figure 5.5: ^{14}C-radiocarbon dated by B. Kromer proves the medieval age of these archaeological findings. **Source:** photo by Blümel (2006).



bly. The Normans (or Vikings) settled in Greenland and Iceland, where even grain could be produced (Brown 2001; Lamb 1982). Starting from there, America was discovered prior to the Spanish Conquest.

In *lower latitudes*, the deserts partly shrank in some periods due to increasing humidity (Namib, Atacama). Indigenous southwest African cultures like hunters or pastoral nomads profited from these hydrologic fluctuations. The higher (global) temperatures have been evidently correlated with a greater monsoonal reach and augmented rainfall. These conditions were instrumental for stone-settings belonging to former huts or wind shelters dating back into the medieval period (Blümel/Hüser/Eitel 2000; figures 5.4, 5.5). The present deserts must have been tropical savannah (grassland with bushes or smaller trees).

The shifting margins of the desert depending on the reach of monsoonal precipitation are among the most common problems of people living in semi-arid regions. It is the small and large-scale climate variability. Times of warming strengthened the monsoon reach and triggered human activities, enlarging their territory and welfare. On the other hand, atmospheric cooling caused aridity and increased short-time variability followed by retreat, migrations or collapse of civilizations.

5.4.6 Climatic Pessima: The Little Ice Age with Famines, Social Crisis and Emigration

The so-called ‘Little Ice Age’ was the last pessimum in the Holocene see-saw of climatic fluctuations. It lasted from about 1330 up to 1850 AD (see figure 5.1). In the early 14th century, climatic conditions deteriorated again: Seasons proceeded irregularly, the vegetation period suffered, ending up in frequent crop failures (Brown 2001; Glaser 2001; Lamb 1982). The greatest disaster in Central Europe within the last thousand years was caused in 1342 AD by a long and heavy rainfall with cloud bursts and thunderstorms (Bork et al. 1998). It is assumed that half of the total soil loss by erosion since the introduction of agriculture is due to this single event. People starved and abandoned the settlements in the lower mountains due to cooling and various unfavourable conditions. The concentration of rural refugees in urban areas led to increasing hygienic problems. Plague spread and killed a high number of victims. The German territory lost about 50 to 60 per cent of its population.

The climax of this crisis was reached between the 16th and 18th centuries. Glaciers advanced, symbolizing periods of distinct cooling with all consequences such as malnutrition. Storms, floods, and

Figure 5.6: Albrecht Dürer's (1525): *Apocalyptic Riders* symbolizes the horrors of the 'Little Ice Age'. **Source:** Internet.

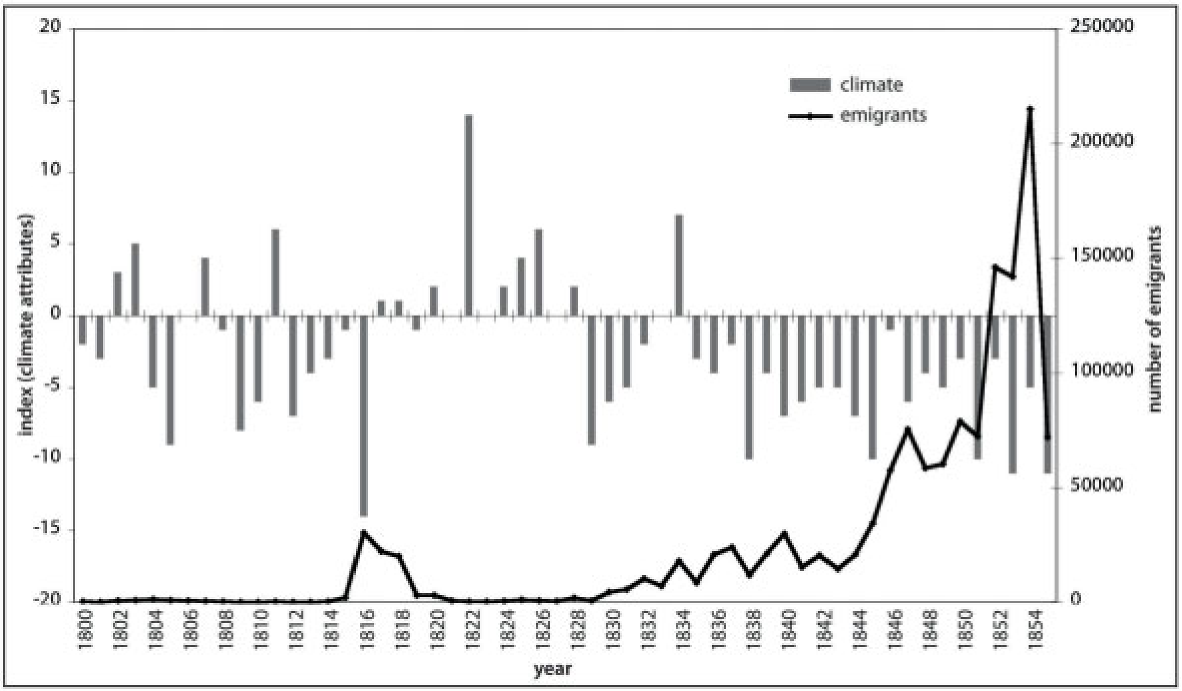
other natural hazards threatened the population. A differentiated documentation of the 'climate downturn' is provided by Brown (2001) and Glaser (2001). Distress and deprivation destabilized the social and political system. The farmers – under severe pressure from their rulers - started rebellions and attacks (1525 AD), but lost their struggle. An additional consequence for the following centuries was that the farmers fell by the wayside, were extremely exploited, and had no rights (especially during the period of absolutism). Overseas emigration took place in waves, triggered by starving, social crises and armed hostilities or wars (especially during the Thirty Years War from 1618 to 1648). Hundreds of thousands of people lost their lives in these decades. Parts of the country were totally devastated. Albrecht Dürer painted his famous 'Apocalyptic Riders' or 'Knights, Death, and Devil' as symbols of the complex horrors of those times (figure 5.6).

Another famous rebellion and radical social change was presumably also triggered by the results of a pernicious climatic constellation, which prevented sufficient food supply for the majority of the population: The French Revolution of 1789 can be regarded as symptomatic: unfavourable climatic conditions (pessima) have often caused or contributed to the destruction of the political and social systems, sometimes under chaotic and anarchic circumstances (Stock 1996: 38).

Many people tried to find a way out of the troubles by emigrating, especially to the 'New World'. The last huge emigration wave left from Ireland and Scotland immediately prior to the end of the 'Little Ice Age' (1845-1850; Ruess 2005). Several years with dramatic crop failure (esp. rotten potatoes) were the main reason. Emigration was not only pushed by desperate situations, but there were also pull factors. The close causal correlation between negative climatic consequences and emigration overseas is illustrated in figure 5.7.

The title 'Little Ice Age' is not really proper: There have been also warm periods in these five hundred years. Ice was not a real problem for the people. As mentioned above, glaciers advanced temporarily but remained in the inner Alps. On the other side, these 'dark centuries' yielded very warm or respectively hot periods. The natural reasons for these internal changes can be found in less solar radiation (Spörer and Maunder minimum; Rahmstorf/Schellnhuber 2006) and solar variability, partly in volcanism (deMenocal 2001: 668). The latest hypothesis to explain the Little Ice Age period was published by Lund, Lynch-Stieglitz, and Curry (2006: 601): Relating to isotope analyses in marine organisms, the North Atlantic Current (Gulf Stream) should have been ten per cent weaker than today. West and Middle Europe received less warmth during the Little Ice Age. One effect was that connections between Denmark and the Normans on Greenland were interrupted. The Inuit population pushed away the weak Vikings and took over their settlements (Lamb 1982, 1989). In general, the atmospheric cooling was connected with a distinct uncertainty and irregularity concerning the course of seasons – the basis for agricultural production (Hummler 1994). Figure 5.8 shows for the 16th century several years in a row with bad weather conditions for sufficient yields. Agrarian societies are very sensitive and vulnerable to such events. Even short series of small or missing yields can evoke an existential food crisis, especially when trade connections or food imports were undeveloped. This simple scenario still applies to many less developed countries. Highly industrialized countries with food reserves can also be affected. These factors should be taken into account when con-

Figure 5.7: The last phase of the 'Little Ice Age': Climate indices above the axis symbolize favourable years for agricultural production etc, indices below (-x) represent precarious years with insufficient crops. The correlation between bad years and the number of emigrants becomes clear. **Source:** Adapted from Ruess (2005) with permission of the author.



temporary global environmental changes are being discussed.

5.5 Climate Change: A Trigger for Growth and Collapse of High Civilizations

After this rapid and cursory excursion through 20,000 years of climatic 'ups and downs', three additional examples will be discussed to emphasize the evident correlation or interaction between climatic environmental conditions and cultural as well as social reactions. The simple hypothesis is that to establish and maintain a structured and culturally highly developed society requires an efficient and reliable primary sector.

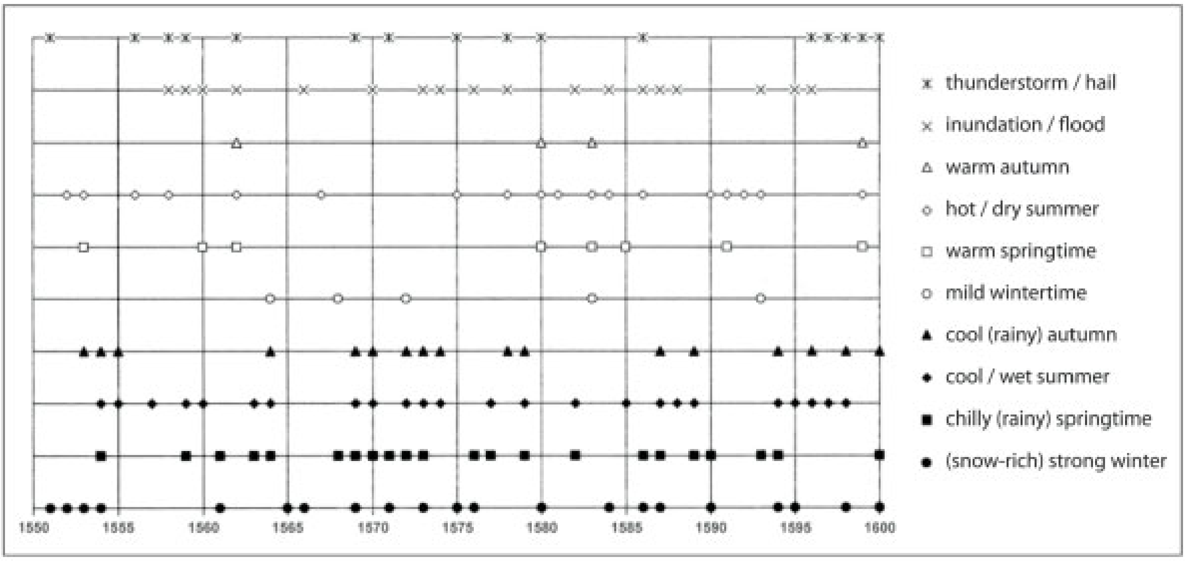
5.5.1 Egypt

The famous Nilonian culture was a 'child of the desert'. During the postglacial Altithermal with its luscious rainfalls (see section 5.4.1 above), the Saharian neighbourhood was a green open savannah – full of animals and people. The River Nile and its opulent valley oasis were only scarcely inhabited in those times. The abundance of water seems to have been less important or even a disadvantage for settlers. Maybe the giant seasonal floods threatened the people. Anyway, the livestock in the 'green Sahara' apparently seems to have attracted people (Kröpelin/Kuper 2007; Pachur 2006).

This changed when the postglacial Altithermal ended around 5300 yBP (3200 BC) and the savannah dried out, and became a desert again (Kröpelin/Kuper 2007). People retreated and, as 'desert refugees', they discovered the oasis of the river Nile and its potentials. Its floods diminished, could be controlled, and served since then as the base of a new agriculture. Irrigation was the technique and a guaranty for crops during the whole year. Abundant fertility and high productivity led to an immense population growth. A feudal regime arose, supported by the surplus (the Old Empire 2620–2100 BC). The famous pyramids symbolize the welfare of the leadership and of the upper class. On the other side, without an abundant food supply and of slaves and workers, the enormous buildings and tombs could not have been realized. (See Issar/Zohar 2004, 2007 on Egypt, and Bolle 2003 on the Mediterranean in general).

In Egypt, climatic worsening (i.e. expanding desert conditions) led to the depopulation of the former sa-

Figure 5.8: Reconstruction of weather and seasons in the 16th century: Germany often suffered during the Little Ice Age under several year-long phases of bad weather conditions. The seasons strongly varied, were incalculable, and prevent a successful sowing and crops. Famines and social crisis occurred frequently. **Source:** Hummler (1994).



vannahs, but it also contributed to innovative cultures and civilizations outside these regions. This example demonstrates the importance of a reliable access to water. In times with declining rainfall and drought in the width of land, waters from distant humid catchments (Ethiopia, Uganda) formed the basis for a new high culture. Such 'exotic rivers' like the Nile occur rather often in dry lands and act as 'arteries' of rural and urban life. Facing global environmental change, even these opulent hydrological systems may change, causing scarcities and conflicts (see the chap. 48 by Adly/Ahmed and chap. 49 by Kameri-Mbote/Kindiki in this vol. on water security in the Nile River Basin; and chap. 68 by Ejigu on environmental conflicts in the upper Nile Basin countries).

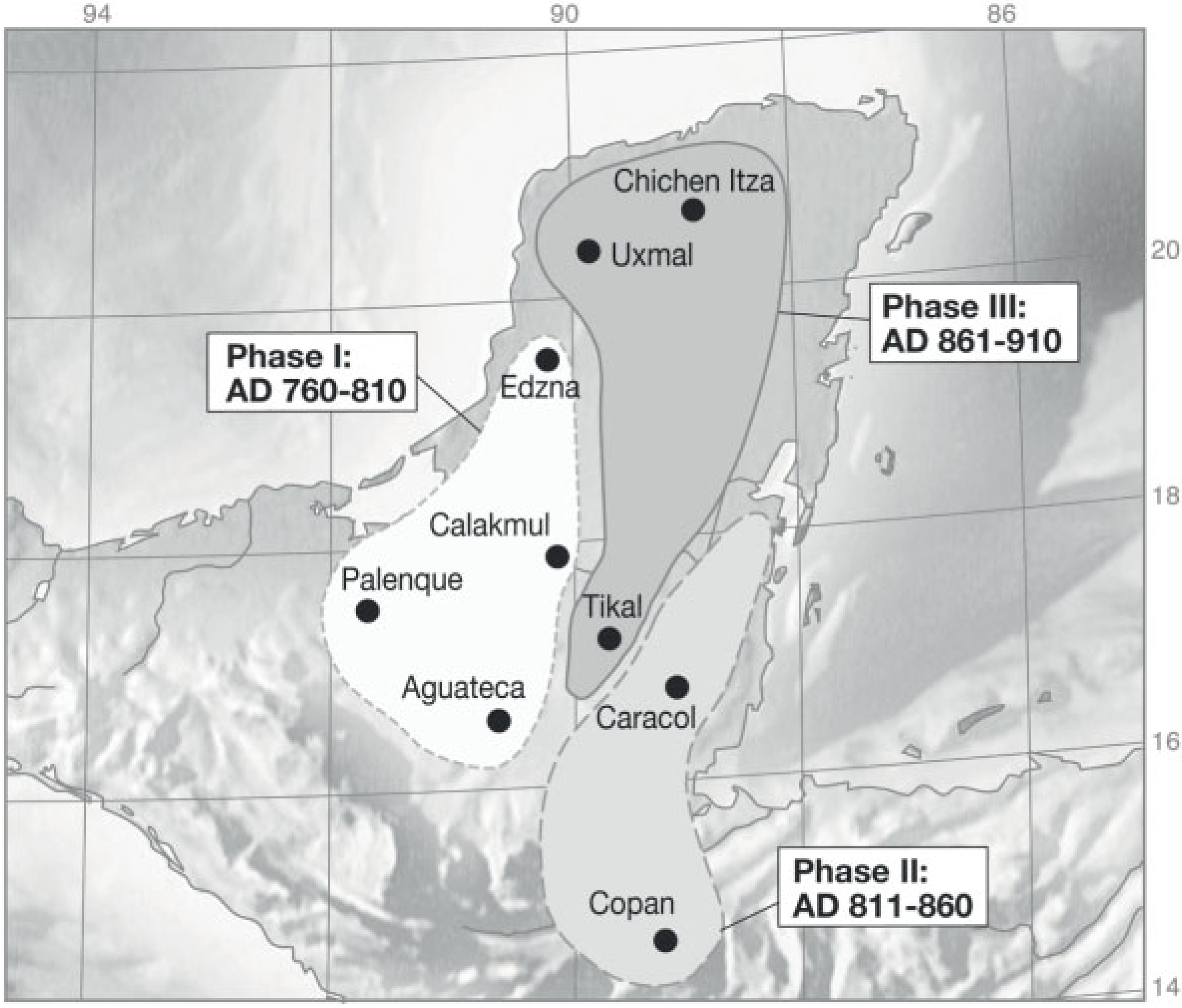
5.5.2 Nasca Civilization: Shifting Desert Margins

Mysterious engravings – giant 'geoglyphes' – are the most well-known characteristics of the Peruvian Nasca civilization. Its fate can serve as an icon to demonstrate the integrative relationship between human beings, climate, and the topographic environment. The previous Paracas culture developed between 800 and 200 BC, followed by the Nasca people. They lived from 200 BC in the fertile river oasis in the Atacama Desert close to the Pacific.

In the Middle of the Nasca Period (after 250 AD) people suffered under increasing aridity. The effectiveness of monsoonal rainfall decreased and the desert margin shifted eastward. Nasca settlements subsequently moved upstream into the mountains. Culminating aridity about 600 AD probably caused the collapse of the Nasca civilization (and of adjacent cultures like the Moche further north). Geomorphological and paleo-ecological investigations support the hypothesis that climatic drought (aridification) and not – as hitherto assumed – El Niño events brought the Nasca culture to collapse (Eitel/Hecht/Mächtle/Schukraft/Kadereit/Wagner/Kromer/Unkel 2005).

Four hundred years later, the eastern Atacama was reoccupied (during the late intermediate period between 1000 and 1400 AD), what coincided with the climatic optimum in Europe and in other parts of the world. The desert then shrank into a small strip of about forty kilometres. *Ciudad Perdida* or the 'Lost City' (Unkel/Kadereit/Mächtle/Eitel/Kromer/Wagner/Wacker 2006) is a giant archaeological witness for the medieval comeback of the rainfall into the lower parts of the western Peruvian Andes. Archaeologists could document that this community – situated elevated on a mountain saddle – had great importance in trade and could supply itself from local rainfall and nearby field terraces (Unkel/Kadereit/Mächtle/Eitel/Kromer/Wagner/Wacker 2006).

Figure 5.9: Phases of the Maya collapse during early medieval times: The main reason is to be seen in droughts and in a great variability in rainfall. **Source:** Adapted from Arz/ Haug/Tiedemann (2007) with permission of the authors.



5.5.3 The Mayan Collapse: Natural Causes for Cultural Dcline

The discussions and hypothesis about the collapse of the Maya civilization (Yucatán Peninsula) are rather old and contradictory.[5] New investigations on sedimentary cores taken on the shelf north of Venezuela prove that climatic changes – increasing drought and great variability in rainfall – diminished the agrarian productivity and water resources between 810 and 910 AD. Haug/ Günther/ Peterson/ Sigman/ Hughen/ Aeschlimann (2005) succeeded in reconstructing the exact time schedule of the proceeding decline. Increasing aridity caused the collapse (figure 5.9). At first, the region around Palenque (figure 5.10) and Calakmul was abandoned (AD 760–810), followed by Copan and Caracol (AD 811–860), and finally in the north with Uxmal (figure 5.11) and Chichén Itzá (AD 861–910; figure 5.12; Arz/Haug/Tiedemann 2007; deMenocal 2001; Peterson/Haug 2005; Curtis/Hodell 1996).

5 There are different positions to be found in the literature: e.g. Webster (2002) argues with the disproportion between population and resources. In Culbert (1973) different opinions are presented. Demerest/Rice/Rice (2004) hint at the complicated findings in different archaeological sites and neglect uniform ecological interpretations. Huntington (1915), as famous representative of deterministic explanations presumed, that an increasing precipitation was responsible for the Mayan collapse

Figure 5.10: The Mayan Archaeological Site of Palenque, in Chiapas (Mexico) experienced its climax between the 7th and 10th centuries AD and was deserted by 950 AD. **Source:** photo by H. G. Brauch (January 2007).

Figure 5.11: The Mayan Archaeological Site of Uxmal, Yucatán (Mexico) that was suddenly deserted without any signs of destruction from wars. **Source:** photo by H. G. Brauch (January 2007).

Before the decline of the highly civilized Mayas started, an impressive growth in population and cultural development took place. Living conditions were supported by favourable agricultural conditions, including reliable seasons, access to abundant water resources and fertile soils. This climate triggered a cultural development: A distinct subdivided social structure originated, comparable with other civilizations. It

Figure 5.12: The Mayan Archaeological Site of Chichén Itzá, Yucatán (Mexico). **Source:** photo by H. G. Brauch (January 2007).

is significant that high civilizations have often constructed impressive buildings with integrated astronomic observatories: Priests and political leaders tried to keep control over their people – by 'observing' the climate as a basis of subsistence.

The dramaturgy of the cultural decline of the Mayas, caused by worse climatic conditions, seems to be similar in different times and regions, and may also be a model for future developments: The basis of the food supply deteriorated. The environment was stressed, soils were overused and eroded, and water became scarce. The starving and suffering people were forced to abandon old values like solidarity and common sense, and they became rebellious. Social disturbances overthrew the hierarchic system and this civilization lost its basic structure. Campaigns against neighbours or emigration have often been a loophole in critical situations.

5.6 Outlook on Present Global Warming – Learning Lessons from Climatic History?

Natural climatic fluctuations and variations were quite common during the past millennia. Humankind has definitely been influenced in its cultural development, regardless of the type of political regime. Can one draw lessons from 20,000 years of climate history for the 21st century? How dramatic might the projected change be (Rahmstorf/Schellnhuber 2006; IPCC 2007)? It may be assumed that natural warming – the next climatic optimum after the precarious Little Ice Age pessimum – is further enhanced by human activities.

The natural system was clearly influenced and damaged by human activities since the beginning of human settlements, but especially during the past 150 years (IPCC 1990, 1990a, 1992, 2007). The present situation has never existed before in world history: More than 6 billion people (causing an enormous change of land cover) and huge emissions of carbon dioxide from the burning of fossil fuels.

The effect of CO_2 emissions cannot be directly determined, but to release fossil energy – i.e. of stored solar radiation – within a short period and in enormous quantities, undoubtedly will have an effect on the atmospheric dynamic. In addition, there is an increasing, accelerated consumption of the global land surface and biosphere. The altered earth surface (parameters of albedo/= proportion of reflected solar radiation, of vegetation cover, transpiration, surface water run-off, etc.) has also influenced the climate. In total, the recent quality and quantity of the anthropogenic impact on the climate does not have any ancient parallels. In Europe, the Near East and North Africa, Antiquity and the Medieval period already caused enormous landscape damages with climatic effects. In both Americas and in Asia, the anthropogenic impact on the earth's surface was enforced in and since the Renaissance by the immigration of Europeans.) Probably all these impacts have an additional lasting and altering effect. As a result, from the perspective of this author, the (pre)historic experiences and comparisons seem to be rather worthless – facing 'totally' new atmospheric parameters (see Claussen/Brovkin/Ganopolski/Kubatzki/Petoukhov 2003 who argued that "the past is not the future").

But many physical rules will remain effective. Warming will lead to more precipitation in some regions. All global ecosystem margins will be on the move. Especially some of the dry-land areas will profit from the shifting desert margins, others will be the losers. Kröpelin and Kuper (2007) remarked on their expeditions that parts of the eastern Sahara have received more rainfall during the last few years. Nomads graze their camels now, where a hyper-arid desert existed during living memory. It is to be expected that the border of arable land and the timber line will shift towards the Polar Regions and higher into the mountains, similar to the post-glacial Megathermal (chapter 5.4.1).

Looking backward and reconstructing ancient climatic conditions can teach us general aspects of complex interactions between environmental conditions and human activities. This is indispensable for understanding the natural system, for prognostic, modelling purposes, and even for the comprehension of social behaviour or reactions. But what really will happen in the macro- and meso-scale dimension depends on the variable borders of air and water masses, chaotic reactions, or very complex feedbacks and synergetic processes. Micro-scale changes and developments depend on the specific geographical situation of the regional features (on topography, drainage systems, settlements and infrastructure, etc.).

Most likely there will be more disadvantages than gains: The synergetic processes caused by the greenhouse effect and the projected progressive warming may have other consequences than the natural fluctuations in the past. Frequency and magnitude of gales, thunderstorms, or flooding are expected to increase (IPCC 2007). The gradient between the cold arctic air masses and warmer mid-latitude or tropical air may escalate. Permafrost will disappear in high mountains and cause more mass movements (rock falls, landslides). Torrential rain will lead to a flooding of lowlands or alluvial plains and landslides. A rising sea level will threaten the areas along the coastline as well as flat islands. Energy and water supply will be affected by diminishing glaciers – there are many additional aspects to be considered.

Undoubtedly humankind with its more than six billion people has changed the global ecosystem in different ways, not only the atmosphere. Together with all synergies and feed-backs, humankind has become much more vulnerable than in the past. We must face these challenges: Stop the emissions and take actions to guard against the hazards and risks mentioned above. Growing damages must be faced because an overcrowded earth is much more put at risk. There is no doubt about increasing social and economic damages because even precarious sites have been settled by the poor and vulnerable people.

Already now there are conflicts on the distribution and use of scarce water resources. The expected shifts in the ecosystem margins due to altering rainfall conditions, new types of conflicts may arise or intensify. The productivity of the arable land and pastures underlies altering conditions, too. The social conflict potential in large cities or in overcrowded areas and the youth bulge especially in less developed regions is another fact to be taken into account: Migrations with all their consequences will be triggered and possibly lead to violent conflicts. The spectre of human reactions on changed natural conditions is widespread and multiple.

The review of (pre-)historic interactions between climatic fluctuations, evolving environmental changes and human societies can be helpful for general assessments and prognoses. But very simple deductions, models, or parallels will be false – the world has become too complex, as roughly described above. The Nobel laureate in chemistry, Paul Crutzen, coined a proper term by changing the name of the most recent period in earth history – the late Holocene – into the 'Anthropocene'. This term expresses very well the creative and pernicious human influences on the natural global system (see below chap. 98 by Oswald/Brauch/Dalby).

The quality and quantity of inputs have reached new dimensions. Modern man is able to damage fundamentally or even destroy his basic living conditions. Ancient cultures were adapted to natural milieus. They profited or perished when climatic changes occurred. Nature often constrained the society and determined the opportunities of human beings. Now, humankind is able both to control the natural system and to lose control. According to a report by the British economist Nicholas Stern (2006), the costs of not acting will be much higher than early adaptation and mitigation methods in coping with global and climate change (Brauch/Oswald/Mesjasz/Grin/Kameri-Mbote/Chourou/Dunay/Birkmann 2009).

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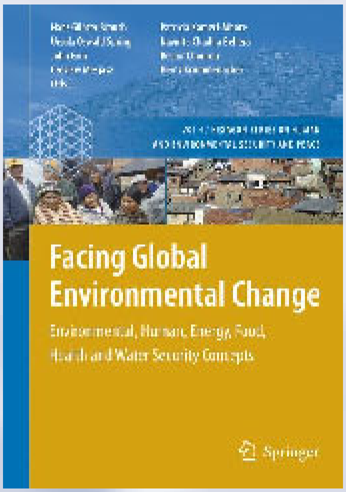

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