

Chapter 2

The Changing Climate of Africa

Part I: Introduction and Eastern Africa

2.1 Introduction

Describing conditions similar to the twenty-first century, perhaps the earliest written record of climate in Africa is that of Theophrastus (372–287 B.C.) who wrote of the Red Sea coast that “a little north of Koptos [on the Egyptian Red Sea shore] there grows on the land no tree except that called the thirsty Acacia [*A. tortilis*], and even this is scarce by reason of the heat and lack of water, for it never rains except at intervals of 4 or 5 years, and then the rain comes down heavily and it is soon over” (Hort 1916–1926).

Seneca wrote A.D. 60–65,

In that part of Egypt that stretches round Ethiopia there is either no rain at all, or it occurs only at long intervals. . . . The deserts of Ethiopia are destitute of streams, and few springs are found in the interior of Africa; therefore there are ugly stretches of sandy waste, without tree and without inhabitant, sprinkled at rare intervals by showers which they immediately swallow up (Clarke 1910).

Sub-Saharan Africa experienced a series of violent episodes in the shape of natural calamities during the twentieth century: disease pandemics, tsetse fly expansion, vegetation change, and increases in elephant populations to the detriment of their habitats, are among the more striking. This makes one reflect whether it is in the nature of Africa to be a violent continent, lurching from one extreme to another, or whether there might not be some overall change in the environment taking place which has triggered these reactions. Such a factor to look for would be climate. The great Sahelian drought of 1968 to the 1980s, with claims of at least 100,000 human deaths between 1968 and 1974 (some claimed 200,000–400,000 deaths between 1972 and 1973 alone) but which De Waal (1989) argues is a fiction and that there was no evidence for any excess deaths among the farming population, nevertheless focussed attention on climatic change in Africa. It is perhaps strange that we have tended heretofore to think of climate as an essentially stable factor of the environment, although several observers in South Africa in the nineteenth century postulated that southern Africa was becoming increasingly drier, disputed

by later workers. There has been argument about the alleged increasing desiccation of the Sahel for a century, and the tendency has been to credit this to land mis-use rather than to climate (Rapp 1974, Coe and Foley 2001). In East Africa there is abundant evidence of short-term change as witnessed by the drying out and re-filling of the shallow Rift Valley lakes. There are also several records of drought periods in recent history, but whether these changes are long term, capable of triggering pronounced changes in the environment, is still unknown. In considering oral accounts of historical events such as famine, we should bear in mind the strictures of McCann (1999), what he terms “simplistic climatic reductionism,” that climate and human action do not necessarily bear a direct relationship to one another. The more developed the human societies, the more complex the effects of climatic disturbance, which are reflected in economic and political effects. Thus famine is caused often by war and scorched earth policies, rather than lack of seasonal rainfall itself, the effects of which might otherwise be ridden out. But I would not go so far as Watts (1983) who sees famines as “social crises that represent the failures of particular economic and political systems”, arguing that traditional African social systems were well adapted to the threat of drought and that great famines are post-colonial phenomena. One old man in Darfur informed De Waal that in the pre-colonial 1913–1914 famine no one helped another person except sometimes his own brother or father. No traditional social system helped them. Watts’s view may apply to today but was not necessarily so in historic times, although this in De Waal’s view is Malthus’s interpretation of famine as the great population leveller; De Waal defining famine as dearth or hunger but to him it does not mean death, which is caused often by diseases resulting from malnutrition.

But we know that lack of food, i.e. famine, does cause massive animal mortality, and politics apart, the same can happen to humans. The last 2 million years have experienced recurrent and widespread climatic fluctuations in Africa, with hydrological periodicities ranging from decades to centuries to millennia. The impact of these cyclical and random fluctuations of climate upon the flora and fauna, and upon man, has created a constantly changing mosaic of land occupation. The classic example of major climatic change upon the fauna is the distribution of the Nile crocodile *Crocodylus niloticus*, once ubiquitous on the continent. Today in the north it remains in pools in the Tibesti Massif in the heart of the Sahara, 1,300 km from either the Niger or the Nile, with no possibility of migration across the Saharan desert; while fossil remains of both white rhinoceros *Ceratotherium simum* and a species of *Kobus* antelope have been found in the Ahaggar mountains of central Sahara. Conversely, at one time Mediterranean plant species like oak *Quercus* spp. and mammals such as deer *Cervus* spp. penetrated the Sahara from the north. Changes in human populations are seen particularly in regions such as the Niger Bend and Egyptian Nile floodplains, where favourable humid conditions led to increases in human population followed by devastating reduction due to drought, leading to re-occupation by flora and fauna before the cycle resumed. But wetter conditions do not necessarily mean that suitable niches are offered for man to exploit, for in the Sahel with moister conditions come increases in mosquitoes and malaria, mosquitoes alone being a sufficient deterrent to occupation. Other diseases

such as river blindness, transmitted by black fly *Simulium damnosum*, and expansion of tsetse fly and trypanosomiasis, all severely limit occupation unless sufficiently high densities of human population can be achieved whereby the vector habitat is destroyed. However, malaria, which has probably always killed more people in Africa than any other disease, showed a striking increase in the highland areas of eastern Africa in the years between 1980 and 2000, leading to the suggestion this was due to climate change inducing conditions favouring mosquito transmission of the causative organism *Plasmodium falciparum*. But temperature, rainfall, vapour pressure, and the number of months suitable for transmission of the causative organism, were shown not to have changed significantly in the past century, or during the past 20 years. Data were tested from four sites: Kericho in western Kenya with an 87% increase in severe cases/1,000/year; Kabale in south-west Uganda with 30%; Gikonko in southern Rwanda with 38%; and Mukunya in northern Burundi with 28–49% increases. Significant spatial and temporal variation was shown in both temperature and rainfall leading to the conclusion that economic, social, and political factors were the cause; not climate change (Hay et al. 2002). But also in Kenya, excessive rains in 1997–1998 caused an outbreak of millions of the poisonousrove beetle ‘Nairobi fly’ *Paederus sabaeus*, which causes painful blistering of the skin if crushed and is especially hurtful to the eye, first recorded from Nairobi in 1916. Some 30.2% (N = 1,208) of the population of Nairobi were affected because it is attracted to electric lights at night, entering houses, but cases were reported throughout Kenya, Uganda and Tanzania. An inhabitant of moist habitats and probably formerly associated with the Nairobi River habitat, adults emerge during the rains.

2.2 Rainfall

Tropical rainfall exhibits greater variability in annual amount than does temperate rainfall, and it is characteristic of Old World tropical regions that the isotherms and isohyets run closely parallel to one another showing the steepest gradient from humid to arid conditions on the globe, such that minor latitudinal deflections have large effects. Straddling the Equator, Africa experiences a boreal summer from June to August, and an austral summer from December to February, with consequent differences in the annual rainfall pattern. The eastern Sahara has been comparatively dry throughout geological times except for intervals in the mid to late Oligocene when a moist climate prevailed which has never been equalled since. Conditions in central, and perhaps also northern, Sudan, resembled those of the moist savannahs of West Africa, while in Egypt a semi-arid climate may have prevailed. For two to three centuries before the late 1700s to early 1800s drought in inter-tropical Africa and rainfall anomalies in eastern and south-eastern tropical Africa appear to have been inversely related, suggesting a forcing mechanism which produces regional rather than continent-wide rainfall patterns (Verschuren 2004).

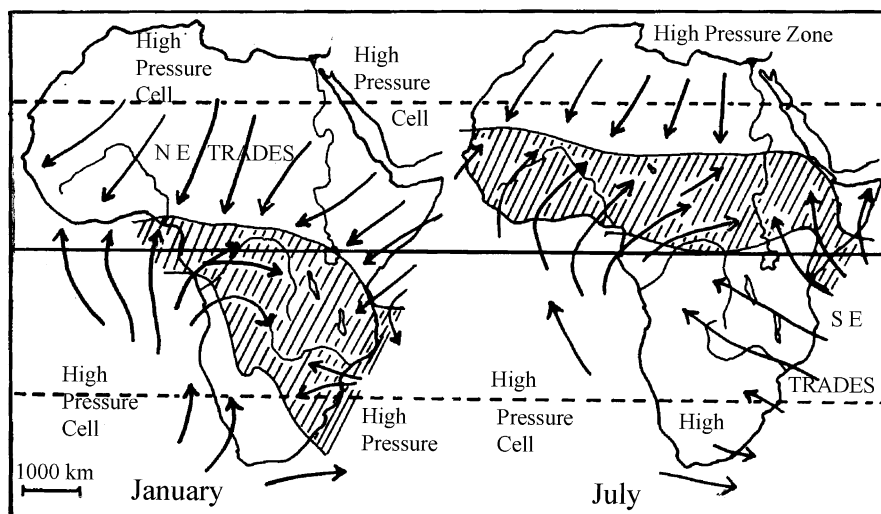


Fig. 2.1 General atmospheric circulation and rain belts in January and July. Cross-hatched areas indicate regions receiving >50 mm of rainfall in January and July (After Boucher 1975)

Boucher (1975) has described the climate of Africa between the tropics as dominated by three features: firstly, the large, sub-tropical high pressure areas over the Sahara and south Atlantic ocean; secondly, the air flow equator-wards from these cells, producing the “Trade” or “Monsoon” winds;¹ and thirdly, the ITCZ, or Inter-Tropical Convergence Zone, where these winds meet (Fig. 2.1). Superimposed upon this pattern are irregularities due to elevation, moisture sources, and other disturbances. The ITCZ moves from about 15°S to 15°N following the sun with a time lag of about 30 days, and along the line where well-defined winds from the two hemispheres converge they generally form a belt marked by rainfall due to ascending air currents which thus migrates north and south. Some now call it the Intertropical Discontinuity or ITD.

North of the southern Africa zone, areas south of the Sahara receive rainfall associated with the ITCZ. In lower latitudes, especially near the equator, rainfall is distributed throughout most of the year, but in the higher latitudes, towards the southern margin of the Sahara it is confined to the summer months. The Sahel and Soudan zones are semi-arid regions to the south of the Sahara with rainfall between 150 and 800 mm. A substantial area of the Sahel lies close to the zone of the 250 mm annual rainfall isohyet, a value generally indicating the limit of agricultural productivity.

The majority of East Africa is under the influence of monsoons, the south-east monsoon during the northern summer and the north-east monsoon in the southern summer. The former is comparatively moist but shallow, at least near the coast. It approaches the coast of south Kenya and Tanzania as Trades from the east-south-east, but inland divides abruptly. One branch continues westwards across Tanzania as a weak current fanning out north and south over the interior; while the other

branch flows northwards parallel to the coast, this division being caused by the plateau and highlands of Kenya and Ethiopia.

Southern African rainfall is erratic in time and spatial distribution, influenced by the region's position in relation to the major circulation features of the southern hemisphere. From the equator to about 20°S the mean annual rainfall isohyets have a general east-west trend, seasonal variations in regional distribution of rainfall occurring in response to movements of the ITCZ. South of 20°S the atmospheric controls become more complicated as the circumpolar westerlies assume greater influence and the isohyets adopt a nearly north-south alignment, except in the southern Cape, with rainfall decreasing from more than 800 mm in the east to almost complete aridity in the Namib desert in the west (Tyson 1986). The sub-tropical regions are influenced by semi-permanent high pressure cells of the general circulation of the atmosphere, characterized by a high degree of intra and inter-annual variability.

2.3 Recent Changes in Pattern

There were two contrasting climatic episodes in Africa in the nineteenth century, firstly drought and desiccation throughout at the beginning of the century, followed by very favourable climatic conditions in the arid and semi-arid regions of West Africa. Modelling suggests the earlier desiccation could have resulted from a 12% reduction in rainfall from the present mean, or a 6% reduction accompanied by a small reduction in cloud cover. The mid-nineteenth century rise could have been accounted for by a 10% increase in rainfall, or 5% if there was a small increase in cloudiness (Nicholson and Yin 2001). Contrasting with 1931–1960, rainfall changed substantially over the 60 years up to 1990, most notably over tropical north Africa where during 1961–1990 mean rainfall declined by up to 30%. Compared with elsewhere in the world the decline in Sahel rainfall is unparalleled. Along the tropical margins of southern Africa, rainfall was reduced by about 5%. Austral summer rainfall decreased by about 10% in parts of Botswana and Zimbabwe. In some areas rainfall increased, most notably in equatorial East Africa with a 15% increase reflecting largely a series of wet years in the 1960s, and the southern coastal region of West Africa experienced a 10% increase.

Annual rainfall variability, which is high over much of the continent, when measured with respect to mean rainfall amount has generally increased with the greatest increases in Tunisia, Algeria, the Nile Basin, and the extreme south of the continent; although this variability is not statistically significant when the continent is viewed as a whole. Overall, areas of increased variability are generally greater than those of reduced variability, the latter restricted to the north-east. South Africa has seen increases in variability of more than 5%, but most of equatorial Africa has seen little change (Hulme 1992).

Spatial variability of rainfall over Africa generally has seen a significant decrease in May, August, and September, most notably in coastal regions and

parts of the North African littoral where decreases have been more than 8%. The months of November-December have seen an increase, probably reflecting an increased November rainfall over eastern Africa and a more variable pattern of change over southern Africa in December-February. Temperatures have risen in southern Africa over the twentieth century which may cause increasing aridity and greater fluctuations in rainfall (Hulme 1996). In 1998 many countries in East Africa had up to ten times the normal amount of rain, but the situation worsened in 2007 when flooding occurred from west to east across the continent from Mali to Kenya north of the equatorial region, affecting an estimated one million people and making 600,000 homeless, being excessively bad in Uganda, Ethiopia, and Sudan.

Changes in seasonality have occurred also, boreal summer rain declined over tropical North Africa while in southern coastal regions of West Africa and parts of west equatorial Africa the July-August rainfall has increased by about 10%, but there has been some decline in the December-February winter rainfall of about 15%. Around the Gulf of Guinea, September-November rainfall declined. Rainfall has also become somewhat less seasonal in north-west Africa. In the Sahel seasonality has remained constant despite decrease in the June-August rainfall, reflecting the continuing dominance of the northerly summer migration of the ITCZ in generating rainfall, but it shows increased variability, generally less than 5% in the west and greater than 5 up to 15% in the east. In much of eastern Africa seasonality has decreased.

2.4 Desertification and Drought

The term desertification is used more often in a general sense meaning the spread of desert-like conditions in dry environments such as steppe or savannah, but Swift (1996) sees it as covering three distinct, albeit related, phenomena: drought, which is defined as two or more years of rainfall well below average normally substantially depressing primary production, although where historical references to drought are quoted the duration of the moisture shortfall is not known; desiccation, a process of drying out resulting from extended drought of the order of decades or more; and dryland degradation, which is defined as a persistent decrease in the productivity of vegetation and soils brought about largely by inappropriate land use. Some authors have attempted to replace the word desertification with “desertization”, defined as the spread of desert-like conditions in arid or semi-arid areas due to man’s influence or climatic change (Rapp 1974). Whichever term is used, it is not seen as an advancing desert front but a local process initiated by the concentration of grazing, overcultivation, woodcutting, and in some areas, burning; destroying the plant cover beyond the required minimum for protection of the soil against rapid erosion by wind or water. This occurs in scattered patches of bare ground from 100 m to several kilometres in diameter. Rapp saw it as a grave and acute environmental problem both to the north and south of the Sahara. One view considers much of it to result from the settlement of former nomadic herdsman

around artificial borehole wells. This has resulted partly from government strategies to discourage nomads from crossing international borders.

About the 1960s rainfall began to decline in the Sahel, in the Soudano-Guinean region in the late 1960s, culminating at the beginning of the 1970s in widespread and severe drought in Mauritania, Niger, western Chad, and eastern Mali, with Senegal and Burkina Faso less affected. Although it was not unusual for monsoon rains to fail in some of these regions each year, it was almost unknown for them to fail so widely in several consecutive years. Winstanley (1973) saw this as providing further evidence of recent changes in the general circulation of the northern hemisphere and the equatorial shift of climatic zones, a trend perceived first in the 1930s which became more marked in the 1960s. The rainfall deficit continued, and in 1981–1983 it was especially dry in many Sahelian countries as well as in parts of eastern and southern Africa. In East Africa from Somalia south to Mozambique, extending inland to Zambia, the rains failed or were delayed from 1978 to 1980, and there was serious drought in South Africa at the end of October 1982. Two dry years in equatorial Africa in 1983–1984 were accompanied by a near continent-wide drought from 1983 to 1987. Northern and southern anomalies match each other, thus in 1950–1959 it was wet across much of northern Africa and south of about 13°S. In 1968–1973 when it was dry in the north, it was also dry in the south. Although rainfall in the Sahel declined below the 1968 drought level in 1984 this was not accompanied by excessive famine as early season rain was sufficient to produce crops. Cattle populations suffered severe declines in 1973 but then showed some recovery to 1977. Extreme drought and famine occurred again in Niger at the beginning of 2006, spreading to northern Uganda, northern Kenya, Somalia and the Horn of Africa in the east, considered to be more severe than droughts in 1984, 1999, and 2000 in the East African region.

It is now believed drought conditions, particularly in the Sahel, equate with periods of lower temperatures in the mid-latitudes and, or, a reduced meridional temperature gradient. The general explanation of the 1968–1973 Sahel drought is seen in a shift equatorwards of the climatic zones, and consequently a suppression of the northward progression of the ITCZ. This causes the Sahara desert to expand or contract at its southern border, but not to shift north or south.

During the eighteenth century much of northern Africa experienced an overall increase of drought but the climatic conditions as a whole were probably more similar to those of the previous two centuries than to those of the 1970s. The last two or three decades of the nineteenth century saw a return to conditions similar to those of the sixteenth and seventeenth centuries, but perhaps not as extreme. They were similar to the Neolithic in that there was increased rainfall in equatorial eastern Africa, throughout the whole Sahel, and along the margins of the Sahara and in the central Sahara. An abrupt reversal began about 1895, leading to severe droughts throughout in the early twentieth century, particularly from about 1910 to 1920. Conditions then remained fairly stable until 1961 when high rainfall was widespread across Africa from east to west. Rijks (1978) claimed that stream flow records in the Sahel suggested a cycle of approximately 30 years composed of about fourteen average years plus seven wet and seven dry; but this concurrence appeared

to have occurred only three times. Nicholson (1982) has stressed how such instances can be random events and that apparent trends can not be extrapolated forward in time as climatic fluctuations occur abruptly, while cycles lack predictive value and simply reveal past events.

The moister climate in the second half of the nineteenth century came to an end earlier in the south than in the north; during the 1880s in the Malawi, Tanganyika, and Victoria basins, and in 1898 in the Rudolf and Stefanie basins. After several dry decades the Malawi basin became wetter in the 1930s when levels in East Africa were falling. Then in 1961 lake levels from Rudolf and Stefanie in the north to Malawi in the south began to rise rapidly. Scaëtta (1932) considered that Rwanda had experienced a progressive drying up dating from the lowering of the level of Lake Victoria at the end of the nineteenth century.

2.5 High Rainfall

In Gabon the mean discharge of the Ogowi River in November 1961 was 48% above average, the highest recorded for any month between 1930 and 1964. The Ubangui's mean discharge for that month was 44% above average for the period 1911–1964, the discharges for September 1961 to February 1962 being the highest recorded since 1916 for each month, while the annual discharges for the Ubangui and the Ogowi were the highest on record. Discharge of the Zaïre River at Kinshasha in November 1961 was the highest recorded between 1910 and 1983 and its mean discharge of 28% above normal in 1962 was the highest ever recorded, but in 1998 very high flows were recorded at Kinshasha. Above average precipitation followed in 1962–1964 in the Lake Victoria region and the equatorial lakes Edward and Albert. From 1961 to 1981 the White Nile delivered on average twice as much water to the Sudd as it had done in the first half of the century. Rainfall also remained higher than average over the Sobat and Blue Nile catchments, making the Nile flow in the Northern Sudan and Egypt higher than it had been in the first half of the century.

From about 1965 river discharges and lake levels declined in the northern equatorial region and above, but not in the south where Lakes Rukwa and Malawi reached their highest levels about 1980 and then declined. The discharge of the Zambesi above Kariba was high from 1973 to 1980, the mean since 1949 being some 40% above that of 1924–1949. In 1981–1982 its flow was much reduced, recovering in the next decade it then fell in the 1991–1992 southern African drought more than ever recorded before.

2.6 Historical World Climatic Change

Gregory wrote in 1906, “The past variation of climate is an attractive study, as it controls so many questions in geology, geography, and meteorology” (Gregory 1908). He was referring to global glaciation but outlined the many theories advanced

to explain climate change on a global scale, concluding it appeared probable that “variations in climate, which have been established on adequate evidence, can be accounted for by differences in atmospheric circulation.” Today we would add history and ecology to Gregory’s “questions”, but most agree with his conclusion of atmospheric circulation driving climatic events.

In the 1970s great interest developed in historical climatology for predictive purposes relating to cycles, accented especially by such cases as the Sahel drought (Bray 1971, Lamb 1972–1977, Winstanley 1973). Although much of the work refers to temperate latitudes the general inferences relating to increasing or decreasing global temperature apply to changes on the African continent, although as Bray pointed out, a change of more than 3°C in the higher latitudes may be paralleled by one of less than 1°C in the tropics. But where this affects a marginal habitat the results for an ecosystem can be just as important. A dissenting voice was raised by Mason (1976) who stated there was no firm scientific basis for predicting the future behaviour of climate on the scales of years, decades, or centuries. The Sahel droughts of the 1910s, 1940s, and 1970s, were seldom repeated in any regular pattern, and the period 1931–1960 was probably one of the most abnormal 30-year periods in the last 1,000 years. He considered that almost all alleged climatic cycles were either artefacts of statistical sampling associated with such small fractions of the total variance as to be virtually useless for predictive purposes, or a combination of both.

Historical climatic studies show that at the beginning of last century the world was emerging from a period of colder climate that had lasted for several centuries. The physical, geophysical, glaciological, and botanical data, all show similar temporal patterns, synchronous on a global scale, for the cooling which followed the Little Climatic Optimum, and the warming after the Little Ice Age. For the first three or four centuries A.D. temperatures were probably similar to those of the 1930s, with a trough around A.D. 1–150, and a minor peak at 150–250. There followed a slight depression around 600–700, with greater warmth than present occurring from about 900 to 1200. Notable low temperatures occurred in the 1430s, 1560s, and 1590s, and temperatures as a whole then started to decline around 1650–1700, with further notable lows in the 1690s and early 1700s. After the first decade of the eighteenth century there was the first discernible upward trend. This has continued into the present, with warm periods in the 1730s, about 1780, the 1830s, 1870s, and 1930s; and was accompanied by cooler temperatures in the 1740s, about 1790, the early 1800s, about 1850, the 1890s, and about 1910. For the first half of the nineteenth century, and perhaps for 200 years before, conditions were somewhat droughty (Bray 1971). Africa is warmer today than it was a century ago, increasing through the twentieth century at about 0.5°C/century, with slightly greater warming in the June–August and September–November seasons than in the remaining months, but there is no evidence for widespread desiccation of the continent during the twentieth century. The 6 warmest years on record have all occurred since 1987, with 1998 being the warmest to 2002, the rate being not dissimilar to that experienced globally. The periods of most rapid warming, the 1910–1930s and post 1970s, occurred simultaneously in Africa and the world

(Hulme et al. 2005). The synchronicity on a global scale, Bray concluded, added evidence to the possibility that there is a physical control over climate which operates on a global scale.

The most likely form for such control would be variation in solar radiation retention or receipt by the earth, or variation in solar output. Generally there appears to be a lag effect of solar activity on climate, but 3 in 12 geophysical, physical, glaciological, and botanical indices, were significantly correlated with a solar activity index; and 11 in 12 significantly correlated with a cumulative solar activity index. Bray pointed to the close relationship between solar activity and a wide range of climatic indices. Glaciation is associated with periods of lower solar activity and deglaciation with higher periods, provided they are of sufficient length. Solar activity equates also with botanical data as measured by trends in forest lines, species' diversity, etc., giving a warmer interval in the first millennium which culminated about 1200–1300, this interval being marked by high solar activity. A period of lower solar activity from the thirteenth to the nineteenth centuries was accompanied by a cooling trend, and the warming to the present is associated with a general return to normal solar activity. Willet (1960) found an intensification of the monsoonal type of general circulation accompanied an increase in solar activity.

2.7 Prehistoric to Historic Climatic Events

Climatic change in East Africa's prehistory has been the subject of considerable investigation in relation to the dating of fossil hominids, but much of this relates to a period too remote for present-day interpretation of cause and effect. Previously a series of high rainfall periods, or pluvials, was believed to be generally correlated with Ice Ages in Europe, but it is now accepted that the contrary is true. Ice Ages in Europe were matched with aridity in Africa. The last glacial, the Würm, of about 18000 B.P., corresponded in East Africa to a period of rapid warming in the early Holocene, and most of tropical Africa witnessed increasing aridity during this period. But pollen studies from Dama Swamp on the western edge of the Eastern Arc Mountains in Tanzania display a remarkable lack of change through the period 38000 B.P. to present, and no marked shift in composition of C_3 and C_4 plants (Marchant et al. 2007), unlike on Mount Kenya (Ficken et al. 2002). Moist forests appear to have been present continually throughout the Last Glacial Maximum (18000 B.P.) with environmental stability for 10,000 years before and after, possibly related to Indian Ocean rainfall patterns. In terms of temperature, Moreau (1966) has suggested that during the last 70,000 years the ecological picture presented by Africa has been nearer to that associated with the glacial maximum than to present day. About 16000 B.P. temperatures rose fairly steadily to about 2°C higher than present for a period of about 8000–4000 B.P. They then declined, until between A.D. 1400 and 1850 they were a little below present, so today's climate may be regarded as intermediate.

The first East African pluvial, the Kageran, began about 600000 B.P. It was succeeded by the Kamasian, followed by a relatively brief inter-pluvial and then the Kanjeran, which ended about 80000 B.P. During this pluvial relatively heavy rain extended throughout Sudan to Egypt, causing the northward spread of plants such as *Ficus ingens* (Miq) Miq., *F. salicifolia* Vahl, *F. sycomorus* L., *Celtis* sp., *Phoenix sylvestris* and a reed, *Arundo* sp.; remains of which have been found at Kharga Oasis (Jackson 1957). Following this pluvial, about 70000 B.P. climate became very dry throughout most of Africa, much apparently being uninhabitable arid country and Kharga Oasis is now one of the driest places on earth. This was followed by fluctuations in temperature in the subsequent 20,000 years, a warm optimum possibly occurring between about 5000–2600 B.P.

Pollen studies of Sacred Lake on Mount Kenya indicate treeless vegetation around the lake 34350–32350 B.P. and a tree line developing from about 31,000 to 27000 B.P. About 29000–14000 B.P., a time equal to the glaciation in Europe, average annual temperature in tropical Africa decreased, on East African mountains from 4°C to 7°C below present. During the pluvials glaciers on East African mountains reached lower altitudes, the lowest estimated at 3,000 m compared to 4,500 m in the mid-twentieth century. Thus the temperature was believed to have been 5–7°C colder which may have allowed certain plant species to spread from their main centres of endemism, such as *Podocarpus milanjanus* Rendle to Mount Cameroun, some 2,500 km distant from its East African centre. The tree heath *Erica arborea* L. occupies the higher altitudes on the Rwenzoris and the Ethiopian and Cameroun mountains, but also an extensive range in Europe from Iberia to the Black Sea. The effect of temperature depression to 5°C would have lowered the limits of the montane flora from around 1,500 m to 700 or 500 m (Moreau 1963), producing conditions for a continuous distribution of *E. arborea* from Ethiopia to the Cape, plus a westward extension to Cameroun. However Bonnefille et al. (1990) from Burundi highlands pollen analysis, suggest during the glacial period between 30000 and 13000 B.P. the average temperature decrease was 4° +/- 2°C and not 5–7°C.

During the late Pleistocene the Ethiopian Plateau highest peaks between 4,130 and 4,580 m were glaciated in two stages, with snowlines at 3,600–4,100 m and 4,200 m. Mount Kenya experienced a drier, colder climate, from about 26000 to 12000 B.P., with low lake levels and aridity from about 18000 B.P. and highland vegetation dominated by small tree, shrub, and grass pollen, suggesting a widespread suppression of forest trees and more open vegetation than as at present. From about 23000 to 11000 B.P. inter-tropical Africa experienced much greater aridity than present, which became intense and widespread from 15000 to 13000 B.P. Between 15000 and 12000 B.P. lowland forest was much more limited than now in the White Nile headwaters. Treeless vegetation was then followed by a major period of forest development from about 10000 B.P. to present (Bakker and Coetzee 1972). Bonnefille et al. (1990) consider the optimum period for glacial advance in East Africa was about 21500 B.P., when the climate was cold but relatively moist.

The Lake Rudolf basin appears to have been drier for longer, from 35000 to 10000 B.P., the same dry sequence being identified at Lake Nakuru. The last major wet period, the Gamblian, was of post-glacial age and lasted until about 12000 B.P., with three maxima in East Africa when glaciers descended much lower than in the mid-twentieth century.

The period from 30000 to 20000 B.P. was wetter than present in the Sahel and Egypt, and Lake Chad was greatly expanded from 26000 to 20000 B.P. Lakes of tropical character still existed in 23000 B.P. in the Afar and Main Rift at levels higher than those reached in the Holocene. Ball (1939) argued for an ancient "Lake Sudd" on the Nile extending from the sudd area to beyond Khartoum, some 1,050 km in length with an area of about 230,000 km², the disappearance of which was occasioned about 20000 B.P. by the Lake Victoria outlet being captured by the White Nile system. Adamson and Williams (1980) refer to the sudd region as the Southern Sudanese Trough, an immense fault-bounded sedimentary trough the focus of drainage in the southern Sudan, with sediments up to 10 km thick (the 10–15 million years' old lakes Tanganyika and Malawi have sediments up to 4 km thick). Butzer and Hansen (1968) refer to a great palaeo-sudd basin which may have maintained an internal drainage until the Middle Pleistocene. It was one of five or more separate hydrographic units of the Nile Basin which were disrupted by the creation of the rift valleys in mid-Tertiary times, about 25 Mya. Thus although the Nubian and Egyptian Nile is an ancient river, the Nile hydrographic system as we know it today is of comparatively recent age.

Between more than 40000 and 12500–12000 B.P. there was no major contribution to the Nile from East African lakes. About 27000 B.P. the Nubian Nile carried appreciable sub-Saharan waters of which a greater than modern proportion derived from the southern Sudan. The typical summer flood regime of the Nile was established in Egypt no earlier than 25000 B.P. when rifting caused the White and Blue Nile basins to merge with the Saharan Nile after the early Pleistocene. About 24000–18000 B.P. it aggraded an exceptionally broad floodplain with discharge and sediment levels only slightly greater than those of present. The level of Lake Victoria fell significantly, perhaps drying out about 18000–17000 B.P., pollen evidence indicating it dried up completely sometime between 15900 and 14200 B.P. Although these periods of total desiccation are now considered to have been briefer than formerly assumed they would have had enormous effects upon the ecology of a wide region, this being the most arid interval in 20,000 years. The minima coincided with major climatic disturbances worldwide, including severe weakening of the Afro-Asian monsoons, tropical droughts, and cooling at higher latitudes. The minimum lake level ended sometime between 15900 and 14200 B.P., levels then falling again between about 14000 and 13000 B.P. A rise in temperature about 12600 B.P. was accompanied by wetter conditions and lakes in general regained their levels.

Pollen analysis from the Rwenzori mountains' Lake Mahoma shows that during the last 15,500 years large changes in climate and vegetation took place in the area, the greatest about 12600 B.P. from a cold dry climate with a temperature probably 6°C lower than present, to moister and warmer conditions. Prior to this date the lake

was surrounded by a dry type Ericaceous vegetation with a *Hagenia-Rapanea* zone at lower altitude while bamboo forest was rare or absent, replaced by an open type of forest. The forest in the lowlands was much less extensive than in modern times. Soon after 12600 B.P., following a slight rise in temperature, bamboo forest surrounded the lake remaining until the present. Uganda's Kibale forest formerly extended to the Rwenzoris and was probably continuous with the montane forest. Evidence indicates that in the recent past moist montane forest was restricted to localized refuges from which it has subsequently spread, suggesting a general change from dry to a moister climate, while dry montane forest was more widely distributed. Lowland forest probably spread across the country about 12000 B.P., but a drier period after 7000 B.P. coupled with deforestation by man, is likely to have caused forest retraction between about 6000 and 2000 B.P. A small upward shift in the vegetation belts suggests slightly warmer and wetter conditions. About 1000 B.P. widespread forest destruction began in the lowlands, mainly on the Uganda side of the Rwenzoris, where a lower intensity of human disturbance dates back to about 4600 B.P.

The Early and Middle Holocene saw a great extension of lacustrine conditions in Ethiopia: lakes Ziway-Shala, Galila, Gawani, and Abhé, along the Awash River alone covered an area of about 10,000 km². River floodplains were covered with several tens of metres of water. From 17500 to 5000 B.P. the Nile discharge was markedly greater than present, and exceptionally high floods appear to have occurred about 12000–11000 B.P. Tree species in gallery forest on Sudan's Jebel Marra, about 600 km north of the present lowland forest border, suggest a northward shift of about 400 km of the border under wetter conditions sometime after 12000 B.P. (Wickens 1976). Brief periods of reduced Nile flood discharge are indicated about 11500 B.P. and on several occasions between 9000 and 5600 B.P., but in 10000–8000 B.P. maximum lake levels were reached with a lesser wet period, the Makalian, lasting to about 4000 B.P. Lakes rose up to 100 m above present levels, and a lake filled the Magadi-Natron basin 50 m above its present level to cover 1,600 km² in the early Holocene. During the cold European phase of about 10500–10000 B.P. more arid conditions prevailed at sites such as Lakes Victoria, Chad, Rudolf and Afrera. But in addition to the major declines in Lake Victoria's level, there were additional lesser declines of decreasing magnitude approximately every 1,000 years in unison with palaeomonsoon fluctuations over Arabia, Pakistan and East Asia (Stager et al. 2002). Maximum humidity occurred on the East African Plateau about 5,000–4,600 to 3000 B.P., but in the Lake Victoria Pilkington Bay area possibly earlier, between about 9500 and 6000 B.P. Lake levels then fell markedly between about 4800 and 4300 B.P. as conditions became cooler and drier declining to those of the present where surface water is limiting. Sand dunes invaded the flood plains in Nubia, and an exceptionally low period of Nile floods occurred between about 4180 and 4080 B.P. followed by extremely high floods about 3840–3755 B.P. Inscriptions in Nubia dated to about 3750 B.P. indicate the minimum level was not much different to present-day, but floods were 5–10 m higher. This was followed by a temporary humid phase about 2800 B.P., and apparently about 2700 B.P. small lakes and swamps existed to the

east of the White Nile in an area presently arid plains. In the desert to the west of the Nile there are numerous tree stumps of acacia, tamarisk *Tamarix* sp. and also *F. sycomorus*, with diameters of 34–40 cm and a density of 5–11/ha, indicating that an open savannah existed some 200 km farther north than this vegetation can exist today. A humid phase intervened again with a lesser Nakuran wet phase beginning about 2850 B.P. when climate in Europe became warm. About 2500 B.P. higher Nile levels buried the dunes in Middle Egypt.

The general trend in climate in East Africa during the past 2,000 years, as established from pollen studies, seems opposite to that of the Afar and Ethiopia. In Kenya's Cherangani Hills and on Mount Kilimanjaro a change to drier conditions similar to present took place about 2,000 years ago.

Figure 2.2 shows the reconstructed mean annual temperature and rainfall in the Burundi highlands from more than 40000 B.P. to present.

This pattern of changes agrees with numerous continental and marine records, showing that the monsoon circulation and related rainfall over the northern tropics and equatorial East Africa were considerably stronger during the early to mid-Holocene as a result of changes of the earth's orbit around the sun (Gasse 2002). Abrupt climatic changes were detected at about 8300, 5200, and 4000 B.P. The first was probably reflected in a large rapid drop in lake levels, to be followed about 6500–5200 B.P. by rapid sustained recovery and cooling due to a humid period, which was wetter than today but drier than the early Holocene. This was concomitant with a decline in lake levels and vegetation cover.

2.8 The Development of Human Influence

Almost contemporaneously with the beginning of this recovery to a moderately humid period, at about 5300 B.P. hierarchical societies formed in the Nile Valley and Mesopotamia and Neolithic settlements in the inner desert of Arabia were abandoned. From about 5000 to 4000 B.P. the climate was dry, lake levels were very low and drought affected the whole of northern and tropical Africa. A large climatic event took place about 4000 B.P. with a 300 year drought forming a thick layer of dust over Mount Kilimanjaro's ice cap. Termed the "First Dark Age" Kilimanjaro had less ice on its summit then in a period which represents the greatest historically recorded drought in tropical Africa, and one which extended apparently to the Middle East and western Asia (Thompson et al. 2002). Volcanic activity in Uganda's Fort Portal area dates to about 4190–3950 B.P., possibly initiating a migration of people to the Rwenzori area.

The Nile from Khartoum to the Delta was inhabited by man in the Lower Palaeolithic soon after the emergence of *Homo* sp in East Africa and Ethiopia, already occupying quite large sites on the edge of floodplains or on the top of residual hills or the desert plateau overlooking the floodplain. Cultural resemblances in the Mesolithic period of about 14000–4000 B.P. between Khartoum and further west, indicate communication across the now desert country

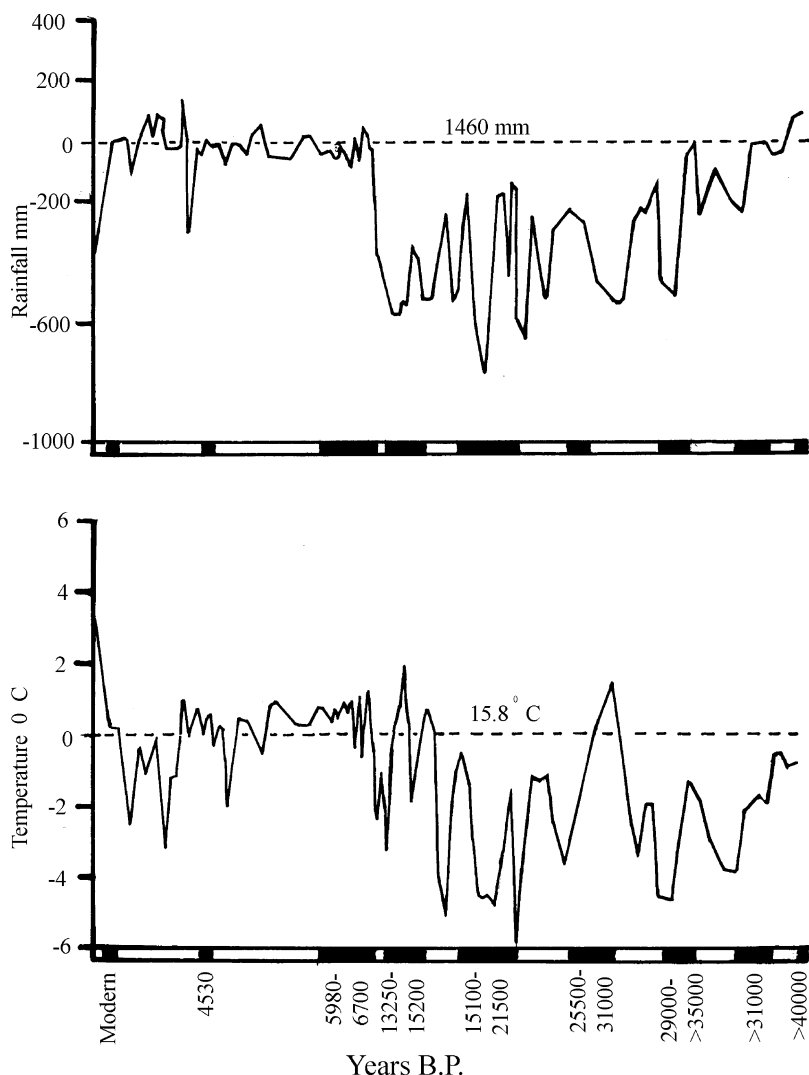


Fig. 2.2 Reconstructed mean annual rainfall (*top*) and temperature (*bottom*) in Burundi Highlands over 40,000 years, as deviations from the modern values (Adapted and simplified from Bonnefille et al. 1990)

must have been relatively easy. The Egyptian Sahara was arid towards the end of the Pleistocene, becoming less so during the Early Holocene when temporary lakes occupied hollows formed by wind in the preceding arid phase and allowing occupation in early Neolithic times between 9400 and 7700 B.P. In northern Sudan the wet period continued as the Makalian wet phase into Neolithic times, and much of the area which is now a lifeless desert was inhabited, remains from 50 km north of Khartoum dating to 6000–5000 B.P. Animal remains from this area

include those of leopard, otter, civet cat, honey-badger, warthog, giraffe, buffalo, greater kudu, oryx, and elephant. The presence of the snail *Limicolaria flammata* indicates a rainfall greater than 400 mm, whereas the presence of oryx suggests it was perhaps not more than 600 mm (Jackson 1957). Floods at Khartoum in Neolithic times when generally much wetter conditions prevailed in the area were some 5 m higher than present, as is attested by the finding of bones of the swamp-dwelling Nile lechwe *Kobus megaceros*, the water mongoose *Atilax* sp., and an extinct species of reed rat. The latter was most closely related to an extinct species found over 3,000 km west of Wadi Halfa in what is now desert, and the nearest surviving reed rats occur now in western Darfur (Arkell 1961). The evidence from the floral composition indicates it was much drier between Egypt's Early Dynastic and Pyramid ages 5100–4100 B.P., losing many savannah type species that had been present since the Neolithic (Bell 1970). Rock paintings in the west of the Libyan desert include elephant, rhinoceros, and the extinct buffalo *Bubalus antiquus*; while at Jebel Uweinat, where Egypt, Libya, and Sudan meet, giraffe, gazelles, oryx, possibly Barbary sheep, and ostrich, are represented dating from pre-5400 B.P.

Cattle herdsman are considered to have entered the Libyan desert about 5000 B.P. At this time there must have been enough rain to provide grazing grounds away from the Nile valley, at least on a seasonal basis. Plant remains in Egyptian tombs belong to species now found no nearer than in the southern part of the Red Sea Hills near the Eritrean border; namely *Moringa aptera*, wild olive *Olea africana* Mill., and *Mimusops schimperi*. Although their presence could indicate the flora may have persisted further north in dynastic times, it cannot be discounted that dried specimens may have been imported to Egypt. That they were placed in tombs suggests they were accorded some significance. But the indications are that in Old Kingdom times the climate of north Sudan and southern Egypt was somewhat wetter than present until about 3500 B.P. enabling pastoral tribes to live in areas which are now desert both sides of the Nile, but not wet enough that the Egyptians could settle away from the river. Shorthorn cattle appear about 4550 B.P., but in the Central Sahara were present before 6000 B.P. By Predynastic times sizeable sedentary farming and herding communities occupied slightly elevated localities adjacent to the Nile floodplain. After about 4500 B.P. increasing desiccation of the Sahara led to a southward migration of nomadic pastoralists in the west along rivers like the Niger and Tilemsi, culminating in the colonization of the West African savannahs and the introduction of domestic cattle into that region with settlements of cattle pastoralists in the Sahel, and by 3500 B.P. the Kintampo Culture had appeared in Ghana, a savannah-forest ecotone culture. The southward migration also extended through eastern Africa, the first appearance of domestic stock among Late Stone Age settlements on the east of Lake Turkana dating to 4500 B.P.

The Neolithic communities of Egypt's Western Desert grew barley and sorghum and raised cattle, sheep and goats; as well as continuing hunter-gathering, but the Western Desert was not filled with lush vegetation and teeming game, vegetation was probably thin and concentrated around ephemeral lakes, the area being an open desert with grasses, acacia thorn bushes, and a few tamarisk trees. Fauna comprised the

Libyan hare *L. capensis*, red-fronted gazelle *G. rufifrons*, Dorcas gazelle *G. dorcas*, African wild cat *Felis sylvestris*, and ostrich. By 2000 B.P. desiccation must have meant that it was increasingly difficult to maintain cattle in the desert, leading to large scale movements into the Nile Valley.

2.9 East African Climate

North of the equator rain tends to fall mainly in the spring. As the equator is approached, for example in north central Africa, the heaviest rain falls in June to July, up to October. At the equator rainfall is bi-modal, with light rains in October to December and heavy rains in March to May. Meteorologically equatorial eastern Africa is one of the most complex regions of the African continent. The large-scale tropical controls, which include several major convergence zones, are superimposed upon regional factors associated with lakes, orography, and the Indian Ocean influence, resulting in complex climatic patterns which change rapidly over short distances (Nicholson 1996). In East Africa there is an almost complete dependence of temperature on altitude of roughly -1.11°C for every 305 m (Griffiths 1958). But the cause of aridity in the region is poorly understood.

Rainfall is strongly quasi-periodic with a dominant time-scale of variability of 5–6 years, which is the same as for the El Niño-Southern Oscillation (ENSO)² phenomenon and for sea surface temperature fluctuations in the equatorial Indian and Atlantic Oceans, indicating, together with other factors, that long-term rainfall fluctuations in the region are linked to quasi-global climate fluctuations (Nicholson 1996). The two regions with the most dominant ENSO influences are eastern equatorial Africa during the short October–November rains, and south-eastern Africa during the main November–February rains. But it is now suggested the driver to climate change in East Africa may be the Indian Ocean Dipole rather than the ENSO phenomenon. This is an apparently independent circulating system in the Indian Ocean partly responsible for climate. Occurring inter-annually in the ocean's tropical part, it exhibits a phase of anomalously warm sea surface temperatures over the western Indian Ocean and cold in the eastern respectively. This has significant impact on regional atmospheric circulation and rainfall anomalies extending into eastern and southern Africa, and was possibly the cause of widespread localized drought and floods in 1997. During a positive phase sea surface temperature drops in the south-eastern Indian Ocean, across the far East and northern to north-eastern Australia, while temperature rises in the western equatorial Indian Ocean; the converse taking place in the negative phase (Fig. 2.3). These sea surface temperature changes cause changes in the convection patterns over the Indian Ocean, warming bringing heavy rainfall over East Africa and droughts in the Indonesian region. What induces the lateral shift is not fully understood, but tropical climates oscillate at intervals of 3–7 years between an El Niño phase, when warm tropical waters well up off the Pacific Coast of South America, and a La Niña phase when cold tropical waters well up. Some climatologists suggest

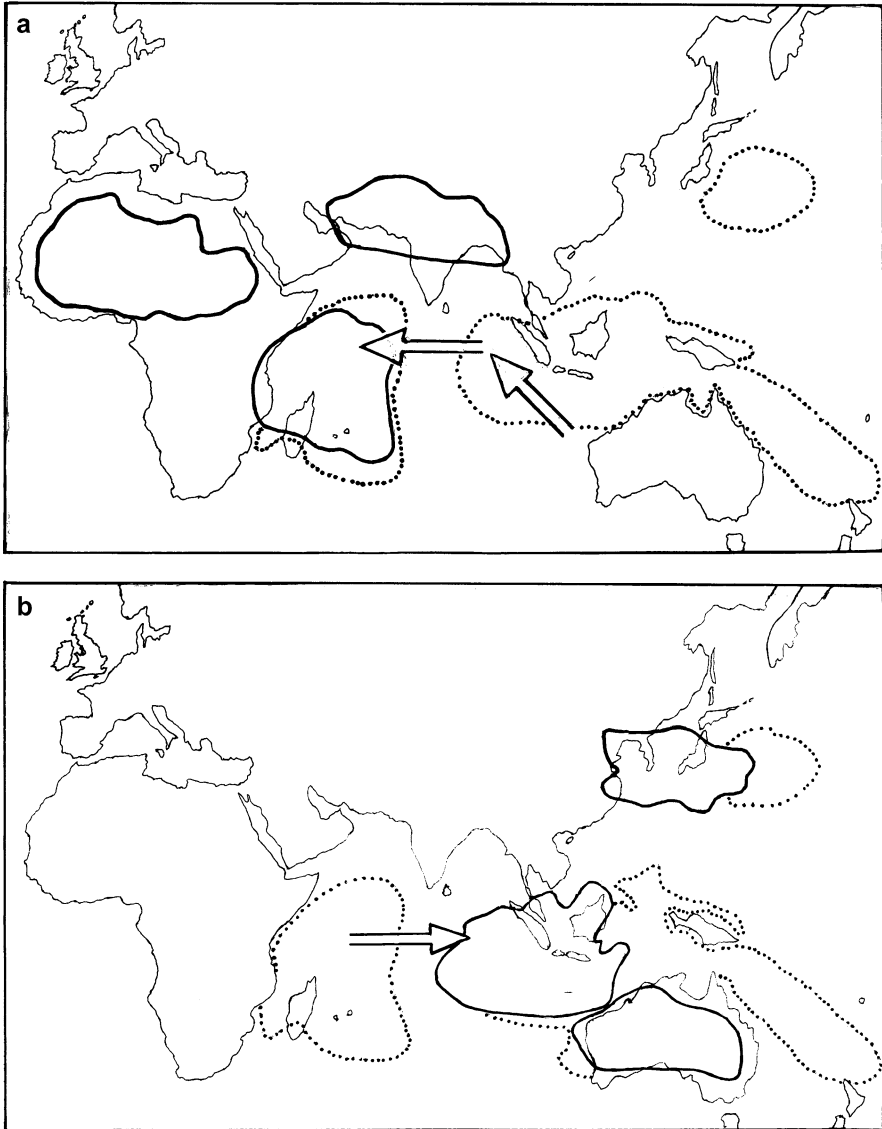


Fig. 2.3 Top positive dipole, bottom negative dipole, sea surface temperature pattern areas indicated in broken outline. In the positive phase low sea surface temperatures in the south-east Indian Ocean across to north-eastern Australia and high temperatures in the western equatorial Indian Ocean, cause heavy rainfall with cloud areas indicated in bold outline. In the negative phase the converse occurs, with low sea surface temperatures in the western Indian Ocean and heavy rainfall areas in the east. Arrows indicate direction of shift (After Marchant et al. 2007)

this affects the Indian Ocean and thus the Indian Ocean Dipole, but others indicate the phases could evolve independently (Marchant et al. 2007).

We saw that the majority of East Africa is under the influence of monsoons, the North-east Trades blowing during the southern summer, and the South-east during the northern summer. The former, reaching to the west of Lake Victoria, are relatively dry, coming from the desert areas of Arabia without any long sea track. On the coast the south-east monsoon brings a moisture-laden air mass across the Indian Ocean in April to early June, the South-East Trades, often causing rain in July as far inland as the Uganda border, the “long rains” during which half of Kenya’s annual precipitation falls. But the layer is shallow so does not carry much rain and the higher mountains of Kilimanjaro and Kenya protrude through it into the drier predominantly easterlies. Anomalously, various parts of Kenya have shown persistent opposing rainfall trends for 30 years or more. Winds from DR Congo and the Zambia-Zimbabwe regions also can give rise to quite heavy rainfall. This is followed by the short rains in October to November. South of the equator a unimodal distribution re-occurs as in the north, with a single rainy season in November to April. In January the ITCZ lies over southern Tanzania then moves north to a limit about half-way through the Sudan in July, before returning south. The amount of rainfall that the surface airflow carries is insufficient to account for the observed rainfall over East Africa and it appears that moist air feeds in at higher levels, one such flow at times being north-westerly, with a trough high over Egypt. But as yet, although several theories have been advanced, how East Africa gets its heavy rain remains unexplained. Orography is very important, the high ground being wet and the low dry. The zone of convergence of the Trades could result in some of the rainfall over the Lake Victoria basin, but the main zone is well to the west where the tropical rain forest has its limit. The moister “Congo” air rarely drifts past this limit into Uganda.

The north-east coast presents an arid anomaly due to the fact the South-East Trades recurve across the equator and adopt a south-west orientation. Owen (1833) in 1824 recorded that the rains began at Mombasa with partial showers on 25th March, 10 days after the *south-west* monsoon had set in, suggesting that the pattern over the north-east coast may have been operating further south 150 years later causing slightly earlier rains. The coast is aligned SW-NE north of the equator so that the humid south-west airflow fails to cross the coast and instead flows parallel to the shore, causing Somalia and the Arabian peninsula to fail to get significant rainfall. Over West Africa when these winds turn south-west they are then perpendicular to the coast and thus flow directly inland, precipitating heavy rainfalls.

Kenya’s Tsavo East NP comes into this interesting picture for its centre is marked by a southerly extending tongue of less annual rainfall, often subject to drought. This tongue represents the centre of the divergence between the airstreams which turn and flow along the coast and those which have sufficient westerly direction to flow inland.

Only 4% of East Africa receives more than 1,270 mm rainfall/year, so that all permanent and reliable water supplies may be presumed to originate in this 4% falling on the high altitude catchment areas. Kenya’s Aberdare Mountains bamboo zone loses about 1,270 mm in evapotranspiration from a rainfall of 2,032–2,286 mm, giving an annual water yield of 762–1,016 mm. Transpiration

varies little from year to year but rainfall may decrease. For areas receiving 1,016–1,270 mm of rain no substantial water yield can be expected. Forest areas with less than 1,016 mm rainfall are unlikely to have anything except sporadic stream flow although exceptions to the generalization exist, and some grasses, notably *Pennistenum clandestinum* Chiov and *Cynodon dactylon* (L.) Pers., have been known to use approximately as much water as natural forest (McCulloch and Dagg 1965).

2.10 The Nile

Nubian and Egyptian evidence suggests a moist interval beginning before about 9000 B.P. interrupted by some drier spells, and terminating in stages between 4900 and 4350 B.P. About 5000 B.P. the annual Nile flood was at least 5 m higher than present, then falling to extremely low levels between 4130 and 4080 B.P. Bell (1971) has hypothesized how Egypt entered a “First Dark Age” as a result of a prolonged and severe deficiency in Nile floods which would have resulted primarily from a rainfall deficit in the Blue Nile catchment area, following upon a Neolithic Wet Phase which declined to approximately the modern level of aridity by about 4350 B.P. This conclusion is based in part on a change in hunting and desert scene depictions showing both a change in the animals hunted and the background landscapes, as well as a general exodus from the Libyan desert as evinced by the cessation of rock paintings and abandonment of Neolithic sites. Low Nile floods, rainfall always being deficient in Egypt, caused widespread famine leading to collapse about 4180 B.P. of the Old Kingdom central monarchy. A papyrus from that period reads, “The River of Egypt is empty, one can cross it with dry feet,” and “Upper Egypt has become a desert” (Vandier 1936). Failure of the floods was most severe between 4180 and 4135 B.P., and for a few years between 4005 and 3992 B.P. This was part of the widespread fluctuation in climate which played a significant role in the collapse of many centres of culture flourishing in the Early Bronze Age from Greece through the Near East to the Indus Valley, bringing on the First Dark Age of Ancient History as a whole. Bell considers the real ‘Dark Age’ probably lasted for 20–25 years only, famine being important as an explanation of the collapse of the Old Kingdom.

One of only two references to cannibalism in Ancient Egypt occurred in a tomb inscription of the first great famine about 4180–4130 B.P. south of Luxor, “All of Upper Egypt was dying of hunger, to such a degree that everyone had come to eating his children.”; although it is considered “everyone” is an exaggeration. Several other references of this period refer to famine. A letter to his mother from her son who was 600 km away in Thebes in Nubia above Wadi Halfa collecting food, refers to the low Nile and explains the difficulty in finding food, “All the country dies of hunger,” and “Anyway, here, they have begun to eat men and women!” (Vandier 1936).

From 4150 to 4000 B.P. there were indications of improvement in natural conditions. By 4130 B.P. inscriptions seem to describe them as less severe and floods were adequate or better between 4060 and 4010 B.P. Possibly it was during the former drought a gauge was established on the Nile at Elephantine (Aswan). Famine conditions returned in 4002–3950 B.P., the year 3998 B.P. being a period of disorder probably occasioned by a low flood, drought, and sandstorms. A report dated to June 3839 B.P. on conditions in the eastern desert east of Aswan claimed “the desert is dying of hunger,” but 3991–3786 B.P. was in general a period of prosperity with adequate Nile floods, although no return to the Neolithic Wet Phase in terms of rainfall. No high or low East African lake levels have been dated to exactly the same epoch of Dynasty XII (3991–3800 B.P.) but Lake Rudolf experienced a very high level about 3600 B.P. There was only one mention of “years of famine,” but from 3786 to about 3160 B.P. famine was recorded in numerous years. About 3720 B.P. Egypt was attacked by the Asiatics (Hyksos), perhaps because of famine in their own land. A 7 year famine beginning about 3708 B.P. was prophesied by Joseph to follow 7 years of abundance (Genesis 41, 29–30). Quinn (1992) considers that 7 year periods of fluctuation are credible phenomena related to alternating cool and warm periods. The next famine reference is found in a papyrus of about 3169–3100 B.P. which refers to “the year of the hyaena, when one was hungry.”

In general, early Greek and Roman authors of c500 B.C. to A.D. 100 describe the northern Sudan much as it is today, but Claudius Ptolemaeus in Alexandria (second century A.D.) recorded rainfall and southern winds in the summer which, although rare events in his time, are now completely unknown. This suggests the belt of southerly winds which brings the Sudan its rainfall occasionally reached northern Egypt and this would have meant higher and more frequent rainfall for north Sudan. Studies of tomb inscriptions coupled with mummy labels from about A.D. 400 to the tenth century from the Nile Valley of Upper Egypt indicate a massive unimodal seasonal fluctuation in annual human deaths, mortality peaking in the first half of the year about April, homogeneous across the Nile Valley from Nubia to Memphis (Scheidel 2001). This coincides with the dry period before the annual Nile flood which begins in late June, overflowing in mid-August in Upper Egypt to peak in September and receding in October. Its timing could suggest starvation rather than disease mortality, a pattern which has probably remained constant for millennia although varying in magnitude.

A low Nile flood was reported sometime between 25 and 21 B.C. and failure in A.D. 99 (Garnsey 1988). A tendency towards increased aridity began by at least the second century A.D., and from 300 sand deposition was active again in Middle Egypt and the Libyan desert. That the Nile flood was still very high in the first century A.D. might find some support in the meteorological register of Ptolemaeus, probably based on the years between 127 and 145–151, which indicates, compared to the present, an increased frequency of thunder and weather changes, with relatively frequent summer showers which are unknown today, and frequent northerly winds in winter when they are now least regular. Antiochus’s Egyptian calendar of about 200 indicates frequent weather changes also, such as 15 times

between May and September, today a period of almost uninterrupted fine dry weather. There is some evidence that after the period of very low Nile floods towards 200, the height of the flood increased until about 400 with apparently a great overflow in 545 preventing planting and causing famine. Floods were then very low from 600 to 1550, but high again from time to time in the past few centuries. Adams (1965) considered that in Nubia the annual floods began a long-term rise early in the Christian era with episodic destructive floods between about 600 and 1000. But low flood levels lead to settlement of former floodplains resulting in much destruction when they flood again. The Nile gauge at Cairo beginning in 622 reveals two major periods of very low flood levels separated by periods of very high levels between 800 and 1500. Quinn (1992) deduces from the events that the years 622–999 would be more representative of a cool period in East Africa. Records indicate that Nile floods were generally high until 760, followed by a negative trend indicating a wet climate to the south from 850 to 950, and then abnormally low from 930 to 1080. Spring rains in northern Ethiopia were already below normal in 730–805 (Butzer 1981). The first report of famine in Ethiopia dates to about 849 (Pankhurst 1985).

Very high Nile flood levels occurred about 1100–1200 and historical evidence indicates that about 1200 northern Sudan may have been wetter than present although the East African climate was generally dry from 1200 to 1450, with bursts of recovery of rainfall between 1250 and 1300, and again between 1350 and 1400 (Hassan 1981). A high Nile flood in 1360 caused much damage, and dwellings on Egypt's Isle of Rodah became entirely submerged. In 1371 the flood was again excessive, remaining high until November (Toussoun 1925). Further high levels occurred about 1500 lasting until the late nineteenth century. However, at the same time, after very low minimal levels towards 750, low minima were also maintained for a long period between 1500 and the nineteenth century, indicating low rainfall in equatorial East Africa reflected in the levels of Lakes Victoria and Albert (Figs. 2.4 and 2.5). It may have been this period of dryness which initiated

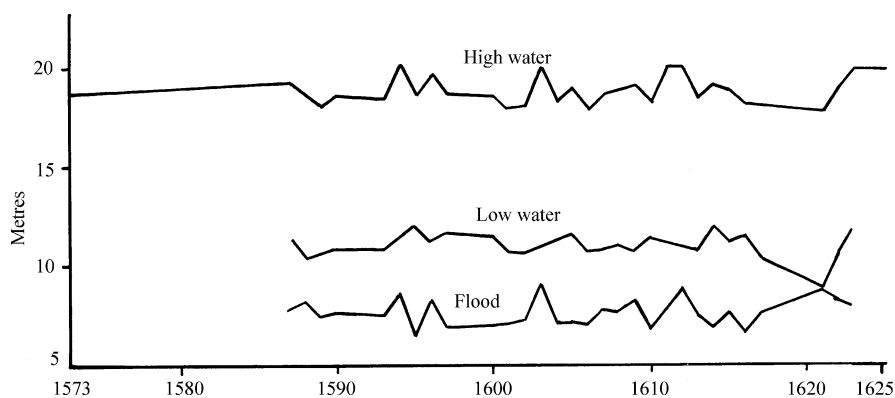


Fig. 2.4 Nile flow level height recordings 1573–1625 in metres

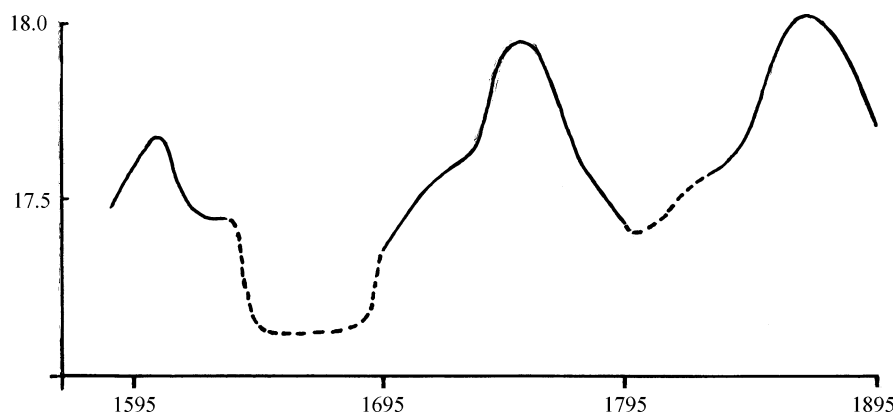


Fig. 2.5 Nile flow level 50-year smoothed means 1585–1895 in metres (After Nicholson 1976)

migrations into Buganda from the north-east some time between 1600 and 1700 (Kiwauka 1971).

2.11 The Nile Records

The Nile floods, usually in September, indicate Blue Nile levels which result from monsoon rains over the Ethiopia catchment area of the Atbara and the Ethiopian highlands. Vossius expressed the idea in 1666 that flooding of the Nile resulted from heavy rainfall in Ethiopia, an idea discounted at the time on the grounds that rainfall on the African continent was insufficient to account for the Nile flow. It was alleged that Vossius, not having visited Ethiopia, got his information from Paez (1629), but there is nothing in the latter's written account to substantiate this. Vossius stated also "They [the ancients] think truly the Nile to rise out of the mountains that they call the Moon, or out of the huge lake called by some Zaire".³ Writing in 1204, 'Abd al-Lat_f al-Baghd_di stated it was said the rivers which came out of the Mountains of the Moon united with others "in the same huge lake, which is of vast extent, from that lake the Nile comes out" (Zand et al. 1964). He could of course have meant Lake Tana, 3,670 km² in area, fed from the Ethiopian Highlands, rather than Lake Victoria, 68,000 km².

The Nile begins to rise in June, reaching its maximum in September then declining slowly to a minimum in May. At the time of its flood the Blue Nile acts as a dam across the White Nile where the two rivers join at Khartoum, causing the White Nile to back up and form the huge swamps of the Sudd where some 50% of its water is lost by evaporation. In April the Nile is at its lowest, and it is then a measure of the White Nile which is fed by rains over East Africa. The Blue Nile draining the Ethiopian highlands provides the major part of the Nile water, some 80% of its flow, but nearly the whole of the remainder, some 16%, comes from the

lake plateau of central Africa via the great reservoir of Lake Victoria, the White Nile receiving its water from Lakes Victoria and Albert. Fairbridge (1984) gives these figures as 68% and 32% respectively for the beginning of the 1980s. The Blue Nile catchment is essentially affected by El Niño phases with Ethiopian droughts leading to 5–15% reductions in the total Basin water budget, while La Niña phases can produce 10–25% increases in rainfall over the White Nile catchment.

Hassan (1981) concluded from an analysis of Nile records that short-term fluctuations in the Nile flood maxima apparently reflected variations in the contribution from the White Nile and these seemed to match variations in the level of Lake Chad, thus reflecting the poleward movement of the ITCZ. Between February and June the White Nile is the main source of supply, and the minimum lower Nile level depends upon the levels of lakes Victoria, Albert, and Edward, and rainfall over East Africa in the preceding months. Average annual input into lakes Edward and George is 5.6 mlrd m^3/s , of which 3.6 is lost through evaporation, leaving 2 mlrd outflow via the Semliki. Evaporation exceeds rainfall by a ratio of 1:0.94. Lake Albert receives an average annual input of 29.6 mlrd of which 7.6 is lost through evaporation leaving 22 mlrd entering the Nile, but evaporation exceeds rainfall by a ratio of 1:0.61. Overall evaporation averages 3.9 mm/day and losses from swamp areas are about 1.5 times that of open water (Hurst 1952).

In the post glacial past at some time flood levels were much higher than today; for a long time several metres higher. In 683 B.C. there was an unprecedented high flood (Jackson 1957). A range of 1.5 m for the years A.D. 641–1522 includes 93% of flood levels, 74% of those in 1587–1890, and 68% of those in 1841–1890. In 1871–1902 the range was 3.8 m. Flows since 1720 have apparently become much more variable and high and low flow sequences much more acute and persistent.

We are fortunate in possessing very long-term records in Africa which can tell us something about the interior of the continent's climate. These are in the form of the Nile flood records. The most ancient date to about 5050–4480 B.P. in the form of inscriptions on rocks marking exceptionally high levels, with floods averaging about 0.7 m or more the highest known being about 4.2 m. The next known figures in Dynasty XII state that a "good flood" was about 3.4 m in the northern Delta, ranging to 11.3 m at Elephantine. Bell (1971) considered it reasonable to infer that floods near Cairo in the early part of Dynasty XII were close to those of recent centuries with the zero point of the ancient scale being at or near average low water level, having been lowered from some former point when levels fell so low that serious famine occurred, particularly between about 4180 and 4135 B.P. A flood in Dynasty XIII was 17.4 m above that of A.D. 16 December 1963. The floods about 4500 B.P. on the old scale averaged about 1.8 or 1.3 m above the unknown zero, the water failing to reach this zero point in some of the famine years. The figure of 6.6 m in 3971–3928 B.P. near Cairo equals the average rise of 6.6 m from minimum to maximum flood for the seventh century A.D. to 1890. The average rise for 642–1521 has been given as 6.5 m, with 100-year averages ranging from 6.1 to 6.94 m, and from 1822 to 1891 a rise of 6.74 m. Excessively high floods occurred in 1817 and 1818, high water continuing to 1829 destroyed many villages and crops and drowned animals. In 1878 there was a great flood when the level rose 9 m at Aswan. The lowest low

water level in modern records was in 1922 when the gauge at Aswan recorded 83.5 m above sea level, at 83 m or less the river being crossed on foot. The normal low level at Aswan is 84–85 m.a.s.l. Compared with 1870–1899 the discharge at Aswan for the period 1900–1949 was 24% less, and for 1899–1900 it was 41% less, the second lowest discharge ever recorded.

The years around 3860 B.P. showed an extraordinary variability in the late winter levels. The greatest known flood recorded at Semna during the Middle Kingdom had a peak volume about twice that of the lowest flood recorded, and about four times greater than that of the larger modern floods. A “good flood” was about 50% above the great modern flood of 1878. There is evidence of water damage to buildings 6 m above the typical high water level in the earlier part of the Middle Kingdom and the Ancient Egyptians would not have built at levels which they expected could be flooded. Thus a number of exceptionally high floods occurred between 3840 and about 3770 B.P. but these were not typical of the period. An inscription dated 24th January 3869 B.P. records an exceptional winter flood about as high as modern high water level and 3.5 m above the modern level for late January. Bell argues this must be interpreted as an extreme prolongation of the monsoon rains and, or, a remarkable and early onset of the spring rains over the Blue Nile basin as the volume of water implied could not be produced by the White Nile due to the flat topography of its course.

A number of inscriptions mostly from the reign of Amenehmet III (3842–3799 B.P.), and some later ones, allow levels to be plotted against date, albeit with some argument, indicating an apparent decline in flood levels from the Middle Kingdom (3971–3570 B.P.) to modern times, with low water level in the Middle Kingdom being close to recent levels. Evidence suggests that during much of about 3991–3780 B.P. high water level was around the 149 m contour level, similar to the late nineteenth century A.D., but the end of the Middle Kingdom experienced a “Little Dark Age” due to a lack of the exceptionally high floods which had characterized earlier years allowing great expansion of settlement. The interval between 3778 and 3745 B.P. saw several years in which the floods fell below New Kingdom levels causing famine, and the somewhat abrupt decline after 3768 B.P. led to famine and the destruction of social prosperity. The prosperous condition of Nubia in the Hyksos period suggests a return to adequate floods. The year 2683 B.P. was a very wet year in Nubia, a record stating, “When the time came for the flood of the Nile, it began to increase greatly every day. . . it flooded the mountains of the southern lands and the low lands of the north. The land was like an inert primordial Ocean, the banks could not be distinguished from the river. . . It happened that a downpour from the sky, in Nubia, made the mountains sparkle as far as their summits. Everyone in Nubia was rich in everything.” (Vandier 1936). Large herds of cattle kept in Nubia in Middle and Early New Kingdom times suggest a less arid climate, but the “vast herds” referred to by archaeologists probably relate to the claim of King Sneferu about 4600 B.P. who allegedly captured 200,000 head of large and small cattle in his war against Nubia.

Providing a series of records dating from A.D. 622 to present of the longest river in the world, the Nile boasts more than 30 nilometers, many dating from ancient times.

Strabo was the first to mention one at Aswan *c*25 B.C., but the most ancient of Islamic Egypt is that constructed at Rodah about 711. Whereas there is some argument over the interpretation of the flood levels prior to the installation of a nilometer in 642, and indeed beyond (Ghaleb 1951), this has little relevance as far as the general picture of climatic fluctuation is concerned. It is sufficient that certain years were marked by very high floods, and others by famine (although high flooding could cause famine through lack of crop planting), illustrative of climatic fluctuations well outside the norm and relating to the amount of rainfall falling in the Nile catchment areas. The validity of these records has been questioned on the grounds of changes in length of the 'cubit', alteration of the records for tax purposes as taxes were levied according to flood height, and silt accumulation in the gauge. But the data do establish shorter periods of prolonged low or high levels, and longer term trends can be substantiated with other evidence (Nicholson 1976). Ghaleb (1936) claimed the Egyptian peasant was too aware of the level at which his land was watered for it to be possible for the authorities to exaggerate levels.

Ortlieb (2004) has outlined some of the difficulties of interpretation, but on the whole analysis of the records, such as that of Quinn (1992, 1993), shows they have validity and indicate a relationship between ENSO and Nile river flood deficient years. From the beginning of the sixteenth century to present about 80–81% of ENSO events correlated with low Nile maximum levels. The annual flood levels are linked with the western end of the Southern Oscillation see-saw (i.e. the events at the western and eastern ends alternate in a "see-saw"), and since 1824 low Nile flows can be correlated with ENSO events, such as high rainfall in northern Peru, central Chile, and north-western Argentina. Prior to this date there is no clear correlation, which may reflect the reliability of the Nile data but in Ortlieb's view more probably relates to large scale modifications of the ENSO system. Large-scale ENSO conditions which correlate with the weakest recorded Nile flows occurred in 650, 689, 694, 842, 903, 967, 1096, 1144, 1200, 1230, 1450, 1553, 1641, 1650, 1694, 1715, 1716, 1783, 1887, 1899, 1913, and 1972, the lowest of all being in 1200; but there were long low periods also such as from 1790 to 1797 which could be related to low summer monsoon rainfall in the Ethiopian Highlands (Quinn 1992). Davis (2001) claims the year 1877 witnessed one of the most dramatic Nile failures in 500 years with the height 1.8 m below average. It has been suggested that because the White Nile plays little part in the annual flood experienced in Egypt, droughts and famines reported in Africa outside of the Ethiopian Highlands cannot be dated from low Nile floods, but ENSO is wide-reaching in its effects causing drought in Australia and deficient summer monsoon rains in India correlated with rainfall anomalies in the Ethiopian Highlands. So we may suppose that the hinterland of Africa is similarly affected, low Nile floods reflecting ENSO effects in the wider African region.

Toussoun (1925) listed high and low Nile levels from A.D. 622 to 1921 and although some of these figures have been questioned for their accuracy, with the record lacking 275 years of low levels (21%) and 192 high levels (15%), they give a general overall record for 1,300 years. Recordings are interrupted in 1470 and are then spasmodic until resumed with regularity in 1839. Figure 2.6 shows the 50-year

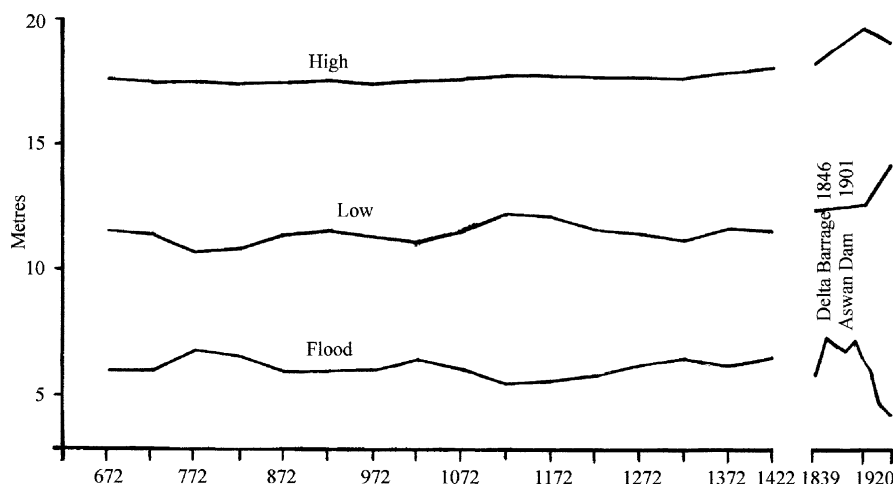


Fig. 2.6 Nile levels 672–1422 and 1839–1920, 50-year means (metres). Flood is high minus low level

mean gauge levels from 672 to 1439, and 1839 to 1920, for flood height, low water, and flood volume, as expressed by high minus low water. This indicates broadly dry periods from about 720 to 870, 900 to 1070, and 1400 to 1450. The average difference between high and low water is 6.7 m, a flood of 9 m or more would cause widespread destruction, but the margin between a good and a bad flood is about 2 m only, noted since the time of Herodotus. The flood of 683 B.C. reached the same height as that of A.D. 1946 when it overflowed the banks between Karnak and Luxor, about 2.6 m greater than the highest of the modern floods and perhaps equal to the lowest of the Middle Kingdom. A similar flood had occurred about 100 years before 683 B.C. commemorated in an inscription at Luxor, “The water of the Nile rose. . . the land was in its power as of the sea; there existed no dike made by the hand of man that could withstand its force, men were like grains of sand on their town. . . All the temples of Thebes resembled a swamp. . . the people . . . were like swimmers in the water.”

At the time of his visit to Egypt in 450 B.C. Herodotus noted, “When the Nile overflows, the whole country is converted into a sea, and the towns, which alone remain above water, look like the islands in the Aegean. At these times water transport is used all over the country, instead of merely along the course of the river.” (Carter 1962). Which suggests such flooding at that period was not regarded as unusual.

In 891 it was reported the Nile was “hidden in the ground to the point at which nothing remained,” something never seen “before or since Islam” (i.e. 640). In a *Commentary on the Aphorisms of Ptolemy* quoted by al-Baghdādi (Zand et al. 1964), it is stated there was a low flood in 903 and again in 913. The year 944 the flood was very low and remained low for 9 years to 953. The year 967 was again claimed to be the lowest flood year seen since Islam and was followed by 4 years’ famine. The flood failed in 1052 causing famine, and again in 1055. The year 1057

was a low year, and then in 1059 a terrible scarcity ensued such as never seen before, drought continuing for 7 years. In fact the average low water for the 7 years was 97% of the 100-year mean to 1100, and average high water was 99%. Nevertheless people were reduced to eating corpses, cats, and dogs. There was famine in 1123, and in 1148 a high flood known as the “great deep.” In 1181 the level was so low that one could pass from the Cairo bank to beneath Méqiâs (site of the Rodah nilometer). The provinces were desolated by drought, many people died and many emigrated. There was much cannibalism, especially of children; punishment for which was burning alive. This drought was followed about 1184 by a high flood known as “the vast deep.” Walls collapsed and fields were inundated causing famine conditions to continue, and in 22 months there were 111,000 registered deaths but many unrecorded ones. Famine followed a low flood in 1191 in which one third of the inhabitants are said to have died. ‘Abd al-Lat_f al-Baghd_di recorded a very low Nile in 1199–1200 leaving the nilometer on dry land, which led to great famine and mortality and extensive cannibalism. He records enormous numbers of dead everywhere, and at Misr there were so many they could not be buried and bodies were left in the streets. He noted the next lowest flood had been in about 960 (=967) (Zand et al. 1964). The famine extended into Syria and people fleeing from Egypt the road to Damascus “was like a vast field sown with human corpses.” According to this author, when the winds came from the East and the South this was a sign of a low flood, while winds from the North and the West presaged high floods.

In 1245–1246 there was a great storm which killed vast numbers of fish in Lake Fayum (more correctly the Birket Qarûn), possibly by stirring-up oxygen depleted bottom water. The bodies became piled up on its shores, among them gigantic Nile perch recorded as forming a sort of embankment around the lake. Herodotus believed Lake Fayum had been constructed by King Moeris as Lake Moeris, a vast 90 m deep lake filling the Fayum depression and about 70000 B.P. occupying an area of 2,800 km². This lake dried out about 11500 B.P. in a hyperarid period, to be recreated about 8100 B.P. from the Nile, reaching a depth of 17 m. After recession to below 12 m it rose again to 24 m about 7140 B.P., then falling again to below 9 m. It then underwent four increasingly high levels from c8150 up to 5190 B.P. separated by lower levels, and then fell due to a reduction in inflow and a drying climate, dropping from 18 m above sea level to 2 m below. Ball (1939) suggests this fall was due partly to the inflow being mainly captured by another channel, but drying climate may have played a part. King Moeris cleaned the channel thus restoring the lake’s size, at least in part. An extensive reclamation of land in the depression took place under Ptolemy II (285–247 B.C.), no archaeological remains pre-dating the third century B.C. having been found and thus supporting the idea of a once greater lake. By 1906 Lyons was to report that control of the Nile water and reclamation of land had diminished the water surface area until only a small and rapidly shrinking lake remained. Ball reported it as 200 km² within a 1,700 km² depression and plotted a progressive increase in salinity from 1906 to 1933, calculating that by 1952 it would be as saline as seawater. He considered that formerly the salinity had been balanced in part by underground percolation of the water due to a higher lake level. By the year 1990 it was reported as

being 220 km² in area with a depth of 3.5–8 m and a salinity of almost 35^{0/00}, the worldwide average for seawater. Its shallowness makes it very productive of fish, but it can no longer support Nile perch, a freshwater species.

After the thirteenth century the years continued to be punctuated by famines with a severe one in 1297. In 1359 a high flood was recorded followed in 1360 by one of a height never seen before. In 1383 a high flood continued to 1400, but in 1404 one could wade across the river at low water. From 1422 records were intermittent but in 1427 the flood was low accompanied by drought and hunger, recurring in 1429. In 1450 famine and death were recorded following a low flood, then there is a period of almost no record from 1470 to 1586, possibly indicating adverse conditions, perhaps extreme drought. In 1478 there was a very high flood such as had not been seen for a long time, with many places submerged. In 1518 there was drought continuing into 1519 but followed by a high and damaging flood.

In 1521 the Ottoman invasion found the country in great misery, and a different manner of recording the Nile flood was adopted in that year when it is recorded the flood reached one of the best levels ever seen (Ghaleb 1951). Regular recording then stopped the following year until 1587. From 1573 to 1625 there are 32 high and 29 low water records, of which 21 of the former (66%) are above the 150 year mean 1422–1572, which differs only slightly from the 847 year mean 622–1469; and all the low water records (29) are below the long term means while flood volume is above (Table 2.1). It appears possible that with resumption of recording the low level benchmark was lowered.

There are no written observations between 1583 and 1619, although for 1620 it is recorded there was despair among the population and wheat was dear. The following year there was a high flood but grain rose higher in price and bubonic plague broke out, particularly among strangers (perhaps people moving into the Nile area from a drought-stricken hinterland). In 1622 there was a very high flood but it fell in time to allow planting and a superb harvest was produced although there was great mortality from plague. There were no reports of cannibalism during this period. Reconstruction of flood levels and comparisons with Lake Chad levels and Senegal River flow indicate a high flow period beginning near 1590 and ending around 1630, with a decrease around 1630–1680 (Diaz and Pulwarty 1992). From 1624 to 1720 there are no records but Daniel recorded in 1700 (Foster 1949) that there was a low flow in 1687, although it was not until 1694 the flood was once more so low people again resorted to cannibalism. In Sennar 1684 is recorded as a famine year when men were forced to eat dogs (Crawford 1951), anathema to the Muslim inhabitants. Possibly this should read 1694 as it would presumably indicate a low Nile above Egypt. Pariset (1837) reported a low Nile causing famine accompanied

Table 2.1 Nile levels

Years	n	High water mean	Low water mean	Volume mean
622–1469	847	18.24	12.45	6.1
1422–1572	150	18.21	12.52	5.69
1573–1625	52	18.9	11.2	7.7

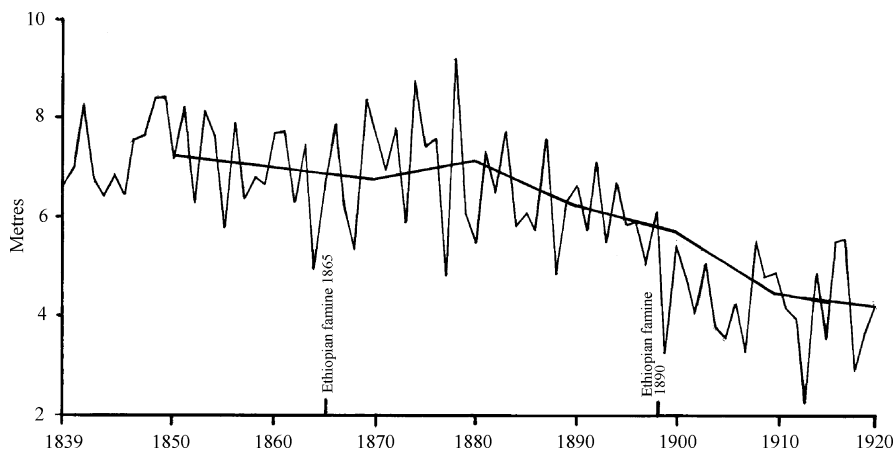


Fig. 2.7 Nile flood (*high minus low water*) in metres, with 10-year means trend

by plague in 1718. The year 1772 was a low year and from 1781 to 1799 all floods except two were below average, with serious drought and famine from 1783 to 1784. In 1801 the flood was very high submerging Rodah. Again in 1817 the flood was high, destroying many villages and drowning men and animals, continuing higher in 1818 than in previous years. Both 1822 and 1829 were recorded as very high years, while 1830 was low. The years 1870 and 1878 were very high and 1892 was “good”.

Figure 2.7 shows flood volume from 1839 to 1920, which indicates an increase in volume about 1840, 1840–1842 being recorded as high years, followed by a levelling off to earlier levels, and from 1900 a steady decline. The years 1839 and 1843 were recorded as low. Lejean (1862) wrote of famine among the Bari of Gondokoro causing many deaths from 1855 to 1861, and in 1864, 1868, 1873, and 1877, the Nile level was recorded as very low. Serious famine is reported in Tanzania’s Usukuma region between 1860 and 1870 indicating widespread drought. The years 1888, 1901, and 1902, were very low also and the flow from 1899 to 1957 was 25% less than that between 1871 and 1898. In 1899 famine spread all along the Upper Nile. The years 1898 and 1899 were years of strong La Niña events.

The extent of these variations may have been influenced by raising of the river bed between Aswan and Cairo by silt deposition, an artificial raising of the low level due to construction in 1834 of a barrage below Cairo, and in 1843–1861 the Delta Barrage 25 km below Rodah. The Aswan Dam, completed in 1902, raised the average low level downstream by 0.6 m, and the average low Nile discharge increased by some 50%. The period from 1870 to 1920 shown in Fig. 2.8 indicates a steady rise in low water level and a steady decline in flood level, perhaps influenced also by construction of the Aswan Dam, but Lyons (1906) concluded the Rodah maximum readings were sufficiently accurate with regard to the annual variation in flood level and

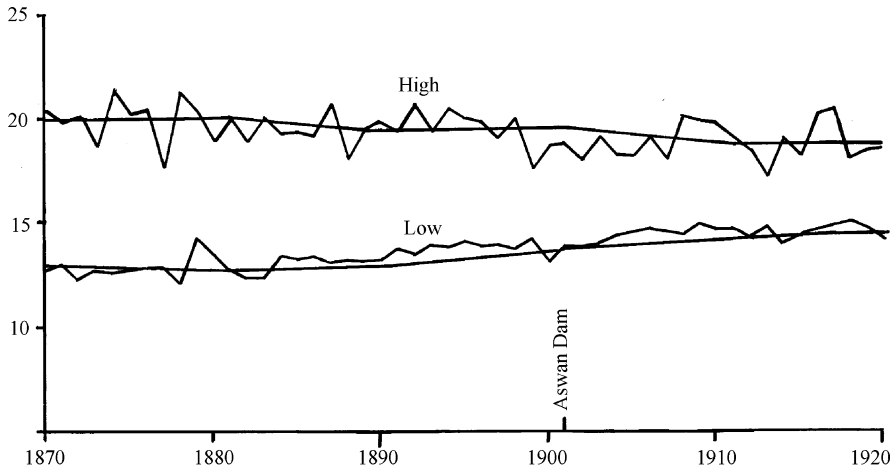


Fig. 2.8 Nile levels 1870–1920 (metres) with 10-year means

concurrent with others that flood levels of about 5000 B.P. agreed with those of the beginning of the twentieth century.

The period from 622 to 1821 was punctuated by many presumably lesser famines as well as good years, the product of differing events. Firstly there were drought years when the Nile was very low in the season between low and high water; secondly there were years when the Nile flood required to water the Delta for planting was very meagre and sometimes absent, and thirdly there was prolonged high flooding so that planting could not take place, which resulted in famine also. Overall it seems that exceptionally high floods caused more death and destruction than did drought.

The prosperity or otherwise of the Nile Delta can be equated with that in the Niger Bend, where prosperity depended equally upon an annual flooding, but whereas it may be simply a question of detail, such detailed annual records lacking for the Niger Bend, events such as drought and floods in the Nile Delta appear to have been of much shorter duration than those in the Niger Bend. Figure 2.9 compares the Nile flood for 1870–1920 with the discharge of the Chari River measured at Ndjaména. Both show declines in volumes, that of the Nile beginning after 1880.

Between c1544 and 1625 Uganda's northern interlacustrine zone, including the "Pakwach triangle" an area bounded by the Albert Nile, the Aswa River, and the Victoria Nile, was affected by drought, famine, and major strife. Oral tradition asserts that long before the seventeenth century Ukerewe Island in Lake Victoria and its adjacent mainland area were invaded by large numbers of wild animals, presumably animals such as buffalo and elephant, causing the people to withdraw, returning again after the animals had departed (Hartwig 1976). This suggests a serious drought, animals from the mainland seeking the marshy areas, and

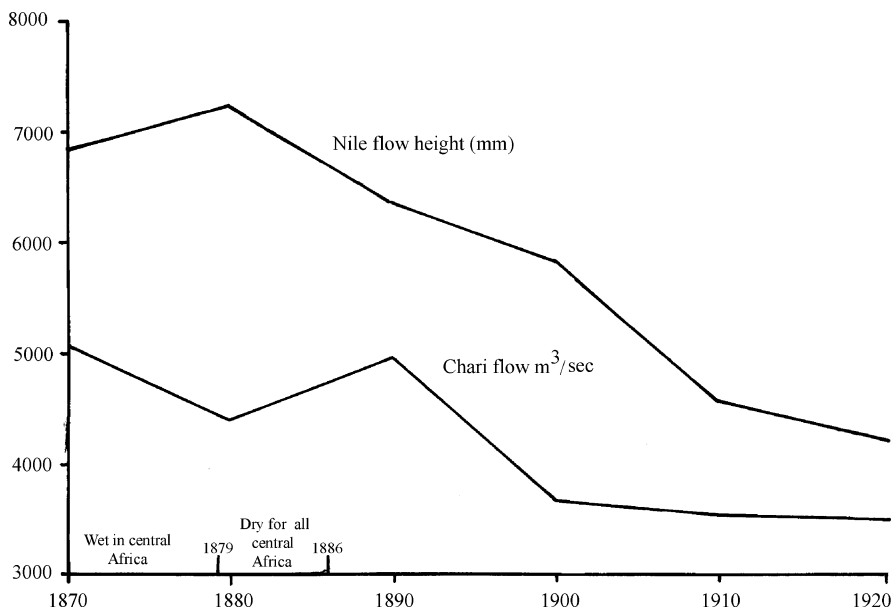


Fig. 2.9 Nile flow compared with the Chari River flow 1870–1920. Two different methods of measurement are used but they show a parallel trend

probably corresponds with this northern Uganda drought. Low rainfall accompanied by famine was experienced in Uganda's interlacustrine region in 1725–1729, 1749–1755, c1761–1769, and c1785–1792. However the highest Nile flood levels, determined by rainfall in the Ethiopian highlands, were reached in 1737–1749 and again in 1755–1759 or 1738–1758, contrasting with drought and great famine in the Niger Bend in 1711–1716, 1738–1743 or 1756, and 1770–1771. The years 1749, 1752, and 1753, experienced relatively weak Nile floods.

Egypt suffered a severe drought in 1833, while in the mid-1830s a chief in Ukerewe was deposed for his inability to stop a drought which had lasted for more than 2 years and caused widespread starvation. As this was the most climatically favoured district in this region of the lake, those on the mainland must have suffered much worse. Population recovery could take more than a generation to replace, even under favourable conditions (Hartwig 1979). This extended drought of the mid-1830s affected Egypt, Ethiopia, the Kamba of eastern Kenya, north central Tanzania, and presumably the Sudan and Uganda, perhaps extending to a much wider area both west and south and could have caused one of the most significant demographic setbacks of the nineteenth century in eastern Africa. Krapf (1849–1850) referred to a great famine all over East Africa about 1833, noting in 1848 that it was "some 15 years ago."

Southern Uganda experienced above average rainfall in 1916–1917 and Lake Albert rose 3 m. Little rain fell in 1917–1918 and lake levels began falling with drought causing famine in many parts. The famine ceased in 1919 but rainfall

decreased to 1923 and the Nile flow was below normal from 1919 because of low rainfall in Ethiopia, the latter following the same pattern as in Uganda, but the run-off from Ethiopia reflected the changes in rainfall more directly. Continuing low rainfall in Uganda finally reduced the volume of water leaving there, the White Nile falling to about 50% of normal between 1921 and 1923, causing the Nile to drop 0.87 m below average at Wadi Halfa, a fall of about 57%. Flow was almost normal again in 1923 because the Blue Nile and Sobat rivers were about 70% above average, overcoming the deficient Uganda discharge. The drought in Uganda was reflected in the level in Egypt 3 years after it occurred, thus the Rodah Nilometer records correlate well with oral traditions of early famines in Uganda.

In summary the Nile readings from 622 show no pronounced changes, the main feature being one of fairly long periods of average high floods, followed by low. But a low flood may occur in a high series and vice versa. From 641 to 1946 ($n = 1080$) a plot of flood numbers against flood heights shows a normal distribution with a low standard deviation (Hurst 1952). In other words, the floods seldom depart from a consistent average. But on average, levels from 1400 to 1850 were low, while from 1869 to 1898 they were high; then from 1899 to 1908 below the twentieth century mean, a large fall occurring towards 1900, with that of 1899–1900 being the second lowest level ever recorded. In 1912–1914 the Aswan discharge was the lowest ever recorded, and the low period continued to 1942. Lamb (1966) states that levels were high in 1722–1781, and 1844–1898, but fell substantially towards or about the end of the nineteenth century; and variations in level in the first half of this century seldom reached the average levels of 1870–1890, while they never equalled the 12 highest years of that period. Exceptionally high levels were however recorded for 1964. Low levels for the long period of 1400–1850 suggested to Lamb that the equatorial rains were either weak, or displaced to the south, and a change in general wind circulation in the late 1950s to early 1960s caused increased rainfall.

Kremer (1910) suggested there might be a connection between the rise of the Nile and rainfall at Zanzibar in April and May, but until the relationship of the atmospheric pressure over North Africa to the flood period was better known, it remained uncertain.

In Tanzania the long rains of 1913 were above average, but on the lake plateau of Uganda the excess was much less, and for the year there was a deficit of 10%. In Sudan and Ethiopia the deficit was 20–30% and the Sudan isohyets were displaced 150–300 km further south. Rainfall recorded at Addis Ababa from 1902 to 1939 and 1946 to 1970, shows maxima in 1915–1917, 1928–1930, 1946–1948, and 1968–1970. Minima occurred in 1918–1920, 1931–1933, 1951–1953, and 1965–1967. From November 1967 to October 1969 rainfall was 200% above average, but this appeared to result from a prolongation of the wet season rather than to a significant increase in summer season rainfall. At periods of high Nile minima, the climate would be wetter than that of lower minima.

2.12 Lake Victoria

Covering an area of about 68,000 km² with a maximum depth of 80 m, Lake Victoria, historically Lake Zaïre, is a shallow body of water which originated as a Miocene lake some 25 Mya and depends for its water budget on precipitation. Regular nocturnal land breezes create a peak in nocturnal and early morning convergence and thundershowers causing maximum rainfall of 2,300 mm near the centre of the lake, compared with 1,000–1,500 mm falling on adjacent shores. Its catchment area is about one sixth of its size in relation to volume, compared to lakes Tanganyika and Malawi with average volumes of 27,600, 18,900 and 8,400 km³ of catchment areas of 195,000, 220,000, and 100,500 km² respectively. But 85% of its water is lost through evaporation under present climatic regimes at a rate of 1.4 m depth per year, and the remaining 13–15% is discharged into the Nile. The bulk of its water budget comes from the direct rainfall onto the lake which is about five times more than that contributed by the rivers flowing into it. But the rivers could be said to tip the balance in contributing to a flow into the Nile, as on average the lake level remains fairly constant and does not persistently increase or decrease. Its dependence on precipitation means that in historical times the fluctuations in level were a direct response to trends in the equinoctial rains over the catchment between latitudes 2°N and 3°S (Butzer 1971).

There is an oral tradition that between 1825 and 1830 the lake level rose appreciably, flooding the isthmus between the Tanzanian mainland and Ukerewe making it impassable on foot and converting the latter into an island. According to Sukuma tradition Mwanza Gulf did not formerly exist, which appears to relate to this period (Hartwig 1976). The Nile was very high at the end of the 1750s and in the mid-1880s, but there is no confirmation of this high lake level at the beginning of the nineteenth century and the event may have been earlier. However local tradition asserts the Ukerewe chief was deposed in the mid to late 1820s for his failure to stop the heavy rainfall. In the 1870s Ukerewe reverted to a peninsula again and during 1876–1880 the lake level was apparently high, as it was again in 1892–1895. Thereafter it began a steady fall to 1902. Gauges were not installed until 1896, when it was at a low point. The level has since oscillated within an amplitude of no more than 1.5 m, until 1961 saw a dramatic rise to a peak in 1964 of some 2 m above its previous 60-year mean, to a level that was probably still 0.5–0.7 m below its 1878 peak of about 14.3 m. The Owen Falls Dam (now Nalubaale Dam), which became operative in 1953, was calculated to raise the water level by 1.2 m, but subsequent records show there was no significant effect as flow is maintained by sluices. The 1961 increase was ubiquitous among eastern African lakes.

The overflow from the Albert basin into the Sudan may stem from the Miocene onwards. This outlet was open from at least 28000 to 25000 B.P., and 18000 to 14000 B.P. Kendall (1969) has provided an interesting account of changes around the lake interpreted from pollen core deposits beginning about 14500 B.P., showing a picture of repeated climatic change from a relatively arid era in which the lake was set amongst a predominantly wooded-grassland type of country.

Almost completely drying-up around 14000 B.P. the lake's level fell by at least 75 m, leaving no more than 26 m depth of water in the lake, closed with no outlet the White Nile dwindling to a mere seasonal trickle in central Sudan. From about 13500 B.P. a period of increasing humidity began, and 12500–10500 B.P. was moderately wet, with a major forest of the evergreen type developing. The lake added to the Nile system about 12500 B.P. when its level began to rise, forest vegetation first appearing around the northern shores about 12000 B.P., prior to which date in the Pilkington Bay area forest was absent or of little extent. The emergence of Lake Victoria in its present form is a Pleistocene phenomenon, perhaps after the Early Pleistocene, at which time the surrounding vegetation was more open. Its overflow to the north greatly extended the area of permanent swamps in the southern Sudan and greatly increased the Nile discharge in the dry season, thus ensuring the perennial flow of the White Nile and the main Nile to the Mediterranean. Around 10000 B.P. the level may have fallen to 12 m below its 1960s level for a short time and the outlet was probably briefly closed again. A breaking-up into ponds may have provided fish refugia leading to some of the rich speciation which later occurred, and during which period the surrounding evergreen forest changed to a semi-deciduous type. This moderately dry phase continued to 9500 B.P., when a wet period ensued once more with the lake particularly full until 6500 B.P., with an evergreen forest near its shores, reverting to a semi-deciduous type in the next dry phase. A shift to semi-deciduous forest 7000–6000 B.P. suggests a slightly drier, more seasonal climate.

The next phase may have been drier or the climate may have been marked by greater seasonality. Then about 3000 B.P. a decline in the forest began, accompanied by an apparent increase in grassland, which Kendall attributed as most likely due to human influence, the destruction of the forest caused by the advent of agricultural tribes. The lowest fossil beach, 3 m above the present level, shows a C^{14} date of 3270 B.P., so persistent high levels do not appear to have taken place in recent times. The drier climate before 12000 B.P. accords with that for the Rwenzori, but the succeeding and comparatively minor changes in climate and vegetation recorded at Pilkington Bay do not appear to be matched by changes on the Rwenzori (Hamilton 1972).

Missionaries reported that about 1876 the lake level was some 2.4 m higher than it was in 1898. This means, if true, that the level around the years 1876–1880 was slightly higher, by 0.5–0.7 m, than the 1964 peak. The level peaked in 1878–1879, falling in 1880–1890, and was high again in 1892–1895. In 1896 recording began at Entebbe, Lubwa's, and Port Victoria. The level fell in 1897, rose slightly in 1898, fell again in 1899, and reached its lowest level for many years in 1900. In 1901 it rose 0.6 m above the 1896 mean (Ravenstein 1901) followed by a steady fall to 0.76 m in 1902. A minor rainfall event in 1917 led to a 3-year rise in the level but not of the magnitude experienced in 1961. Although in 1917 it brought about intensive flooding in the Sudd the inflow had fallen by 1919. The level varying by only 1.5 m between 1902 and 1960, in 1961 there was a sudden rise of 1.5–2.0 m (Fig. 2.10). The Sudd area increased from about 10,000 km² to 30,000 km², but fell back to about 20,000 km² by the 1970s. Nicholson and Yin (2001), using

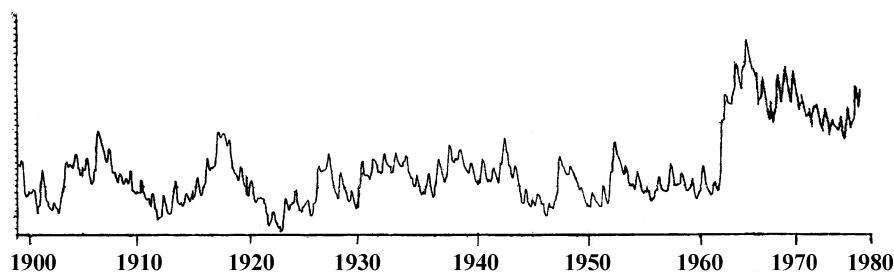


Fig. 2.10 Variations in the level of Lake Victoria 1899–1979. Scale is 10.2–13.6 m at the Jinja gauge (After Mörtz 1967 and others)

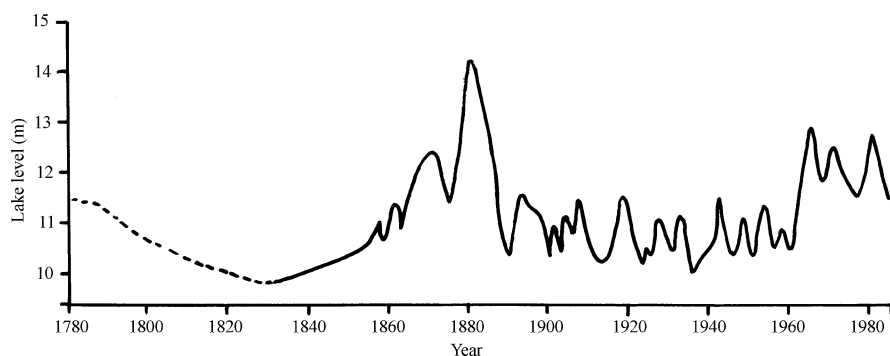


Fig. 2.11 Fluctuations in the level of Lake Victoria 1780–1985. Years prior to *c*1900 reconstructed from historical references (After Nicholson and Yin 2001)

measurements of the level from 1896 and historical approximations prior to this from the summer Nile flow, extrapolated the general trend in level back to 1780, prior to a peak in flow around 1785. This shows the apparently drier conditions from about 1820 to 1850 compared to the conditions in the first part of the twentieth century (Fig. 2.11, Plate 2.1).

Since 1961 there has been an annual excess of rain of 23% over the 1938–1963 average for the lake, the excess being most prominent in southern Tanzania and northern Uganda. Hurst (1952) suggested the main rain-bearing current to Ethiopia in the flood-time was from the south Atlantic, while a current from the Indian Ocean affected the eastern Lake Plateau and southern Ethiopia, and perturbations of this might occasionally cause Indian Ocean rain to fall in the Nile Basin. The early rains in Ethiopia appeared to be of Indian Ocean origin. Simulations indicated that rainfall had been responsible for a rise of 1.5 m by early 1962, and approximately 2.5 m by mid-1964, doubling its discharge into the Nile after 1963 when the level was less than 0.5 m below the maximum it had reached in the 1870s, which may not have been exceeded for almost 4,000 years. Flooding parts of Cairo in 1964 the average annual outflow from 1962 to 1979 was almost double that of 1900–1961, and double the fluctuation in terms of standard deviation. The sustained high level



Plate 2.1a Rocks in Lake Victoria at Mwanza, 1912 (Oehler in Jaeger 1915)

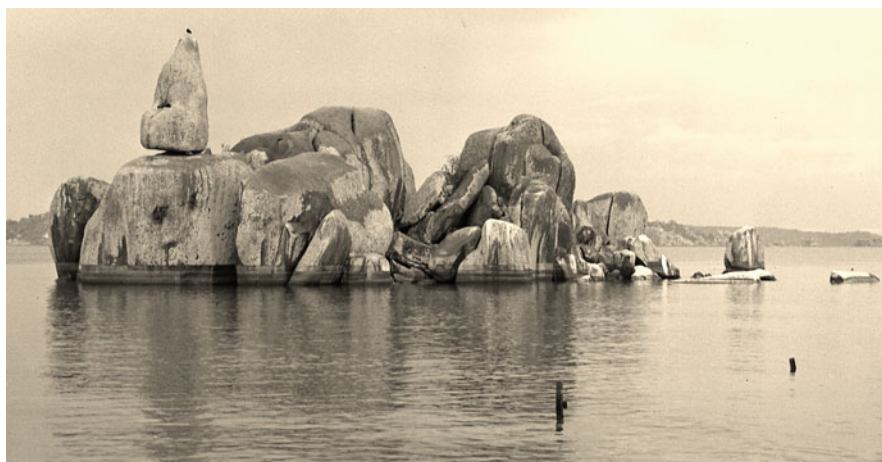


Plate 2.1b The same rocks in 1973. Note water level marks on the rocks (C. A. Spinage)

was the result of a small but persistent increase in precipitation, mainly due to an intensification and prolongation of the autumn equinoctial rains over most of East Africa during October-December, disproving the suggestion that it was construction of the Owen Falls Dam which had been responsible for the rise (Sene and Plinston 1994). The fluctuations in level between 1949 and 1960 showed no correlation with temperature changes, which depend largely upon variations in cloud cover, so evaporation over the lake does not seem to be important. After heavy rain in 1997, the lake level rose by about 1.7 m by 1998.

Since 2003–2005 Lake Victoria has lost about 3% of its volume, the lake being at an 80-year low by January 2006, attributed by some to a 10–15% decrease in rainfall over the catchment area, but by others to an increased offtake of water for a new hydro-electric plant, 55% above permitted levels causing a 45 cm lower lake level (Pearce 2006).

Changes in the levels of Lake Victoria and the Nile can be equated with changes in the subtropical anticyclones in the world atmospheric circulation, and all of the great lakes of Africa have been subject to changes; but interpretation is complicated often by the natural damming of outlets which are destroyed when the head of water builds up again. Major variations in lake level are, however, traceable ultimately to runs of wetter or drier years with the exceptions of Lake Victoria's two major phases of increase, the exact causes of which have not been pinpointed (Kite 1981), possibly because given the tropical pattern of very heavy and localized thunderstorms, estimates of rainfall over the lake and evaporation cannot be made accurately from the small number of point locations where records are made. The observed data may be underestimating the true amount of precipitation, thus modelling suggests the rise in level in 1977–1980 of about 1.5 m could have been caused by an increase of rainfall 25–30% greater than that recorded. In summary, Nile floods can be related to the levels of Lake Victoria and the latter to the climate of eastern Africa. While there are indications of a possible 10-year cycle in rainfall intensity, with a major 85-year cycle also, such cycles are due often to chance. Because of evaporation, lake levels pose a separate question to river levels, responding more rapidly.

2.13 Lake Victoria and the Sunspot Cycle

Sunspot cycles can be correlated with annually banded sediments, varves, dating back more than 500 million years in the pre-Cambrian Nama beds of South West Africa, producing an 11.5 year interval for as far back as can be traced (Zeuner 1945). Other studies suggest an average of 11.2 years within a range of 9–13. Every 11 years sunspots change their magnetic polarity thus producing another apparent 22 year period. Hutchins drew attention to an alleged relationship between sunspots and climate in South Africa in 1886 (Hutchins 1889), identifying a cycle of 11.11 years for Cape Town rainfall corresponding with sunspot minima. In 1925 Brooks calculated a correlation coefficient of +0.87 between high Nile levels and sunspot maxima for the 35 years from 1889 to 1923, and a rainfall/change-in-lake-level correlation coefficient of +0.91, the sunspot cycle averaging 11 years (Fig. 2.12). Brooks's sunspot cycle theory was supported by Gregory (1930) but later demolished by Hurst (1952) who found no such correlation with rivers of equal latitude elsewhere, such as the Parana River in Argentina. He found no correlation also with Lake Victoria levels between 1923 and 1950 when maximum and minimum levels occurred about twice as frequently as sunspot maxima and minima. Hurst compared sunspot numbers also with the *amount* by which the lake level rose

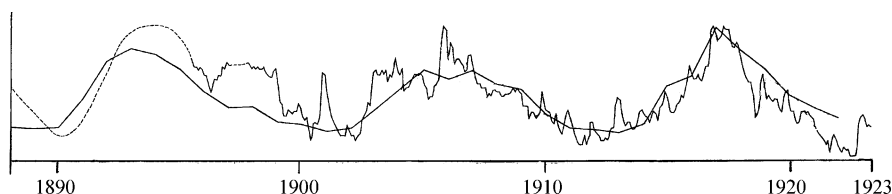


Fig. 2.12 Variation in the level of Lake Victoria compared with sunspot numbers (begin as broken line) 1888–1923 (After Brooks 1925)

and fell between 1900 and 1950 and found no correlation (coeff. corr. +0.38). Likewise, there was no correlation between sunspot numbers and fluctuation in rainfall (coeff. corr. -0.05); whereas his rainfall/change-in-lake-level correlation coefficient for the years 1902–1949 was only +0.69. Hurst came to the conclusion that Brooks's sunspot correlation was co-incidental for the years Brooks had examined. There was an apparent relationship to sunspot cycles between 1896 and 1922, but not from 1923 to 1950, thus giving an overall lack of correlation and therefore the apparent relationship was accidental. Any periodic variation in the Nile flood was negligible compared with the irregular changes in level. Lyons (1906) could find no indication of a relation to sunspot activity or any other form of periodicity in very low or very high Nile levels, although Shuman (1936) claimed to identify both Secular and Bruckner cycles.⁴

Mörth (1967) then claimed that in fact a sunspot/rainfall/lake-level correlation could be demonstrated, the wavelength being 10.2 years, and from 1938 to 1964 lake level fluctuations and rainfall over the catchment area were closely correlated. During this period there was a marked five year cycle in rainfall amount; with peaks in 1942, 1947, 1952, 1956–1957, and 1962, matched by lake level peaks. Prior to 1926 this cycle breaks down, and is replaced with a 10 year cycle. The most prominent peaks during the period 1899–1964 resolve themselves as 1906, 1917, 1927, 1937, 1947, and 1956–1957; which coincide with sunspot maxima. Mörth concluded the 5 year cycle, upon which Hurst destroyed Brooks's theory, was in fact the freak, and although he does not refer to either Brooks or Hurst implies vindication of Brooks's original analysis. He thought "without doubt" there was a 10 year cycle in rainfall and that this periodicity was not confined to the Lake Victoria catchment area, but was widespread in eastern Africa. Whether regular rainfall cycles exist or not is still a bone of contention and it seems to depend largely upon how one analyses the data.

Cochrane (1957) pointed out that actual lake levels would have meaning only if there were no outflow from the lakes, and the only possible relation with sunspots could be the total free water available compounded of the variations in lake level and flow in an affluent river; but he found a qualitative relationship between rate of change of sunspots and the amount of free water available in the Lake Malawi-Shire River system. The amount of free water apparently increased in the groups of years just before and just after peak periods of sunspots, the time when the number of sunspots is increasing or decreasing most rapidly. Between 1915 and 1956, of eight

periods of deficit or zero free water, five occurred in the years of minimum rate of change of sunspots and the remainder within 1 year. Cochrane found a similar relationship to rate of change of sunspots to hold for Lake Victoria, but although annual rainfall measured at Addis Ababa to the 1970s was shown to be significantly correlated with sunspot number with a peak around a 10 year period, no such indication was found in the data from eleven stations in West Africa (Bunting et al. 1976). Anderson (1992) however suggested there may be a correlation between sunspot cycles and El Niño events, their reoccurrence an example of association with a long solar cycle of some 90 years, the events being more frequent when sunspot numbers are weak. But whether African lake levels, Nile levels, and periods of drought, may all be linked ultimately to sunspot cycles, is a moot point.

2.14 Other East African Lakes

Correspondence of Nile levels with the East African Rift lake levels is good after 12000 B.P., but relatively high floods from 17000 to 12000 B.P. have no counterparts in the East African record, the Nubian Nile possibly being influenced by unstudied environmental changes in the southern or eastern Sudan. Beginning about 12000 B.P. the phases of expansion occurring over a period of 2,000–5,000 years were short-lived compared with the phases of contraction. In West Africa between 10000 and 8000 B.P. Lake Chad expanded, and at the same time lakes in East Africa rose tremendously also. High levels of Lake Rukwa have been dated to 9740 and 8060 B.P. when rainfall in Ethiopia was calculated to be 47% above present. About 8500 B.P. Lake Turkana apparently rose some 80 m, overflowing into the White Nile via the Sobat River as determined by its very similar fish fauna. It then fluctuated probably a good deal. Through the Early and Middle Miocene temporary unstable lakes and swamps had occurred in many parts of the Turkana basin, and there was the presence of a non-marine whale, but the origins of this are unknown there being little indication of a connection with the Indian Ocean (Cohen 1981). After about 8000 B.P. some drier climatic periods intervened towards 7000 B.P. Lakes Nakuru-Elmenteita and Rudolf fell, but Rukwa, Magadi, Naivasha, and Victoria, were apparently unaffected. Lake Nakuru had a higher level from 6400 to 6000 B.P. until about 4000 B.P., when it began a trend in decline to present-day levels, a trend which began earlier in Lakes Victoria, Magadi and Naivasha. Lake Turkana was high once more about 4000 B.P. but after 3000 B.P. it contracted gradually to the saline lake that it is today.

Lake levels show a tendency toward very high levels in the late nineteenth century reaching several metres above present levels, followed generally by a sharp decrease toward 1900 and a sharp rise again in the 1960s in lakes Chad, Rudolf, Stefanie, and Rukwa. The late nineteenth century oscillation is indicated also for lakes Magadi, Nakuru, Jilore, Baratuma, and Ngami, which diminished continuously until about 1914. Baumann's sketch of Lake Manyara in March 1892



Plate 2.2a Baumann's sketch of Lake Manyara March 1892 (From Baumann 1894)

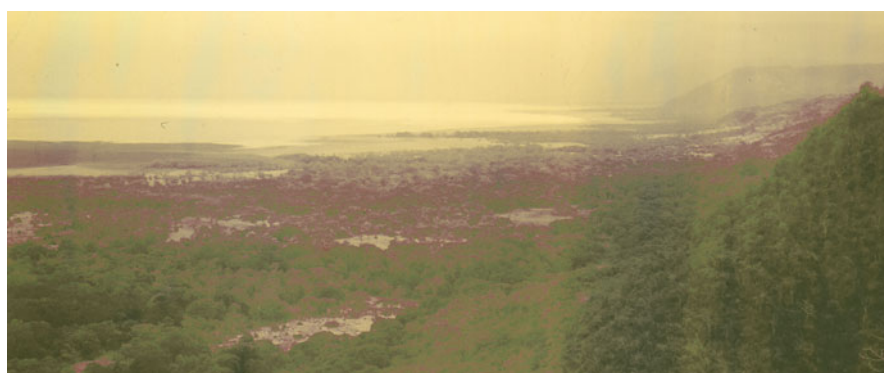


Plate 2.2b A distant view of Lake Manyara in 1956. The water can be seen reaching the base of the sloping escarpment on the right as in Baumann's sketch

showed it to be very full (Baumann 1894) (Plate 2.2), but Werther (1898) found it dry in 1896 except for a pool at the Kwou estuary, a hot soda spring. Apart from a few Grant's gazelle, antelopes which "3 years ago" Neumann⁵ shot from his camp, were absent. Werther considered that Makwa elephant hunters had already almost exterminated them, but their absence was probably due to the drying up of the lake. Jaeger's map of 1912 (Fig. 2.13) shows it shrunk to two small lagoons (Jaeger 1913). In the late 1960s it dried out completely and has fluctuated since. Most lakes remained stable in the twentieth century until the 1960s, then the rapid rise in Lake Victoria's level between 1962 and 1965 was paralleled in lakes Albert, Baringo, Naivasha, Nakuru, Manyara, Malawi, and Tanganyika, as was the early 1970s rise.

From 1960 to 1964 Lake Tanganyika rose 3 m, but changes here are complicated by the build-up of silt bars although the widespread change in other lake levels implied a large-scale climatic feature as the cause. The outlet was barred in 1858, open in 1874, barred again in 1876, and open again in 1880. Between 1879 and 1880 its level declined 4 m in 18 months. Former travellers and local people asserted the waters slowly rise and Cambier observed that the Louakaga, the outflow to the Congo, was obstructed by deposits of sand, masses of papyrus, and other aquatic plants. Towards the end of 1879 the waters during their rise made a passage through the obstruction releasing a torrent, causing a building constructed at the edge of the lake to become some 500 m distant from it (Becker 1887). During the next 15–20 years the level fell 10–12 m, and there was no outflow in 1900. There were then minor fluctuations only to 1961 when the level rose sharply, and in 1964 was almost 3 m higher than it was in 1960. The lowest levels appear to have been in the 1920s and between 1948–1956. Stanley (1872) was told in 1871 the level had been rising since the 1840s, prior to which rice could be cultivated on 5 km of land and the extensive rice cultivation sites had now been abandoned. When he met Livingstone, Ujiji was at the lake shore, but in 1896 there was a wide plain between the town and the shore. In 1998 the level rose by about 2.1 m.

Prior to 37000 B.P. the level of Lake Rudolf was 60–70 m higher than today, then remaining relatively low to several centuries before 9500 B.P. when it must have risen rapidly, fluctuating between 60 and 80 m higher until about 7500 B.P. when it shrank to approximately its late 1960s size. It showed a major fall in level about 4000 B.P., maintaining a lower level for 500 years. High levels occurred in about 3400–2800 B.P. and 2250 B.P. to A.D. 1150, some 25–35 m higher than present during the first millennium A.D.; and in the sixteenth, seventeenth, and possibly eighteenth centuries, matching the high levels of Lake Chad, fluctuating about 10 m in the mediaeval period. Some time between the mid-1500s and mid-1600s it ranged between +8 and +15 m for about a century, and about 1531–1537 the pastoralist Galla peoples “exploded” out of their Lake Rudolf homeland, undoubtedly due to drought; the years 1530–1531 being characterized by an unprecedented low Nile level. Although there is only a single record for this period of 9.01 m low water in 1531, together with the year 1621 this appears to be the lowest level ever recorded, although the years either side of 1531 are unrecorded. Recorded levels became quite low until the 1840s and then rose rapidly +15 m in the 1870s. The level rose again between 1888 and 1895 inundating about 200 km². Prior to 1888 the level had been low enough for a mature fringing woodland to develop. Von Höhnel (1894) reported dead trees stretching into the lake for almost 35 km, their appearance suggesting they had become submerged in the early 1870s. Bright, travelling along the western shore in 1898, noted in many places dead trees at least 90 m out in the water (Sharff 2005). After 1898 it was essentially dry with occasional patchy wet conditions, sometimes with 2 m deep pools, between 1898 and 1955 the shoreline retreating 60 km and exposing 800 km² of fresh land, seemingly reaching its lowest point in mid-1954, 5.5 m below the mean of 1967–1970. It is unique that since 1895 its level has fluctuated over a range of 20 m, a greater range than any other natural lake in the world (Butzer 1971)

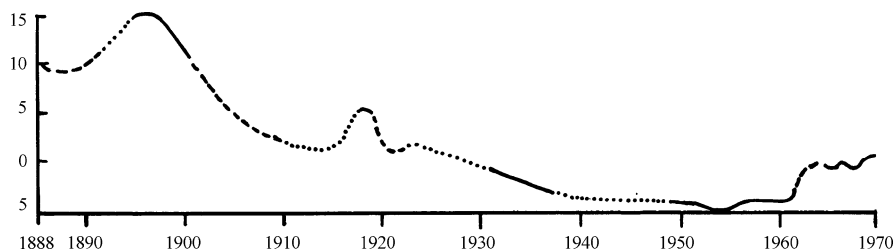


Fig. 2.14 Variation in metres in the level of Lake Rudolf 1888–1970 (After Butzer 1971)

(Fig. 2.14). Harrison (1901) considered it had sunk 3.6 m in 1898, and 8.5 m in three stages, possibly 3 years. In 1899 Smith (1900) considered it was 3.6 m lower in the shallow lake than in 1895. The highs and lows of rainfall recorded at Addis Ababa from 1902 to 1970 show no correlation with the levels of Lake Rudolf since 1902, nor with records at Wush Wush since 1954, and no relation to Nile levels. Thus apparently short term climatic trends are very variable across Ethiopia (Butzer 1971). But Butzer considers it tempting to compare the 8–15 m increases in the level of Lake Rudolf with the high Nile floods of the 1840–1890s, and preceding low levels with low Nile levels from the 1770s to 1840s, concluding that climatic variations with a duration of several decades are comparable over Ethiopia and the rest of East Africa down to 8°S.

Lake Stefanie, 65 km distant from Lake Rudolf, has alternated between a shallow saline lake and a salt plain since its discovery in April 1888 by Teleki and von Höhnelt when it was a saline lake but with plentiful fish, crocodiles, and hippopotamus; the guide claiming the southern shoreline had receded several 100 m in the preceding 3 years. In December 1889 the southern end was dry, but from 1895 to 1897 the entire lake floor was under water. In November 1899 Smith (1900) found the lake to be a sea of mud covered with dead fish, but there was some saline water. At the end of March 1900 Harrison (1901) found “.. a vast extent of ground strewn with shells and heaps of fishbones”. He was informed the lake had dried up at the end of December 1899. At a village he found most of the inhabitants had died, some survivors moving north to the Omo River. He experienced daily thunderstorms which the local people said were unknown at that time of the year. In 1959 only marsh was visible. The lake then rose rapidly at the end of 1961, continuing into 1962 and inundating some 350 km² between 1962 and 1965. By 1968 the whole basin was filled and the shoreline similar to that recorded in 1896, but the water level had apparently been even higher recently to that in 1896 (Butzer 1971). In January 1970 it was virtually dry once again.

The pattern of fluctuation has been shown to be similar for other East African lakes, although there is sometimes an apparent time lag. Thus Lake Naivasha (Plate 2.3), which is fresh, has shown relatively moderate changes in size over the past 9,000 years. Larger than present about 9200 B.P., it appears to have started to contract around 5650 B.P., continuing to do so until it dried out completely about 3000 B.P. Since then its level has remained low and fluctuating (Richardson 1966)



Plate 2.3 Lake Naivasha from the east in 1954



Fig. 2.15 Variation in the level of Lake Naivasha. Scale is elevation in metres a.m.s.l

(Fig. 2.15), with the most pronounced low in the past 700 years between 1780 and 1830 coincident with a 1790s worldwide drought in tropical and subtropical regions. It was low about 1850 according to tribal memories, and observed to be low in 1882, after which it began to rise reaching a high point in 1894 about 1.2 m above its “normal level” (Sullivan 2006) stretching to the cliffs to the east where the railway was later sited, but then declined rapidly until 1902, Mackinder observing in September 1899 it was very low with stretches of weed laid bare (Barbour 1991), but it rose again until 1917 when it reached the railway, about 3 km to the east. The rise was paralleled in 1895 at Lake Nakuru, 40 km to the north in the same Rift



Plate 2.4 Fringing *Acacia xanthophloea* at Lake Naivasha in 1908

Valley system. In the rise stands of *A. xanthophloea* were destroyed at both lakes (Jackson 1930), but as a photograph by Rainsford shows (1909) not all of the trees (Plate 2.4). From 1938 to 1946 it showed a progressive fall dropping 9.5 m between 1917 and 1946, its biggest fall since 1890. There was then a rapid rise of about 2 m in 1961–1964 in common with the other East African lakes. Fluctuations since 1908 indicate a periodicity of about 7 years and an indication also of an 11 year period, the latter matching high levels in 1905, 1917, 1937, and 1948, which equate with the sunspot cycle. It showed higher levels than other lakes corresponding with all three recent solar minima (Maunder, Spörer, Wolf), the earliest being in 1290–1370. Although less distinct, Ojiambo and Lyons (1996) claim to detect a continuing periodicity to 1979, with highs in 1957–1958, 1968, and 1979–1980; discounting the 1964 peak as an anomaly.

Historical references to drought-induced famine, political unrest, and large scale migration, are concentrated in three periods around A.D. 1390–1420, 1560–1625, and 1760–1840, which match the Naivasha low water periods (Verschuren et al. 2000).

Separated by a sill at low water levels, to the south-west of the main lake is the small Crescent Island crater lake, the depth of which has ranged from 27 m in 1894 to a low of 12 m in 1946, and has held water (less than 5 m depth) when Lake Naivasha has been dry. Sediments from this lake indicate a drier climate than present from A.D. 1000–1270, creating saline conditions with one freshwater interval in the early thirteenth century; otherwise the saline conditions were followed by a mostly positive water balance and the establishment of freshwater conditions from about 1270 to 1550, with one recurrence of saline conditions about 1380–1420. After a second pronounced low level about 1560–1590 the level then rose to a high lasting from about 1670 to 1770 when it was continuously above the historical maximum reached in 1894. This ended with a low level in about

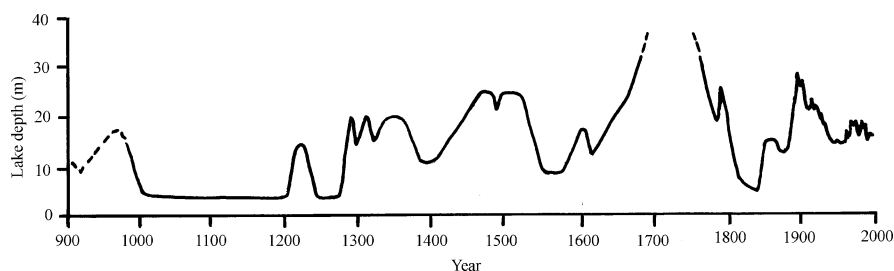


Fig. 2.16 Fluctuations in depth of Crescent Island Crater Lake, Naivasha, Kenya, A. D. 900–2000 (After Verschuren et al. 2000)

1810–1850, but the water remained fresh, before the level rose again to peak in 1894 (Fig. 2.16).

Lake Katwe, a volcanic crater lake in western Uganda, experienced higher levels about 11000, 1200, 900 and 400–100 B.P., the oldest being the highest at about 20 m above its present level. As Katwe has no inlet these higher levels must have been caused by rainfall, occurring soon after switches from arid to moist conditions. Lake Kivu in DR Congo illustrates a more complex situation once emptying into the Nile via the Rutshuru river and Lake Edward, in comparatively recent times this outlet was blocked by volcanic lava from the Virunga range causing the lake to increase in size until it overflowed southwards to Lake Tanganyika. Thus it contains some characteristic species of Nile fish although no longer connected with the Nile system.

These fluctuations suggest that equatorial East Africa was generally drier than today about A.D. 1000–1270, followed by fairly wet conditions to 1850 interrupted with three arid periods around 1380–1420, 1560–1620 and 1760–1840, of greater intensity than any recorded drought of the twentieth century. These dry intervals equate roughly with periods of high solar radiation and the intervening periods with low solar radiation, the highest inferred rainfall period coinciding with the Maunder minimum of 1645–1715. Morice recorded the rains at Kilwa in 1775 as extraordinary, but his experience was limited to half a dozen years between 1771 and 1779 not all of which were spent there (Freeman-Grenville 1965).

2.15 Rainfall, Lakes, and the Nile

A substantial cooling in equatorial Africa during the Little Ice Age from about 1270 to 1850 led to different hydrological responses over East Africa and the western Indian Ocean, for whereas Lake Naivasha was relatively high, Lake Malawi was in a low phase. Tradition has it that in 1827 the lake was so low a local chief waded across near Deep Bay, an impossibility as the depth in 1900 was greater than 500 m there; but he presumably crossed a bay somewhere indicating an extremely low level. This

matched the period of low-level in Lake Naivasha. For some time between 1390 and 1860 it fell by at least 121 m but was very high in 1857–1863 and high in 1873, falling in 1875–1878. It was high again in 1882 but very low in 1890, rising rapidly in 1892–1895, then declining to its lowest recorded level in 1915. From then until 1935 the lake had no overflow to the Shire and Zambesi rivers, almost all flow down the Shire River ceasing, although an overflow had been present from pre-1865 until 1915. From 1915 the lake level rose gradually again reaching its maximum recorded level in 1937 with a total rise of 5.67 m, bursting through the obstruction. After 1937 the level fell slightly but then rose again in 1948 reaching 15 m below its 1937 level. Cochrane (1957) calculated the total river discharge from the lake was only 5–6% of total rainfall falling on the catchment area. In 1998 it rose by about 1.8 m.

Exceptionally heavy rains were recorded at the Kenya coast in 1866–1867, but from 1880 to 1884 there was a major decrease in rainfall throughout eastern Africa relative to previous years of the nineteenth century, most lakes remaining higher than at any time in the twentieth. The period 1895–1899 contrasted sharply with the previous 25 years, lake levels falling tremendously throughout eastern Africa from Ethiopia to Malawi to a level about normal for the twentieth century. In November 1899 Harrison (1901) reported there had been an unprecedented 2 years' drought over the whole of East Africa to the Nile. We saw that Lakes Magadi, Nakuru, Jilore, and Barotuma, diminished until about 1914, and that compared with 1870–1899 the Nile discharge at Aswan for the period 1900–1949 was 24% less, and for 1899–1900, 41% less, the second lowest discharge ever recorded. Duke (1919) reported an exceptional drought at Masindi, Uganda, at the end of 1917, although annual total rainfall was above average. But the following January and February no rain falling created famine.

Generally the fluctuations in levels tell us only that wet and dry periods repeatedly occurred. It is difficult to match them together as they are relatively insensitive indicators due to lag periods and the inaccuracy of records. Thus Nile levels apparently do not record the peak in Lake Victoria which occurred in 1892–1895, they had already declined with the 1880–1890 low levels. One correlation is that in 1890, Lakes Victoria, Malawi, and Tanganyika, were all recorded as low.

In the 1960s a sharp rise in lake levels and river discharges took place, followed by an equally abrupt decline in the 1980s. These changes can be attributed almost entirely to variations in precipitation. Rise in levels of the large East African lakes took place quite suddenly in late 1961, until which time fluctuations in the twentieth century had been modest, with a pseudo-periodicity of about 11 years in the Lake Victoria record. By the end of 1961 the levels of Lakes Victoria and Tanganyika had risen by a metre, and another metre the following year. The greatest departures from average rainfall in 1961 were in northern Kenya's semi-desert region which received more than six times its mean rainfall in November. The catchments of the Tana and Athi rivers received four times their mean monthly values in September to November. South-east Tanzania received five times its normal rainfall in July 1961, the heavy rains being part of a great perturbation which extended far out over the Indian Ocean (Grove 1996).

Over the Lake Victoria catchment area an enhanced rainfall of about 15–25% during the short rains of October–November is expected correlated with El Niño and the African/Indian monsoons, when rainfall shows a positive correlation also with sea surface temperature anomalies over the western Indian Ocean, the Indian Ocean typically responding with a lag of about a season to El Niño with an overall basin scale warming. Although 1961 was not an El Niño year, there was a major drought in Indonesia much in common with its 1997 drought. One of the strongest El Niños took place in 1997 but events over the Indian Ocean were different to expected (Birkett et al. 1999). An anomalous warming of the western equatorial Indian Ocean led to the establishment of an anomalous convection over large parts of the Horn and eastern Africa, which produced an approximate 20–160% increase in rainfall over the Lake Victoria catchment during its short rainy season and caused flooding in the coastal regions of Somalia, Ethiopia, and Sudan. The level of Lake Victoria rose approximately 1.8 m in 8 months, the highest rise since 1961, which had been considered to be unique since lake level recording began at the commencement of the twentieth century. Lakes Tanganyika and Malawi received excessive rain also leading to level increases of about 2.13 m from the end of October 1997 to mid-May 1998, and 1.78 m from 1st December 1997 to mid April 1998, respectively. Lake Turkana received 100–200% more rainfall also and rose some 2 m between September 1997 and January 1998. Over the Ethiopian Highlands during late 1997 rainfall was 100–150% in excess, making it by far the wettest October–December period of the Blue Nile basin last century. High summer rainfall continued in Ethiopia in 1998. Thus due to the anomalous warming of the western equatorial Indian Ocean in 1997, strong convection developed over parts of the Horn and eastern Africa resulting in much greater precipitation during the short rains, independent of that expected to develop from El Niño.

Butzer et al. (1972) considered there was a notable lack of correlation between the high lake levels and glacial advances in the mid-latitude of North America and Eurasia, and increases in the higher latitudes were probably due to reduced evaporation, whereas the early Holocene lakes in East Africa were apparently associated with a modest but significant increase in rainfall. Verschuren (2004) concluded climate inferences from the African lakes based as they are on sediment indicators of lake level and the existence of a simple constant relationship between lake level and rainfall at the relevant time scale, are arguable without other supporting data.

2.16 East Africa's Vanishing Glaciers

2.16.1 The Rwenzoris

Changes taking place of all of East Africa's glaciers have been presented in detail by Hastenrath (1984). On the Rwenzori mountains moraines formerly reached about 2750 m below the present glacial limit. The start of the retreat of ice from

its maximum extent is dated to about 14700 B.P. (Livingstone 1962) when the climate was about 4°C colder than present and drier. The glaciers then shrank with increasing rapidity and continue to do so, although punctuated by advances as in A.D. 1300–1900. An initial retreat of the Lake Mahoma valley glacier dates to about 14750+/-290 years B.P. and suggests expansion and contraction of ice bodies on East African mountains may be more synchronous among high-latitude glaciers than are fluctuations in lake level. The current phase of contraction of East African glaciers began about 1880 with an apparently drastic decrease in precipitation during the last two decades of the nineteenth century, but meteorological records are insufficient to confirm this. Whereas there is considerable fluctuation in the level of precipitation in western Uganda, there is no detectable downward trend since 1960. Decreased humidity increases the exposure of glaciers to solar radiation through reduced cloud cover, and an associated decline in precipitation lowers accumulation of ice and increases absorption of radiation due to the lower albedo of ice relative to snow. As a result the rate of glacier net mass loss rises (Taylor et al. 2006).

About 1500–1800 there were minor advances, but the extent of the glacier ice has decreased greatly in the past 100 years since the Duke of Abruzzi's study in 1906, when coverage was estimated at 6.5 km² and the lowest ice level 4,400 m a.m.s.l. He reported the glaciers were of small extent and all were in retreat. This was proved in some by the existence of recent moraines at a few 100 m in front of the present ice and by freshness of the abrasion of the soil in the neighbourhood of almost all glaciers (Abruzzi 1907). Humphreys (1933) was struck by the recession of the glaciers since 1927. Alexandra Peak, snow-capped in 1926, was now bare rock at its highest point, as was Ensonga at the north end of the Mount Speke ridge; and there was a striking diminution in the size of some lakes since 1926. Buyugu lake was surrounded by an area of mud, two lakes at the headwaters of the Mugusu were empty, and of two in the upper Rumuli valley the upper was a mud flat with a small pool and the lower quite dry. All glaciers retreated rapidly up to 1961 with an apparent acceleration in melting since the 1940s, six glaciers disappearing completely by 1959; but some showed advances in 1961–1962, followed by retreat, albeit at a slower rate, and two showed small advances between 1966 and 1968. These advances were probably connected to the higher rainfall in those years although overall temperature has been increasing since the 1960s at a mean rate of 0.5°C each 10 years, without an accompanying significant change in rainfall. By the 1970s only the central section of the Rwenzoris was glaciated, consisting of six main glacier complexes and some 37 smaller glaciers which are estimated to have covered some 4.43 km² in 1955. In 1987 the area of ice was calculated at 2.01+/-0.56 km² and in 2003 it was 0.96+/-0.34 km², halving in area. If this rate of loss continued the ice would disappear completely within 20 years (Figs. 2.17, 2.18a and b).

Photographs taken in 1891 and 1932 show an important regression of the glaciers on Mount Stanley. This continued between 1932 and 1952 with an acceleration from 1940 onwards (Braucourt 1953) (Plates 2.5–2.9). The Stanley glacier had almost vanished by 2008 (Mumba 2008). But all glaciers showed a clear, and in

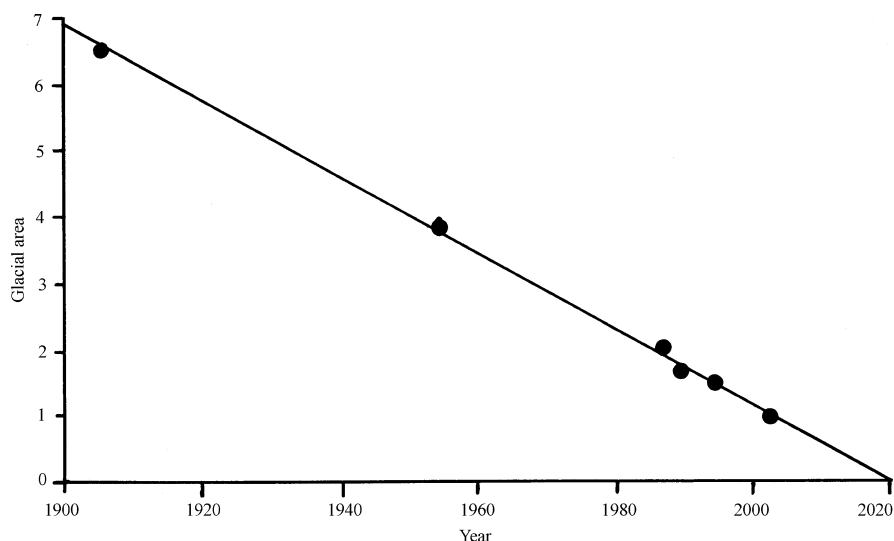


Fig. 2.17 Rate of disappearance of glaciers on the Rwenzori Mountains 1906–2003 in km² ($r^2 = 0.999$) (After Taylor et al. 2006)

some cases spectacular, overall retreat between mid-1958 and late 1966. The Speke glacier showed a marked retreat averaging 1.3 m/year, becoming rapid after 1963. In 2003 it was estimated to have retreated about 600 m since 1906, of which 311 m had been since 1993. Between 1961 and mid-1962 increased rainfall caused several small glaciers above 3400 m to interrupt the rapid retreat underway since 1958, but only the highest mountain streams increased their flow markedly between late 1961 and mid-1963 (Temple 1968).

Where ice was present in 1906 large isolated specimens taller than 3 m of *Senecio adnivalis* Stapf. were growing in 1966, one specimen observed to have grown at least 1 m in 20 years, and in one area a dense cover of *Senecio* forest 3–4 m high had apparently established itself. In 1966 lichens were found colonizing rocks exposed by ice in 1958 (Temple 1968). This indicates much faster rates of colonization and growth at these altitudes than previously assumed by Hauman (1935) and Whittow (1959).

2.16.2 Mounts Kilimanjaro and Kenya

Mount Kilimanjaro's oldest lavas date from about 1 Mya, but by about 120000 B.P. volcanic activity became increasingly sporadic until Kibo became dormant during the last 10,000 years, and there has been no eruptive activity within the past 200 years. Written just after A.D. 953 the Arabic *The Book of the Marvels of India* quotes Yezid, a sea captain of Oman, seeing two twin mountains in the land of the

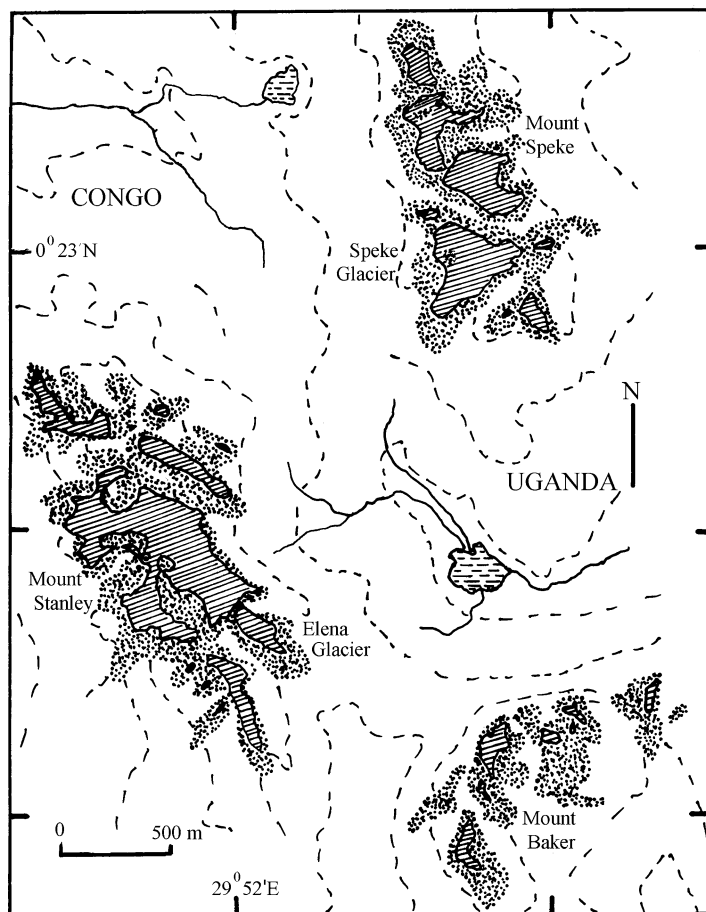


Fig. 2.18 Retreat of the Rwenzori glaciers 1955–1990. Stippled area, extent in 1955; cross-hatched area, extent in 1990 (After Taylor et al. 2006)

Zindjs, “.. I saw two great mountains and a defile between them, which bears the traces of fire and is strewn with calcined bones and charred hides. . . they told me that, at certain periods, this valley is swept by a fire. If there are any sheep or other beasts pasturing in the defile, or if there are shepherds, who let themselves be surprised by the fire, they are burned up, one and all. This fire happens on certain days, and comes running along the ground like a torrent” (Devic 1928). Suggestive of intermittent lava flows this could not have been the peaks of Mawenzi and Kilimanjaro as some suggest, but perhaps volcanic activity in present Tsavo West NP, if it was indeed in East Africa. Devic (1883) suggested it was just bush burning which Yezid saw.

Ice cores from Kilimanjaro’s glaciers indicate ice formed first in the Holocene at 11700 B.P. in the African humid period of that date, and this was followed by a



Plate 2.5 The Rwenzori Mountains' western Speke glacier April 1933 photographed by J. Elissen (From Braucourt 1953)



Plate 2.6 The same in July 1952 (From Braucourt 1953)



Plate 2.7 The snout of the Rwenzori Mountains' Moore glacier June 1958 (Temple 1968)



Plate 2.8 The same late December 1966 (Temple 1968)



Plate 2.9 The Stanley glacier had almost vanished by 2008 (© WWF-EARPO/Sven Erik Haarklau)

warmer and wetter phase about 11000–4000 B.P., a pluvial period of 9000–8000 B.P. being remarkably widespread, while from 4000 B.P. to present was relatively dry and cool. Minor glacial advances occurred also on both Mounts Kilimanjaro and Kenya about 1,500–1,800.

Cosmas Indicopleustes referred to a royal inscription at Adulis in A.D. 300 which referred to the people of Samen (Simen) who lived on mountains difficult of access and covered with snow where the year is all winter with hailstorms, frosts, and snows, into which a man sinks knee-deep (McCrindle 1897). In the sixteenth century there was a lowered snow line on the mountains of Ethiopia, and in the seventeenth century Paez (1629) referred to the summit of the Simen mountains as always covered in snow. But Poncet (1709), who spent 1699–1701 in Ethiopia, did not believe anyone had ever seen snow in Ethiopia. Von Harff claimed to have climbed the Mountains of the Moon c1499 finding much snow on the summit, and that it was raining heavily, this being the month of June, “when it snows, rains and freezes in these mountains without ceasing in June, and the water falls and runs together to the Nile, then the Nile becomes each year very great and, reaching the flat land of Egypt in August, it covers the whole land of Egypt” (Letts 1946). Von Harff’s account is dismissed generally as invention, but it is conceivable that he was referring to the Simen highlands. June to July is the dry season in the Rwenzoris, and June to August with its maximum in the latter month in the Ethiopian highlands.

Rüppell, in his travels in Ethiopia in 1822–1827, encountered a plain at 4,250 m covered barely with a thin layer of freshly fallen snow.

Deglaciation of Mount Elgon is calculated from ^{14}C determinations to have occurred shortly before 11000 B.P. and ice disappeared completely from Mount Badda in Ethiopia by 11500–11000 B.P. In East Africa Meyer (1891) showed that in 1887 the glaciers at the summit of Mount Kilimanjaro (Kibo 5,809 m) were continuous around the crater rim, although the small Furtwängler glacier appears to be less than 300 years old. By 1890 a notch (Hans Meyer notch) was in existence, and by 1900 the Johannes notch was free of snow and ice. By 1912 a third break was present (Leopard notch), and by 1935 a fourth (west of Stella point). Photographs by Oehler show the ice in May 1912, by Kirkpatrick in February 1928, and Spinage in August 1956, March 1973, and January 1975 (Plates 2.10–2.20). Bent (1936) noted in 1935, “Year after year the ice is diminishing,” but at the same time glaciers hanging about the outer sides of the mountain were increasing. His photograph shows little difference to that taken by Spinage in 1956. Since 1935 a steady diminution of ice has continued (Geilinger 1936), however snowfalls can produce a deceptive appearance (Plate 2.21). By 1975 there was very little ice left on the summit at the height of the dry season and this scarcity has persisted. From an estimated area of 12 km² in 1912, glacier coverage has decreased to some 2.6 km² in 2002, the mountain having lost 80% of its ice cap. It was predicted by Thompson et al. in 2002 that at this rate of decline, which was measured as about 0.92 m² between the years 2000 and 2002, the glaciers will have disappeared completely by 2015 or 2020 (Figs. 2.19 and 2.20).



Plate 2.10 The saddle on Mount Kilimanjaro with Kibo in the distance May 1912 (Oehler 1915)



Plate 2.11 The same view January 1975 (C. A. Spinage)



Plate 2.12 Kibo from the saddle February 1928 (R. Kirkpatrick 1928)



Plate 2.13 Similar view August 1956 (C. A. Spinage)



Plate 2.14 Kibo summit viewed from Moshi February 1928 (R. Kirkpatrick 1928)

There was a minor glacial stage on Mount Kenya dating perhaps to before 5400 B.P. but the 'eternal snow' on Mount Kenya is only about 500–600 years old. Moraines reflecting glacier advance are prominent on Mount Kenya and in the Rwenzori Mountains, now about 100–250 m above the present ice margin. On the



Plate 2.15 Kibo summit viewed from Moshi January 1975. The development of the notches in the glacier is clearly visible (C. A. Spinage)



Plate 2.16 The summit of Mount Kilimanjaro from Mawenzi showing extent of glaciation in September 1935 (N. Bent 1936)

former, the glaciers stood in an advanced position from about 200 B.C. to A.D. 300 and from about 650–850, followed by a retreat from 850 to about 1250, coeval with the lowered Lake Naivasha. The most recent glacier advance appears to have peaked about 400–250 B.P. (Verschuren 2004). The Lewis glacier on Mount Kenya has shown a steady retreat since its limits were defined first in 1893, despite a recent minor ice advance which terminated about 1900. Due to the topography the more shielded glaciers have retreated the least, those to the east being more exposed to the sun's radiation shrinking the most, the Kolbe glacier disappearing altogether after 1926. Of its 18 glaciers known in 1899, five disappeared prior to 1963, and one between 1963 and 1987 (Fig. 2.21). In the period of 88 years between 1899 and



Plate 2.17 The summit of Mount Kilimanjaro August 1956 (C. A. Spinage)



Plate 2.18 Similar view taken by air by with peaks of Mawenzi in foreground March 1973 (C. A. Spinage)

1987 the overall loss of ice was about 75% of the 1899 area. The 24 years between 1963 and 1987 witnessed a doubling in rate of loss with almost 40% reduction. In addition, despite the wide range in area and volume of the glaciers, between 1963 and 1987 ice thickness decreased between 10 and 20 m.



Plate 2.19 View of Kibo taken from the Shira plateau to the east May 1912 (E. Oehler 1915)



Plate 2.20 The same view February 1973 (C. A. Spinage)

2.16.3 Causes of Ice Loss

The retreat of glacier ice on East Africa's mountains since the Little Ice Age is believed to be due partly to world-wide climatic trends. On a global scale, air



Plate 2.21 A heavy snowfall hides the diminution of ice 1955 (C. A. Spinage)

temperature is considered to be the most important factor connected with glacier retreat. In the northern hemisphere global temperature declined from 1870 to 1880, then from 1899 to 1940 an increasing temperature was shown on a world basis. Mitchell (1972) has shown that global mean surface air temperature, expressed as 5 year averages, rose steadily from 1880 to a peak in 1944, 0.45°C higher, at a rate from 1909 of $0.014^{\circ}\text{C}/\text{year}$; and then declined at a rate of $0.016^{\circ}\text{C}/\text{year}$ to 1969, and was still declining. But temperature rise alone as a cause of ice loss has not been demonstrated for tropical glaciers. Rather, a complex combination of changes in air temperature, air humidity, precipitation, cloudiness, and incoming shortwave radiation, is considered to govern the fluctuations of tropical glaciers, with reduced precipitation and increased availability of shortwave radiation due to decreases in cloudiness the dominant reasons for this strong recession in modern times (Kaser et al. 2004).

The decades preceding 1880 were very humid, lake levels were high, mountain glaciation was extensive, and precipitation more abundant. In contrast to this seemingly abrupt change to drier conditions, there is no evidence of an abrupt change in air temperature. There has been no marked trend towards drier climate overall in East Africa since the turn of the twentieth century, the early parts of the century being drier than the rather wet 1950s and 1960s, but the glaciers of Mount Kenya and the Rwenzori Mountains seem to have responded to this change in moisture by retreating drastically and in spatially differential patterns.

The magnitude of the ice loss on Mount Kenya is not explained by reduced rainfall, as this is not supported by observations of precipitation in the Kenya Highlands. Solar radiation reflected in cloud cover changes, and dust expressed in albedo effects, have been ruled out also as causes. As the rate of glacier loss on both

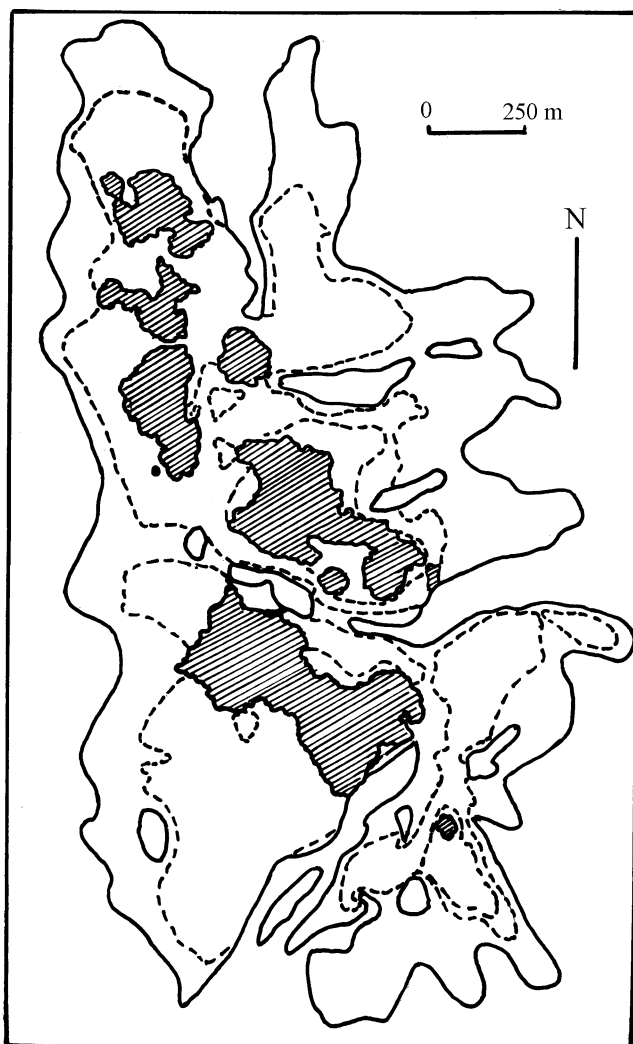


Fig. 2.19 Retreat of the Mount Speke glaciers, Rwenzori Mountains, 1906, 1955, 2003. Solid line, extent in 1906; broken line, extent in 1955; cross-hatched areas, extent in 2003 (After Taylor et al. 2006)

Mounts Kenya and Kilimanjaro is approximately the same, unlike the rate on the Rwenzoris which is much slower, it is possible despite its lower altitude that the same cause of ice loss pertains on Mount Kenya as it does for Mount Kilimanjaro.

On Mount Kilimanjaro climatological processes other than air temperature control the ice recession in a direct manner. A drastic drop in atmospheric moisture at the end of the nineteenth century and the ensuing drier climatic conditions are likely forcing glacier retreat. Mean annual rainfall has decreased by 600–1200 mm

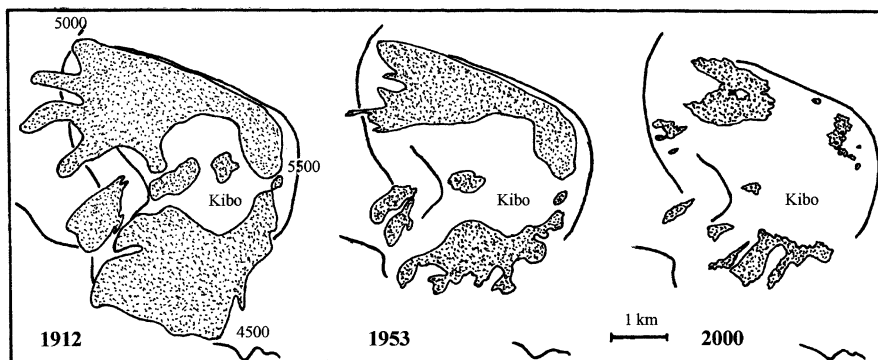


Fig. 2.20 Mount Kilimanjaro's vanishing glaciers 1912–2000. Height contours are shown in metres (After Thompson et al. 2002)

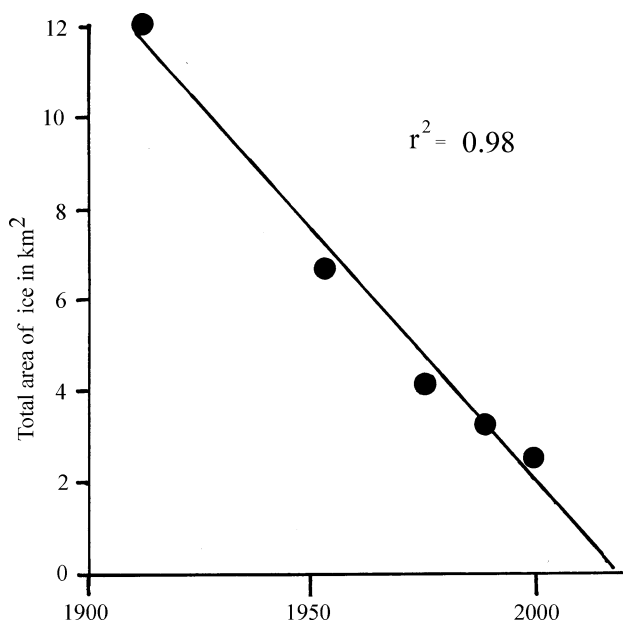


Fig. 2.21 Linear regression of the disappearance of glacier ice on Mount Kilimanjaro from 1912 to 2000 (After Thompson et al. 2002)

in the past 120 years, depending upon at which altitude it is measured. Loss of cloud cover due to destruction of the forest belt, particularly by fire at the higher elevations, may have compounded a general decreasing trend in rainfall, but the enormous size and height of Mount Kilimanjaro represents an exceptional phenomenon amongst glaciated mountains in the tropics, reducing the effect of air temperature on ice recession decisively. The immense and isolated mountain rises far into

the tropical troposphere and penetrates the dry seasons' trade wind inversion, which shows a median base height above Nairobi of about 3,750 m and a typical thickness of 125–250 m. The elevation and shape of the mountain modify the local atmospheric circulation in many ways that remain poorly understood, and one of the puzzles is how did the glaciers form on the summit in the first place. Where did the moisture come from?

Kilimanjaro's glaciers are markedly characterized by features such as penitentes (tall thin blades of closely spaced hardened snow or ice), cliffs, and sharp edges, all resulting from strong differential ablation. The summit glaciers typically have vertical walls mainly along their north and south margin, all of which indicates that they are not experiencing ablation due to sensible heat (i.e. from positive air temperature). These features illustrate the absolute predominance of incoming shortwave radiation and turbulent latent heat flux in providing the energy for ablation. A considerably positive heat flux from either longwave radiation or sensible heat flux, if available, would round-off and destroy the observed features within a very short time, ranging from hours to days. Thus the existence of these features indicates the present summit glaciers are not experiencing ablation due to sensible heat (i.e. from positive air temperature). The Northern Icefield air temperature recorded from February 2000 to July 2002 never exceeded -1.6°C , and there is the presence of permafrost below Arrow Glacier on the western slope at 4,700 m. Mass loss on the summit horizontal glacier surfaces is due mainly to sublimation (i.e. turbulent latent heat flux) and is little affected by air temperature through the turbulent sensible heat flux.

Retreat from a maximum extent of Kilimanjaro's glaciers started shortly before Meyer and Purtscheller visited the summit for the first time in 1889 (some consider they started to retreat about 1850), caused by the abrupt climate change to markedly drier conditions around 1880. Fumarole activity inside the central Reusch Crater may have melted a central opening in the original plateau ice cap, and the vertical ice walls thus created may have helped initiate the twentieth century ice retreat. Intensified dry seasons accelerated ablation on the vertical walls left in the hole, which catch the sun's rays. When Meyer first reached the summit, Reusch Crater was already free of ice. The development of vertical features may have started also on the outer margins of the plateau glaciers before 1900, primarily as the formation of notches, as reported in 1898 and 1912. Once started, the lateral retreat was unstoppable, maintained by solar radiation despite less negative mass balance conditions on horizontal glacier surfaces, and will come to an end only when the glaciers on the summit plateau have disappeared. This is most probable within the next few decades.

Positive air temperatures have not contributed to the recession process on the summit so far. The rather independent slope glaciers have retreated above the elevation of their thermal readiness, responding to dry conditions. If the present precipitation regime persists, then these glaciers will most probably survive in positions and extents that are not much different than today. This is supported by the spatial patterns of glacier extent, which indicate that slope glaciers retreated more from 1912 to 1953 than since then (Kaser et al. 2004).

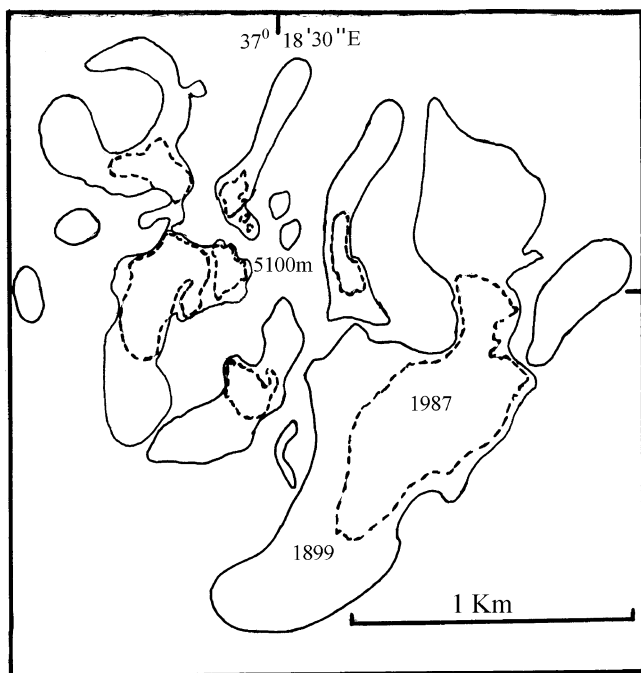


Fig. 2.22 Retreat of the glaciers on Mount Kenya 1899–1987. Solid line, extent of glaciers in 1899, broken line, extent in 1987 (After Hastenrath and Kruss 1992)

From a hydrological point of view, meltwater from Kibo's glaciers has been of little importance to the lowlands in modern times. Most glacier ablation is due to sublimation, and where ice does melt it immediately evaporates into the atmosphere. Any intervals of runoff on the summit plateau are extremely brief and insignificant, and only very small rivers discharge from the slope glaciers. Rainfall reaches a maximum amount at about 2200–2500 m a.s.l. which primarily feeds the springs at low elevation on the mountain. Hemp (2009) has calculated that the forests above 1,300 m receive nearly $1,600 \text{ m}^3$ of water per year, 95% from rainfall and about 5% by fog interception, compared with an average annual water output from 2.6 km^2 of glaciers of about 1 million m^3 , or 5% of that received from fog water deposition. Thus loss of the forests would have a greater effect on the water balance than disappearance of the glaciers of which the hydrological effect would be almost negligible. Loss of these ice fields will be unlikely to have the climatological and hydrological implications for local people that some suppose.

2.17 East African Records

Climatology began in East Africa in 1850, for which year we have 11 months of rainfall records as measured at Zanzibar totalling 2,482 mm with a probable annual total of 2,622 mm, 995 mm being recorded for May; and wind and temperature

records (Sykes 1853), the equipment and methods being as used in India. Assuming the measurements were correct, the annual total was 60% greater than the uncorrected 43 year mean for 1892–1935 of 1,570 mm, this former level being almost reached only in 1906 with 2,361 mm. Next we have 9 months of records by Burton (1872) from March 1853 to February 1854 totalling 2,143 mm, and a record of an apparently exceptionally wet year with 4,242 mm for 1859 also by Burton (a total questioned by Christie 1876). Kremer (1910) provided a record of 1,402 mm for 1864, and then there seem to be no other records until 1874 when we have a run of 5 years to 1878, and another sequence from 1880 to 1884. A hurricane was recorded for 14 April 1872 which flattened plantations in Zanzibar and southern Pemba also devastating the Bagamoyo coast, no such event having occurred within prior living memory. These records are provided for interest more than representing substantive data.

In 1892 the British Association for the Advancement of Science organized the collection of records, and from that year there is an almost unbroken series until the 1960s. Mombasa has records beginning in March 1875 running to December 1880, and then an almost unbroken record from 1891. Kibwezi was monitored from 1894, Machakos irregularly from 1894, and Voi from 1905. Although Zanzibar town has an unbroken series from 1892 to 1936 the site was then moved to the Victoria, now Peoples', Gardens, where higher readings were recorded, so the figures prior to this date have been corrected by the difference. Kremer (1910) provides a number of incomplete records to 1907 for 37 Tanzanian localities beginning in 1892, ranging from Kilwa-Kilindji, Tanga, and Bagamoyo.

People informed Burton in 1859 that rain in Zanzibar had diminished "of late years," which he thought might be due to deforestation (Burton 1872). Inland, Kilimanjaro apparently experienced an exceptionally prolonged famine in the 1850s. But rainfall was apparently high at the coast in the 1880s, falling to a low in 1895 similar to that of 1915–1920, the latter dry phase being longer. At Mombasa it was even lower in 1962, declining from about 1940. Kirk (1892) stated there appeared to have been a gradual but marked diminution of about a third in rainfall at Zanzibar in the last 40 years. His 5 year average for 1880–1884 was 1,241 mm. Ravenstein (1894, in Fitzgerald 1898) gave a mean annual rainfall of 1,622 mm for the 16 years and 5 months from 1878 to March 1894, quite a high figure, but 1893 was recorded as far above the average for all coastal regions. Otherwise, he agrees, "there seems to be some justification for the opinion that the rainfall has become less with increasing cultivation." Rainfall varied apparently from 4,242 mm in 1859 to 1,168 mm in 1874. In 1897 Ravenstein et al. reported that rainfall for November 1896 was "quite unprecedented" for all coastal stations but not for those inland.

With Kirk's 1880–1884 mean as a baseline, rainfall at Zanzibar probably decreased from 1874 and then increased to a peak in 1935–1940, levelling off until it increased again in the 1970s. Generally it remained high during the period falling below the 1880–1884 mean only in 1914–1929 (Fig. 2.22). Mombasa, 240 km from Zanzibar, shows a broadly similar picture with an exceptionally high figure for 1877 of 2,311 mm, confirmed by Wakefield who recorded 2,286 mm at Rabai, 16 km distant (Fig. 2.23).

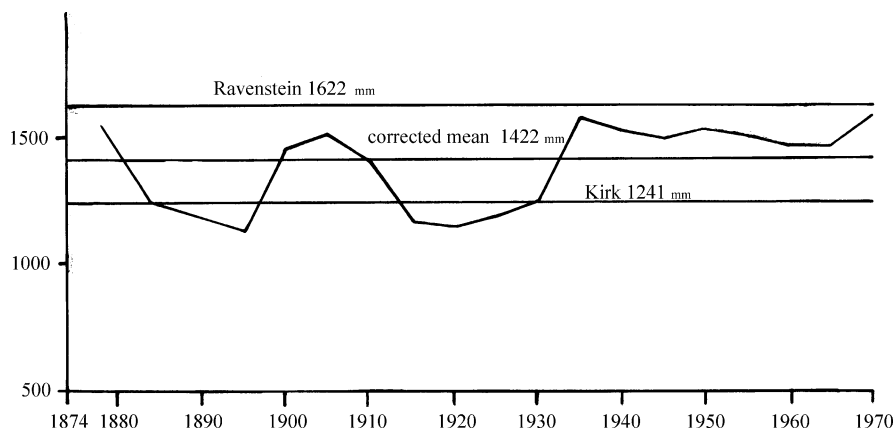


Fig. 2.23 Annual rainfall at Zanzibar 1874–1970, corrected 5-year means (mm)

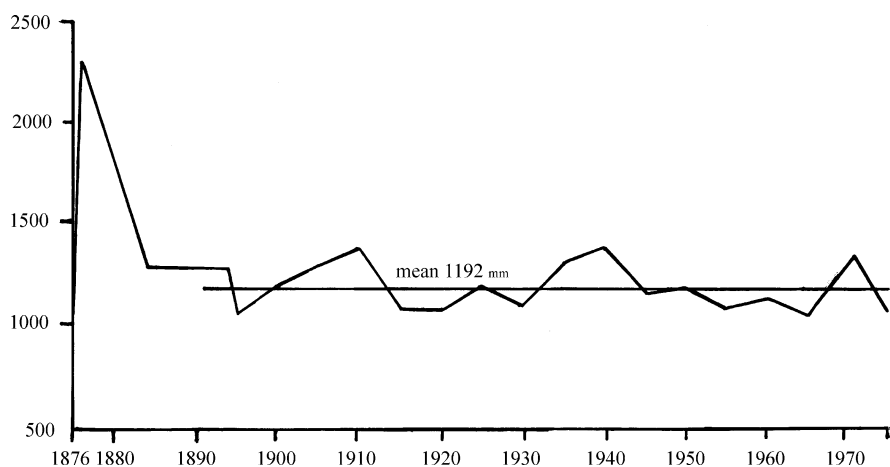


Fig. 2.24 Annual rainfall at Mombasa 1876–1974, 5-year means (mm)

The nearest inland station with a long unbroken rainfall record, from 1896, is Machakos (altitude 1,676 m, lat. $1^{\circ}32'S$, long. $37^{\circ}17'E$). Prior to this, records for 1894 show this was a wet year, 461 mm falling in November with an annual total of 1,066 mm. Rainfall was heavy also at Fort Smith in Kikuyu, with a total of 1,222 mm, the heaviest rain being in December (237 mm). Machakos records show a decline in rainfall from 1915 then increasing to 1965, followed by a fall (Fig. 2.24). There is a fairly long but disjointed run from Voi (altitude 558 m, lat. $3^{\circ}23'S$, long. $38^{\circ}35'E$), of interest with relation to Tsavo NP (Fig. 2.25). These records begin properly in 1938 with some disjointed ones going back to 1912. An

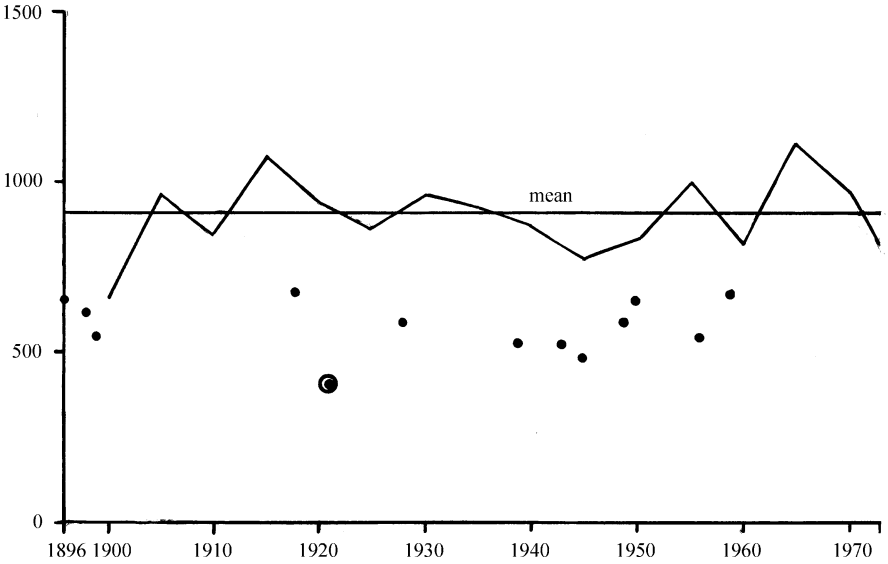


Fig. 2.25 Annual rainfall at Machakos 1896–1973, 5-year means (mm). Circles indicate dry years, circled circle indicates year with more than 25% below average rainfall

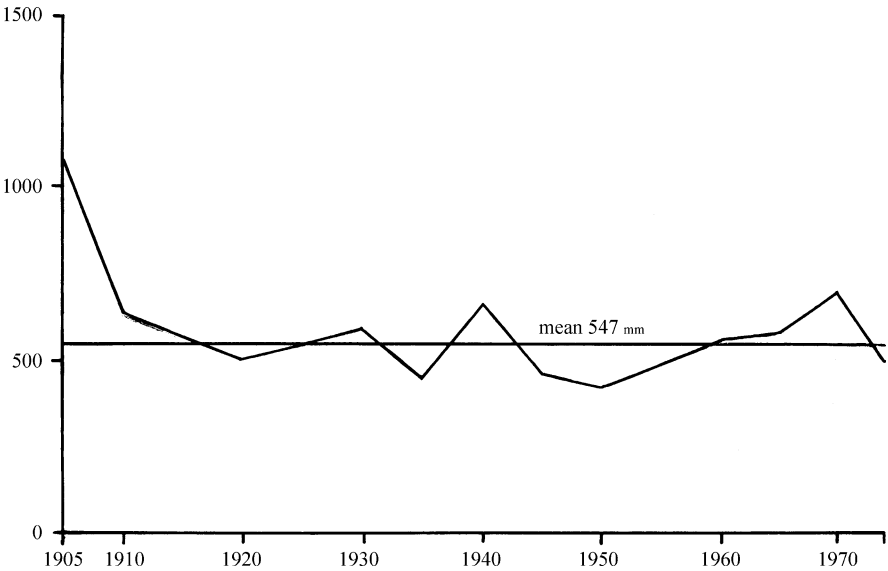


Fig. 2.26 Annual rainfall at Voi 1905–1974, 5-year means (mm)

attempt was made to start collecting at nearby Kibwezi in 1913, but began properly only in 1917. Figure 2.26 shows the stations compared. Cumulative departure of rainfall from the long-term mean at Machakos and Athi River from 1894 to 1905

respectively to 1960 shows increased rainfall from 1905 to 1943, followed by a decline below the mean then rising to the mean in 1960 (Morgan 1967).

There is an inverse correlation between temperature and rainfall showing initially a quite marked increase in rainfall for a small drop in temperature, and then a steady decline to 1920-1924 as temperature rises. There then appears to be a marked drop in temperature from 1935 as rainfall increases to a peak in 1935-1939. It then shows a gradual decline which does not match the rate of temperature increase, until the sudden drop in temperature in 1964-1969 shows a small increase in rainfall.

The Zanzibar temperature series follows broadly the increase in global temperature from 1905 to 1970, the increase at Zanzibar being $0.02^{\circ}\text{C}/\text{year}$ compared with $0.014^{\circ}\text{C}/\text{year}$ globally, and a decline from 1964 to 1970 of $0.21^{\circ}\text{C}/\text{year}$ compared with $0.016^{\circ}\text{C}/\text{year}$ globally. Of note is that the record for 1850 indicates an annual mean maximum temperature of 29.1°C and that for 1878 of 29.3°C , compared with the mean for 1892-1935 of 29.4°C , but much higher minima of 24.5°C and 24.3°C compared to 21.2°C (Figs. 2.27, 2.28 and 2.29).⁶

Mombasa has temperature records dating from 1891. These are erratic to begin with and possibly suspect, until 1934 shows a tremendous surge of 1.6°C in mean annual temperature due to change of locality. After this there is a rapid decline which apparently starts before the global decline and may be suspect also, the locality changing again in 1945. However from 1964 the sharp decrease of $0.58^{\circ}\text{C}/\text{year}$ matches world decline but is apparently 36 times greater. The Voi

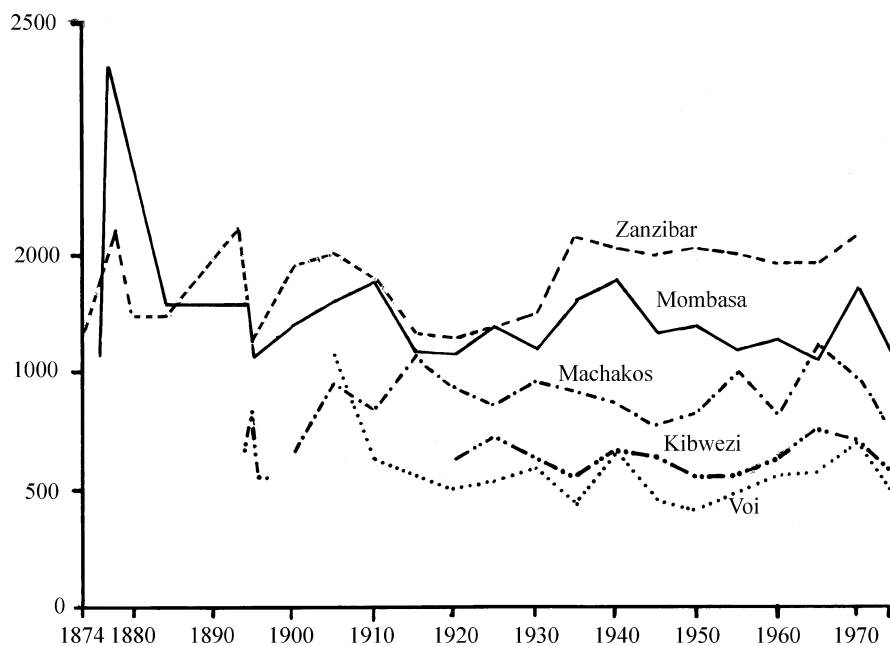


Fig. 2.27 Annual 5-year mean rainfall (mm) recorded in East Africa at Zanzibar, Mombasa, Machakos, Kibwezi, and Voi, to 1974

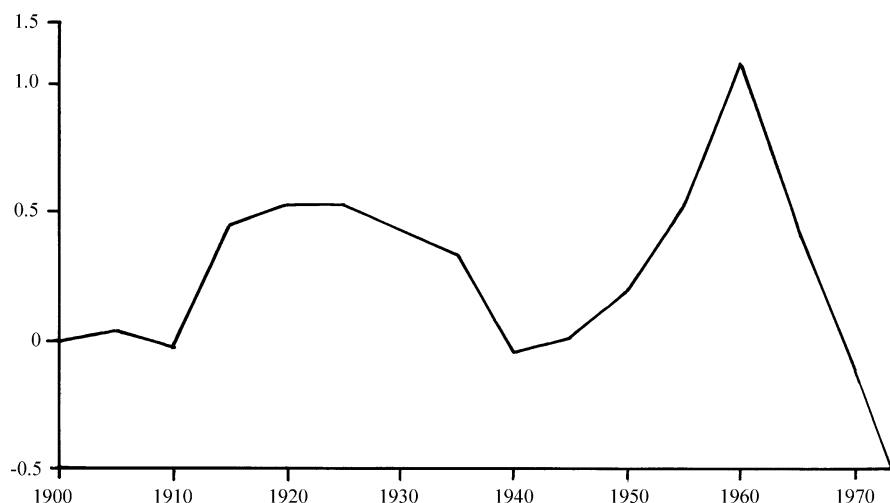


Fig. 2.28 Zanzibar annual 5-year mean maximum temperatures in degrees centigrade to 1973 related to temperature in 1900

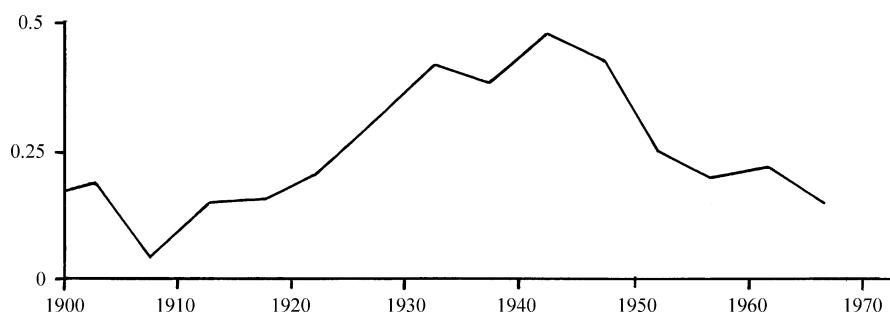


Fig. 2.29 Global 5-year mean surface air temperatures in degrees centigrade to 1969 (After Mitchell 1972)

records from 1944 parallel the global trend quite closely, more so than the seaboard stations, and show a decline from 1964 of $0.27^{\circ}\text{C}/\text{year}$. The indications are that eastern Africa has followed the global pattern of temperature from 1900, and probably from 1880, but changes appear to be of much greater magnitude than the world average.

2.18 Effects of Historical to Present Climate in Eastern Africa

Drought was widespread in inter-tropical Africa from the late 1700s to the early 1800s and most areas from 900 to 1270 were drier than today with maximum aridity possibly in the 1790s, although Baronius (1741), writing in 1588–1607, recorded

that in 484 there was such a drought in Africa, presumably meaning North Africa but perhaps Nubia and Ethiopia, that all the springs and rivers dried up and men and animals struggled for the withered grass roots in the open fields. So great was the famine that all living creatures died in heaps and their carcasses lay in every road without anyone to bury them. This was followed by plague marching into Africa. He remembered also Gelasius (St. Gelasius pope 492–496), writing of the hunger which fearfully troubled Africa. In equatorial East Africa relatively moist conditions from about 1270 to the 1750s were interrupted at least twice by 10 year periods of severe aridity around 1400 and the late 1500s, matching historical records from Angola, Uganda, Tanzania, and Rwanda, of drought-induced famine, migration, and conflict between pastoralists and agriculturalists. Overall, in the past 1800 years in central Kenya there were at least 7 of these 10 year arid periods, more severe than any drought recorded in the twentieth century (Verschuren 2004). Prolonged and severe drought was experienced in Kenya in 1390–1420, 1560–1625, and 1760–1840, the latter two droughts overlapping with droughts in Ethiopia in 1543–1562, 1618, 1828–1829, and 1864–1866. The period of widespread marked drought in East Africa at the end of the nineteenth century was confirmed by the rainfall records. Mombasa rainfall for the year 1892 was 47% of the 1,200 mm 67 year mean 1891–1958, and for 1898, 56%. Machakos recorded 32% for 1898 and 41% for 1899 of its 902 mm 62 year mean 1896–1958. Zanzibar was relatively unaffected, for although its rainfall was 16.5% below the long term mean in 1892, in both 1898 and 1899 it was 20% above. But droughts have thus been a recurrent phenomenon in East Africa for as far back as records exist, although it is difficult to piece together an overall picture due to the fact that droughts tend to be limited by area, or when wider may not necessarily be reported from all affected centres. Again, they are usually recorded as “famines,” and famines may be caused by floods as well as drought and also are not always climatic in origin. The severe famine reported by Baumann in 1892 affecting the Maasai of Ngorongoro, was mainly due to the death of their cattle from rinderpest (Baumann 1894). A series of localized famines in Tanzania in 1929–1932 was largely the result of locust depredations, although climate and locust plagues are connected. Table 2.2 lists some reported droughts and famines.

2.19 Ethiopian Famines

An outbreak of famine and disease was reported for Ethiopia sometime in the twelfth century, followed by another in the twelfth or thirteenth. Several famines and epidemics, the latter believed to be smallpox, were mentioned in the thirteenth and fourteenth centuries: famine in Showa in 1252 and again in 1258–1259, a “great epidemic” in 1261–1262, famine in 1272–1273 followed by mortality in 1274–1275 of the “nobles of Walalah and their sultans” (Pankhurst 1985). Drought conditions were usually followed by ‘plague,’ which might refer to smallpox, bubonic plague, cholera, dysentery or typhus. A “cruel famine” occurred in Ethiopia sometime

Table 2.2 Some reports of droughts and famines in East Africa. Bracketed years indicate event occurred sometime within that period

Year	Event
(1637–1645)	Famine in Kikuyuland
(1730–1738)	Famine in Kikuyuland
(1814–1823)	Serious famine in Duruma
1830	Drought in central Kenya
c1833	Great famine all over East Africa
1834	Ukerewe Island (Tanzania)
1836	Famine in Ukamba
1840	Famine in Ukimbu (Tanzania)
c184	Famine in Wanyika
(1850)	Drought and famine in Dodoma region, Tanzania
1850s	Prolonged famine in Kilimanjaro region
1856	Drought and famine on mainland south of Zanzibar
(1860–1870)	Serious famine in Usukuma
1861	Drought in Nyamwezi (Tanzania)
1863	Famine in Kikuyuland
(1870)	Drought and famine in Dodoma region
1876–1877	Famine from Mombasa to Kilimanjaro
1878	Drought and famine in Dodoma region
1880–1881	Famine from Rufiji to Ethiopia
1882–1883	Bad famine at the coast
1883–1886	Drought and famine in Dodoma and Arusha-Meru region, Tanzania
1882–1884	Bad famine at Sagalla, Teita area
1884	Famine in Kikuyuland
1884–1886	Serious drought and famine in Handeni, Tanzania
1885	Drought “extensive and long” in Teita
1891–1892	Drought and famine in Arusha-Meru region
1894–1896	Serious drought and famine in Handeni
1895	Famine in Kikuyuland
1896	Short severe famine in Kamasia. Drought in Karamoja
1897	Exceptional drought in northern Kenya. Omo River dries up. Famine in Karamoja
1897–1900	Drought and famine in Arusha-Meru region
1897–1901	Serious drought and famine in central Kenya
1898–1900	Serious drought and famine in Handeni
1898–1900	Serious famine in Bunyoro, Uganda
1898	Lake Rudolf low. Big game practically non-existent but Turkana grazing herds there.
1899	“Bad and memorable” famine in Ukamba
1899–1900	Bad famine in West Usambara, Tanzania
1900	No sign of Lorian Swamp in northern Kenya, recorded by Chanler in late 1892 Rendille tribesmen say there had been no rain in Samburuland for 3 years Terrible famine killed many people in Busoga, Uganda
1901	Famine in Kikuyuland
1907–1908	Serious drought and famine in Handeni
1909	Famine in Ukamba
1910	Serious drought and famine in Handeni

(continued)

Table 2.2 (continued)

Year	Event
1912	Drought reported at Lorian Swamp, but water present at end of 1913
1916–1918	Serious drought and famine in Handeni
1917	Famine in Kikuyuland. Exceptional drought at Masindi, Uganda
1918	End of great famine in Mwanza area. Famine in Masindi
1919	Drought in Turkana
1920	Famine in central Tanzania
1925	Serious drought and famine in Handeni
1927	Rains failed in Soroti, Uganda
1928	Famine in Soroti. Lorian Swamp dry in May. In 14 days 6 small, 3-quarters grown elephants seen to die, older animals having trekked to the Tana River. “Hundreds” seen daily searching the swamp for water
1929	Drought in Tanzania
1932–1935	Serious drought and famine in Handeni
1933	Bad drought recorded in Kenya Game Department Annual Report. Rain at Lodwar in Uganda less than 13% of 1922–1950 average
1933–1934	Drought in Tanzania
1937	Drought in southern Tanzania
1938	Rains failed in Tanzania. Great Ruaha River at its lowest
1943	Famine in Kikuyuland
1948	Famine in Kikuyuland
1949	Recorded as one of the worst drought years experienced in Tanganyika Game Department Annual Report
1950	Drought year reported in Kenya Game Department Annual Report
1951	Drought in northern Kenya. Lorian Swamp dried out mid-March. Eleven elephants known to have died but estimated deaths put at 50, “nearly half the normal population”
1953	Severe drought in Tanzania
1961	First recorded Tsavo drought (although records show others occurred in the area in 1884–1885). Animals also affected in Nairobi National Park
1973–1974	Athi-Kapiti plains drought with large wild animal losses

between 1314 and 1344. There was drought and famine sometime between 1508 and 1540 with many cattle dying. Drought was experienced in 1543–1544 recorded as a terrible famine, said to have been worse than that which occurred at the time of the destruction of the second temple in Jerusalem. People believed “God had strengthened the fires of hell, which devoured the trees, plants and the earth itself” (Budge 1928). Drought was reported in 1560–1562 and famine in 1567, followed by no rain for 3 years from about 1569 to 1571, with cattle dying and some people resorting to cannibalism. In 1611 torrential rains were experienced, but famine was reported. Paez (1629) reported famine followed by plague about 1620. Famines were also reported for 1634–1635, 1650, 1653, and “great famine” in 1668. Famine is reported also for 1700, 1702, and throughout the entire country in 1706. There are reports of famines also in 1747–1748 and 1752. In 1772–1773 there was a major famine and another famine was reported in 1788–1789, and drought in 1800. The latter correlates with a

low point of the Nile, the other post 1595 being from about 1635 to 1695, which perhaps correlates with the famines of 1634–1706, but the mid-eighteenth century famines are matched by relatively good Nile flows overall.

Drought is reported in 1826–1827. The Shawa region experienced famine in 1828–1829 and there were many cattle deaths. Drought is reported again in 1835 and another about 1865. Failure of rains in 1835 was reported in Shoa (Kirk quoted in Pankhurst 1968). There was drought from 1888 to 1889 leading to the great famine of 1888–1892, far exceeding the impact of the 1971–1974 drought, the effects of harvest failure compounded by rinderpest plague, a *Spodopterus* plague, locusts, and rats. Rinderpest destroyed the cattle and the people could not plough, creating famine of acute proportions which caused a variety of fatal epidemics to break out: smallpox, typhus, cholera, and dysentery; while at the end of 1889 there was an epidemic of fatal influenza. The Awash region was estimated to have lost perhaps 80% of its population. Wurtz (1898) estimated a third of the whole population died, two-thirds in the south of the country; although in April 1892 some rain fell in Shawa and in southern Ethiopia, and in Hamasen the famine was less acute. Vignéras (1897) wrote that the plain of Burka which had a numerous population prior to 1890, was scarcely inhabited in 1897. In the Arussi region it was reported large numbers of people had migrated northwards after losing their cattle (Pankhurst 1985). Famines could be localized, deadly famines occurring only a few kilometres from abundant harvests, a pattern seemingly especially common where sharp divisions between highlands and lowlands creates local microclimates (McCann 1987).

A drought in 1899–1900 is claimed only from a fall in the level of Lake Rudolf and a low Nile flow, while a drought in 1913–1914 is matched by a low Nile flood of 10% below the average from 1890 ($n = 23$). In 1921 drought occurred caused by a complete failure of rains from October 1920 to May 1921, and in 1932–1934 a low level of Lake Rudolf again suggests drought, drought being recorded in northern Kenya in 1933–1934 and famine in British Somaliland. In 1953 there was drought in Tigre and Wollo, and in 1957 drought and locusts caused a large number of deaths there. Again in 1964–1965 there was widespread drought. In the drought of 1970–1973 some 200,000 people are estimated to have died, the situation compounded by a cholera outbreak. Rains improved in 1974 and 1975, but in Harrar and Somalia drought continued. In 1975 there was again a catastrophic famine.

Drought beginning again in mid-October 1983, famine in 1985 was attributed to years of agricultural neglect creating impoverished soils and habitat.

2.20 Sudan Famines

Escayrac reported in Kordofan in 1853 the Nubas stated the water had left their country, their wells being “double the depths of their fathers’”. Having dug one well deeper to the depth of the height of a man to find water a few years ago, now they

had to dig three or four times deeper to find water which was less abundant. But in some wells, he noted, the water could disappear one year and return the next, even to a higher level, so that long abandoned wells sometimes could be dug out with success. Jones (1938) argued that in Nigeria the Geological Survey had concluded the water table was stationary and many native shafts ceased to yield water because of the manner of construction. In the dry season, if wells are overdrawn the sand rises in the bottom and cleaning out leads to cavitation at water-level. Sooner or later the walls collapse and the well is abandoned. Previously many wells had been maintained by slaves.

Recent climatic deterioration has been severe in the Sudan where in White Nile Province annual rainfall in 1965–1984 was 40% below 1920–1939 levels and the wet season contracted by 39–51% (Walsh et al. 1988). In 1958–1975 the desert moved south 90–100 km, threatening more than 3,000 million ha, the principal factor causing desertification being overgrazing (Novikoff 1983). In 1984 there was a dramatic reduction in rainfall with the single driest year on record since records began in 1900. Following on 15–20 years of reduced rainfall this triggered a devastating famine. In North Kordofan south-west of Khartoum, traditional homeland of the Kababish nomads, an elder reported the grasses had begun to disappear beginning with *Blepharis linariifolia* Pers. The *Commiphora* bush had died and the baobabs in the valleys, and there was no regeneration taking place. When he was “young” (c1940s?) game was plentiful in the area, with leopard, hyaena, wild dogs, Barbary sheep, giraffe, oryx, and ostrich; but now only Dorcas gazelle remained and that was confined to the desert (Asher 1986). The disappearance of the large mammals was due probably more to over-hunting than lack of rainfall. Ghabbour (1972) reported that dense acacia scrub which could be seen in the area of Khartoum in 1955, was now not to be found until 90 km south of it. Lands bordering the Sobat River looked so parched from the air that one could not imagine how they supported ‘impenetrable’ forests in the nineteenth century.

2.21 Uganda and Kenya Famines

A reduction in forest cover about 3000–2000 B.P. in Uganda may indicate a drier climate or clearance by man. Although the level of Lake Victoria was affected by the formation of its outlet to the north, the former low lake levels and the pollen sequence were independent of this (Butzer et al. 1972). Dale (1954) attempted to relate climatic changes to the Nile records during the past 2,000 years using only minimal flows which reflect the Uganda Nile. From A.D. 0 to 1200 it was drier than as at present with an accentuated dry period between 760 and 800, and a rather wetter period from 1075 to 1130. Dale believed the greater part of Uganda would have been short grassland when the first Bantu immigrants colonized the area about the fourth century A.D., and not the fire-climax savannah woodland and bush of today. Drier conditions in the fourth and fifth centuries, and at the end of the eighth, may have caused forest regression, especially if the people fired the grasslands.

Many communities in Uganda of the Lwo and Paraniotic peoples apparently dispersed following several decades of drought in the eighth century. Low Nile levels between 1009 and 1017 suggest drought in Uganda and it may have continued long enough to cause a break-up of the Nilotic cradle land, which according to tradition occurred during famine about 1031–1058. Webster (1979) notes the earliest traditions of famine in the interlacustrine region are found among the Lwo, the first famine possibly having affected an area near Lake Rudolf about 1031–1058. The second concerned the Agoro Mountains about 1139–1166, and the third related to cattle disease in the same area about 1328–1355.⁷

Dale considered it not improbable that in the year 1000 the area of high forest, excluding mountainous areas, was the smallest in the whole of the past 2,000 years. Some expansion may have taken place in the wetter twelfth century, the forests of Budongo, Bugoma, and Kalinzu perhaps attaining half of their 1950 size. The Impenetrable Forest, Kasyoha, Kitomi, Kibale, and Zoka forests, are likely to have been largely riparian. Robertshaw et al. (2004) consider there was a period of increased aridity around the end of the twelfth century, and 1180–1400 witnessed an increase in the number and size of agricultural settlements in the relatively more humid regions north of the Katonga River. Webster (1978) considers the Nile records indicate a period of prolonged drought from 1285 to 1350 such that it seemed unlikely most of Uganda, or indeed the East Africa region, could have supported an agricultural population, and that a similar drought had not occurred since in Africa. This had caused the Kintu people to migrate to the Lake Victoria shore. He identifies a prolonged drought in East Africa from 1400 to 1409 which was a major factor in the collapse of the Bacwezi Empire, in turn replaced by Lwo drought migrants who laid the foundations of the Bunyoro-Kitara Empire. Other famines are reported among various clans in northern Uganda in 1343–1370, 1355–1382, 1382–1409, and 1432–1463. Wetter conditions then ensued to 1500 and the rain forest spread spectacularly where not prevented by man. If fire is prevented much of the bush which receives a rainfall of more than 1,140 mm rapidly turns into forest and forest reached a maximum between 1400 and 1600 during the wetter conditions, only to halt and retreat in the seventh to mid-nineteenth centuries with a reversion to lower rainfall beginning early in the sixteenth, in Kitara a period of aridity seemingly having set in around 1520. North of the Katonga River extensive forest clearance took place with the return of the more humid conditions at the beginning of the fifteenth century, possibly starting in the preceding drier episode. The forest retreated until about 1850, then apparently advancing again to the present. The advance appears to have been taking place also in southern Sudan, as at the foot of the Imatong mountains, until counteracted by human destruction. Major earthworks were constructed in Uganda at Munsa and Kibengo during the forest expansion period, but whether these were to keep out elephants or were defensive structures can only be surmised, although the latter seems the more likely. At Munsa they were abandoned by the beginning of the eighteenth century.

About 1559–1586 drought was such in northern Uganda that one tradition states “the sun burned their corn.” Herring (1979) suggests that 1587–1623 was a period of

continuously low rainfall in Uganda, known as the *nyarubanga* drought, with total crop failures in 1588, 1601–1602, 1613, and 1617–1621, apparently culminating in a great famine in 1621–1622 accompanied by migrations and wars, claimed to have been the worst drought ever to have afflicted the interlacustrine area within the recall of oral tradition (Webster 1979). Allegedly in 1617–1623 Lake Albert ceasing to spill over the White Nile ran dry at Pakwach; and the Ilembo clan have a tradition of migrating across Smith Sound (Mwanza Gulf, south Lake Victoria) on dry land (Itandala 1979). Unfortunately there are no Nile records for 1618–1620 and there are gaps between 1587 and 1617, perhaps reflecting extreme conditions and anarchy in Egypt. Sargent (1979) claims the nilometer data indicate distinctly dry years c1588, 1601–1602, 1613, and after 1617, culminating in “the lowest ever recorded Nile level in 1621–1622,” and that there were 40 years of below average rainfall punctuated by five severe droughts. Thus the *nyarubanga* famine of about 1587–1589 and the great famine of 1621–1622 in northern Uganda, were part of a continuous drought event which seemingly extended throughout eastern Africa. Toussoun’s (1925) Nile data do not support this, but Quinn’s (1993) derived figures give lows for 1589, 1600, 1604, 1607, 1618, and 1621. In the seventeenth century desiccation drove the pastoral Acholi from Karamoja into Uganda.

Famine in about 1706–1721 in Uganda caused the dispersal of a Lango clan. Further droughts were reported in eastern Uganda in the 1720s, with the *nyamdere* famine in north-east Uganda about 1724, and northern Uganda in 1761–1764, causing the agriculturalists to move west or into the hills. The Sor, who inhabited the mountain massifs in Karamoja, claimed the rains failed for 4 or 5 years consecutively at the end of the eighteenth century, the vegetation withered, and whole forests died. The plains between the mountains of central and southern Karamoja became a “battleground of wandering peoples. Human beings and cattle and numerous wild animals were killed by the appalling conditions. Groups survived only by preying upon one another” (Herring 1979). The prolonged drought in the inter-lacustrine region ended in the 1780s. Further drought followed in Uganda in the 1820s and then a major drought in the mid-1830s which led to a number of wars and migrations. Leake (1917) reported that in eastern Uganda near Mount Tororo the Karimojong stated that about 1866 they lived on the Apulé river south of the Magori Hills, but the river dried up shortly afterwards and now was only a seasonal spring “which always used to produce water 12 years ago, on the west side of Mount Tororo, is now completely dry, and there is much similar evidence everywhere that the country has been drying up.”

However the lower Zaïre river experienced an extraordinary high flood at the end of 1882 and beginning of 1883 although this may have been due to high rainfall in the west of the continent, the rains for 1882 and 1883 being recorded as extraordinarily rich on all the Angolan coast and Upper Guinea (Danckelman 1884). Pechuel-Loësch (1887) quoted a report of 1886 of a long drought in an area in central DR Congo in the region of the Sankuru River which had caused the death of the fan palms (*Hyphaene?*), but Uganda experienced exceptional rainfall at the end of 1891–beginning of 1892. The lesser rains were unusually heavy in October–November, continuing into the regular rains in March and then, after a slight check, continued to the end of July.

Famine in 1898–1900 almost completely depopulated Bunyoro but some attribute this latter not to climate alone but to the colonial war which was being waged, crops being destroyed and cattle confiscated, while epidemic disease became rife. All of the major climate changes appear to coincide in Bunyoro with significant changes in socio-economic conditions in the area (Robertshaw et al. 2004). Serious famines occurred in Bunyoro in 1907, 1914–1915, and 1917–1918, with high mortality. Subsequent to this, although famine periods continued to take place, mortality was avoided by administrative measures.

In eastern and central Uganda the climatic changes influenced demographic trends, drought forcing agriculturists to seek new areas and pastoralist groups to expand into others. By mid-nineteenth century all the agricultural groups had retreated to west of the 1,200 mm isohyet, leaving the drier eastern area to the pastoralists. Normally tribes were separated by sparsely inhabited frontier zones, but 40 years of below average rainfall punctuated by five droughts destroyed the ‘no-man’s land’ between tribes in northern Uganda through enforced clustering along the Albert and Victoria Nile. Further migrations took place again in the drought and famine between 1890 and 1905 leading to assimilations of different tribes.

Evidence suggests the Kikuyu settled in the forest area of what became known as Fort Hall District in the sixteenth century, probably in response to drought, one oral tradition suggesting they came from the east somewhere in the region of the Kenya coast north of the Tana River. Kikuyu tradition records a famine between about 1637 and 1645 (Muriuki 1974), but perhaps it was 15 years earlier. The Kamba are believed to have moved into the Machakos Hills in the seventeenth century. Another Kikuyu famine is recorded about 1730–1738, and indications are that there were very dry conditions in Kenya in the late eighteenth century. West of Lake Victoria in Kiziba on the lake’s mid-west coast and Rwanda regions, oral tradition refers to a drought sometime between 1741 and 1768. The Nandi and Marakwet moved about 1780 because the rivers were drying up but famine references in the south fall outside of the normal pattern dating to 1795–1830 in Kiziba and Rwanda, although famine after c1785–1790 upset the *status quo* everywhere between Mount Kenya and the Nile valley.

Sometime between 1814 and 1823 apparently a very bad famine struck the Kenyan Duruma people (about the present-day location of Tsavo East NP) causing many deaths, but this is mentioned only in a single Arabic source (Ritchie 1995), although there is record of a prolonged drought from 1760 to 1840 in Kenya and it was probably a peak in this period. Widespread drought in 1836 caused a number of Wakamba in Kitui, who had moved to there in the mid-1700s, to move again in the search for resources (Ambler 1988). Krapf (1860) reported a great famine in Ukamba in 1836 which drove numbers of Wakamba to move among the Wanyika near the coast. Termed “the long famine” *yua ya kiasa*, in Wakamba tradition, another famine was reported among the Wakamba in 1851, but Krapf (1860) merely noted that one of his contacts had quit his village in the southern Yatta

Plateau because of a famine from which the country was suffering due to lack of rain. Another famine was reported raging in Ukamba in 1862 followed by a major famine in central Kenya with another famine in Ukamba tentatively assigned to 1871 (Forbes Munro 1975). This was followed by 20 years of repeated poor rainfall and failed harvests. In December 1876 and at the beginning of 1877 there was famine from Mombasa, through Teita, to Kilimanjaro,⁸ and Jackson (1930) noted famine at the coast in 1882–1883, famine in Ukamba at this date being traditionally termed “the star famine” *yua ya ndata*, referring to a comet in September 1882; while Thomson encountered famine conditions there in 1883 (Thomson 1885).

Kikuyu tradition records famine in 1863 and 1884, and there were droughts accompanied by smallpox between 1898 and 1902. Wray (n.d.) experienced famine at Sagalla in Kenya in 1882–1884. He came to the conclusion during his residence there from 1882 to 1912 that seasons of drought and plenty probably followed each other, recording that in 1882 it soon entered a cycle of scarcity of rain and food during which at least a quarter of the population perished. This was followed by a season of plenty and then one of scarcity again; but as means of getting supplies up from the coast improved the famines had less effect. Gissing (Kremer 1910) travelling from Mombasa to Teita and Ndara and back between May and June, reported the rains were delayed and it was an extraordinarily dry year. Thomson (1885) reported famine in Teita, Ndi, and Ndara, while (Kremer 1910) reported an uncommon drought at Nguru mountain and Fischer (1885) reported severe famine at Mgera. Due to drought, by June 1885 the population of Teita (Kilima Kiboma) was reduced mainly by emigration from an estimated 32,000 to 52 persons, of which only six were men. In 1880–1881 famine had been reported from Ethiopia to Rufiji along the east African coastal region, as well as in Zimbabwe’s Matabeleland (Kremer 1910). In 1891–1892 there was much drought in Kenya’s Maasailand and Kikuyu but Lake Victoria rose some 1.8 m higher, causing unusual floods on the Nile in September 1891, not the time of the usual high Nile due to floods from the Atbara and Ethiopia (Lugard 1892). Gregory (1896) reported a bad drought had occurred on Laikipia in 1892, “Here and there around a water-hole we found acres of ground white with the bones of rhinoceros and zebra, gazelle and antelope, jackal and hyena, and among them we once observed the remains of a lion. . . The year before there had been a drought, which had cleared both game and people from the district.” Hobley (1929) reported a bad famine in Kikuyu in 1895. The Nile rose beginning in 1895 following the rise in Lake Victoria which covered a pier constructed at Port Alice (Vandeleur 1897), but Kamasia experienced a short famine in 1896, and in 1897 central Kenya suffered severe drought referred to as *yua ya ngomanisye* “the famine that went everywhere.” In Ukamba in Kitui and Ulu in 1898–1899 it was bad and “memorable,” estimated to have killed 30% of the population. Tate (1904) claimed the death toll was an estimated 50% despite much famine relief.

The poor harvests due to drought were exacerbated by swarms of locusts in 1894 and 1895 which swept from Meru in Kenya through Ulu into Kikuyu. This caused

people in 1897 in the Kitui region to migrate north to Mount Kenya. By early 1899 central Kenya was experiencing its worst famine within living memory. Accompanied by an epidemic of smallpox it was this, rather than starvation, which caused death on a massive scale (Ambler 1988). Famine continued until 1901 although there was abundant rain in the last months of 1899, for the fields were overgrown, their owners dead or absent, or lacking the energy or the seeds to plant. Even those who planted had to wait for the crops to grow and mature.

Rainfall at Voi was very deficient in 1934 with 59% below average recorded although Zanzibar and Mombasa were very wet that year. In 1945 it was 50% below average at the same station, and a drought period is shown for 1949–1951. The year 1949 was a dry year for Zanzibar (34%), Mombasa (39%), Voi (40%), and Machakos (35%); all stations with more than 25% below average. These records thus correlate with known conditions inland.

Machakos experienced the longest recorded runs of consecutive drought years in 1896–1899, 1949–1950, and 1974–1976; while single drought years were reported for 1907, 1913, 1928, 1933, 1939, 1944, 1950, 1954, 1961, 1965, 1972, 1980, and 1983 (Tiffen et al. 1994); but these years do not match the lowest rainfall years. After 1900 lowest rainfall years were 1908, 1910, 1918, 1921, 1928, 1934, 1939, 1943, 1945, and 1949, averaging 33% below the mean. Deficient years after 1950 averaged 22% below (Figs. 2.30 and 2.31). The years 1931–1936 experienced six moderate to severe droughts, while 1969–1976 experienced ten. Although more droughts were recorded in the 1970s there is no evidence of a generalized trend towards a drier climate. Famine was recorded in 1909. In Kikuyu further famines were recorded in 1901, 1917, 1943, and 1948 (Muriuki 1974) (Fig. 2.32).

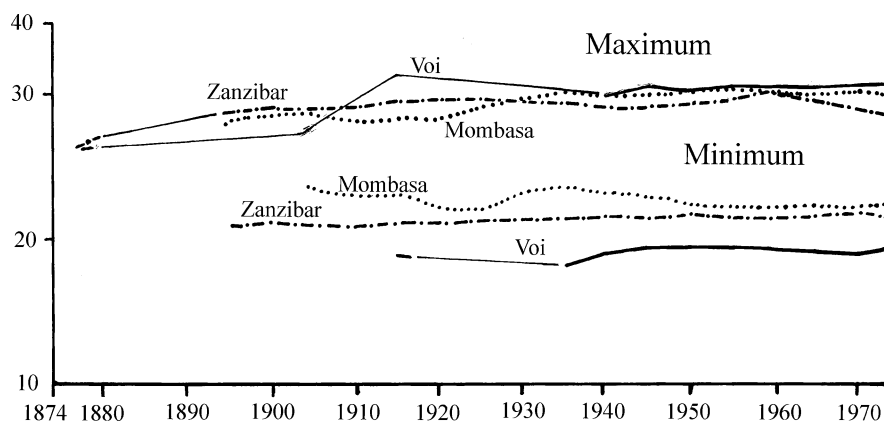


Fig. 2.30 Annual maximum and minimum 5-year temperature means in degrees centigrade recorded at Zanzibar, Mombasa, and Voi, compared

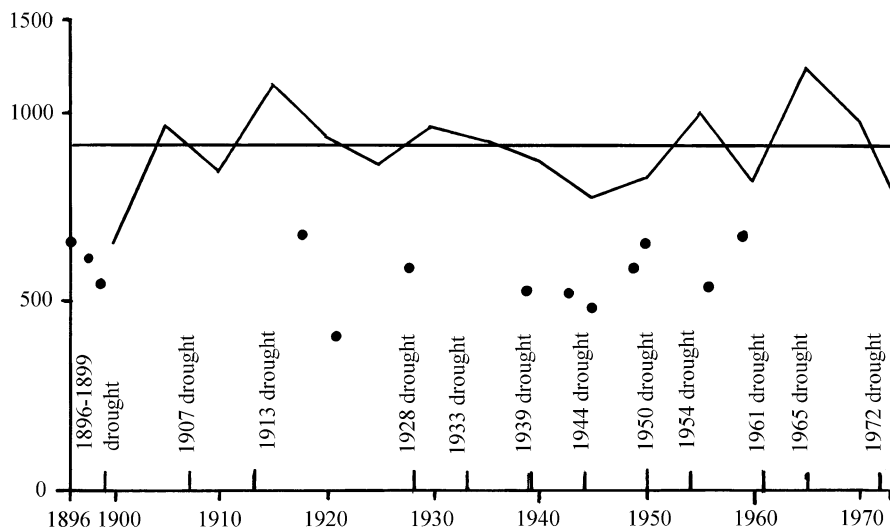


Fig. 2.31 Annual 5-year mean rainfall (mm) recorded at Machakos, Kenya, 1896–1973, with (blocked circles) lowest rainfall years compared with reported drought years

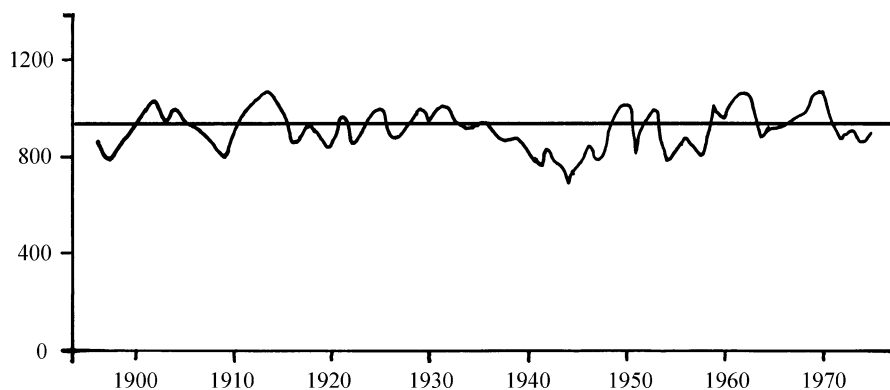


Fig. 2.32 Smoothed annual 5-year running mean of rainfall (mm) recorded at Machakos, Kenya, 1896–1976

2.22 Drought and Famine in Tanzania

In the early seventeenth century the people of Mount Meru in northern Tanzania migrated to there from the Usambaras, indicating there was drought reaching inland from the coast. According to tradition the worst ever drought in Handeni was known as *kidyakingo*, occurring perhaps around 1700 or at the time of the 1730 Kikuyu famine. Tanzania experienced repeated droughts and famines in the nineteenth century but the famines were not always due to drought. Ukerewe suffered

severe famines in the 1820s and 1830s, although the Gogo and Sandawe of the central region recalled one serious famine only in each decade in the 1860s and 1870s. A famine about 1840 which caused serious mortality among the Kimbu of western Tanzania was apparently due to grain being spoilt by too much moisture, one suggestion being that it was contaminated by ergot (Hartwig 1979), but a fusarium toxin such as that which causes alimentary toxic aleikiiia, or ATA, seems more likely. About 1850 a severe drought was reported for Dodoma when most of the cattle died (Brooke 1967). In December 1856 Burton (1858) reported the mainland south of Zanzibar was suffering drought and famine. Drought revisited the Dodoma region in the 1870s and a severe drought occurred in Tanzania about 1878 with apparently catastrophic mortality (Brooke 1967).

Famines occurred in Ugogo in 1881, 1885, and 1888–1889, that of the late 1880s being present throughout the north-east. Drought in Handeni district in 1884–1886 was reported to be the worst known within 50 years' memory beginning in late 1883 with a drought that lasted through the long rains of early 1884, but most farmers obtained food reserves close to home and continued farming, clearing land, and burning (Giblin 1996). A missionary reported in 1887 of northern Nguu that to a great extent the area was depopulated by a famine "2 years ago, which drove away the people into Uzeguha, and they have not yet returned. Where there used to be villages and shambas [cultivated plots] there is now nothing but jungle" (Parker 1887). Handeni experienced another major famine in 1894–1896 and again in 1898–1900. In 1898 drought in Bonde killed even the manioc (Iliffe 1979), but the effects after 1884 were often exacerbated by the German occupation and later colonialism (Giblin 1996). Feierman (1990) refers to a "great famine" in the Western Usambaras from 1899 to 1900. Tradition accords famine at least once every 15 years in Usambara, and Mount Kilimanjaro's Chagga people believed that a red glow on the summit of Kilimanjaro at night presaged dearth (Iliffe 1979); perhaps an atmospheric effect equivalent to that of the English adage "red sky at night, shepherd's delight" which signifies dry weather.

Handeni witnessed further droughts in 1907–1908, 1910, 1916–1918, 1925, and 1932–1935. In 1920 there was famine in central Tanzania with many people dying, but the second major eastern Africa drought period appears to have been from 1928 to 1934, although this is not shown by the coastal records. Giblin (1996) claimed that following each of the major famines accompanying the droughts from 1894, there were epizootics of *nagana* and theileriosis, and in Ulunga district it was observed in 1930 the famine had lowered the fertility of women by more than 25% (Koponen 1996), thus the effects on both animals and humans last well beyond the actual event.

East Africa experienced further droughts in 1993, 1997, 1999–2000, and floods in 1997–1998, which had devastating impacts on ungulate populations killing individuals directly through starvation and indirectly through making them susceptible to predation, parasites, and diseases. Mass die-offs of buffalo occurred in Kenya in 1993–1994.

At the end of 1991 famine again threatened Ethiopia, Sudan, Mozambique, and westwards into Angola. From the beginning of 1992 much stock died in Ethiopia,

Somalia, and Kenya. Northern Kenya and Somalia experienced serious drought again from 2001 to 2006, considered to be the worst ever recorded. Droughts have continued and serious drought was reported again in Kenya in 2009.

2.23 Notes

1. Trades are easterly low-level currents on the equatorial side of the sub-tropical high-pressure cells. The south-east monsoon is the same air mass when diverted towards or across the equator.
2. El Niño is a disruption of the ocean-atmosphere system in the tropical Pacific which affects weather around the globe. El Niño-Southern Oscillation (ENSO) is one of the primary causes of inter-annual climatic variability, not only in tropical regions but on a global level. ENSO events tend to recur every 3–7 years lasting from 3 to 6 seasons, sometimes as long as 24 months,
3. Putant nempe Nilum oriri aut è montibus Lunæ, ut vocant, aut è vasto lacu quem Zaire nonulli, alii aliter adpellant.
4. A Secular Cycle is a long swing of Wolf numbers of varying length, Wolf numbers being provisional sunspot numbers expressed as an empirical index number derived from the number and area of sunspots. Secular Cycles have been claimed in tree-ring growth, varves, rainfall, temperature, and lake levels. Sometimes they are of such small amplitude as to be unrecognizable in certain locations. The Bruckner Cycle is a cycle of twice the periodicity of two consecutive solar cycles, about 22–23 years, but the reality of this cycle has been questioned (Quinn et al. 1987).
5. Oscar Neumann not A. H. Neumann. He made no mention of this in his published account (1895) but commented upon the different species of birds and the thousands upon thousands of pelicans and flamingoes. Following along the west shore at the north end of the lake about a 1,000 zebras and wildebeest romped about, and numerous different game. Of antelopes shot in total on the trip (not at Manyara alone) he lists 1 impala, 9 Grant's gazelle, 2 Thomson's gazelle, 1 hartebeest, 19 topi and 24 wildebeest.
6. These temperature readings were taken in the "shaded corridors of the Residency, unaffected by sun and sky radiation" (Kirk 1890).
7. Some historians have criticized Webster for an uncritical use of oral sources. Thus do oral histories of droughts refer to a single event or a series of catastrophic events, or are they simply metaphors for periods of food insecurity, some of which may have resulted from factors other than shortage of rainfall? See Robertshaw et al. (2004) for a discussion.
8. This was part of an El Niño related drought, perhaps the most powerful in 500 years, marked by extreme departures from normal atmospheric pressure which caused large numbers of deaths in North Africa, India, north-west Sri Lanka,

China, Korea, southern Java and Borneo, and north-east Brazil, among the more reported places, combined Asian deaths being estimated at 20–25 million; the drought leading also to widespread forest fires. The climatic event was repeated in 1895–1902 with deficient rainfall over almost the whole Indo-oceanic area (see Davis 2001).

African Ecology

Benchmarks and Historical Perspectives

Spinage, C.

2012, XLI, 1562 p. 332 illus., 4 illus. in color., Hardcover

ISBN: 978-3-642-22871-1