

Arid Environments as a Valuable Source of Information on the Climate Change Impacts.

Jaroslav Balek

The Foundation Aquasana - Water for the Health,
Karlsbad, Czech Republic

Abstract

Once quiet scientific discipline, climatology has become a matter of conflict and dispute between scientists, politicians and non-governmental activists. Since the Kyoto conference in 1997 there have been emphasized and disputed impacts of man on the climate change and proposed methods leading to the climate change reduction, perhaps even elimination. A majority, consisting of the scientists and politicians, claims that the climate is rapidly changing and man and his industrial and other activities have been responsible for the climate whims such as hurricanes, droughts, floods, etc. Politicians, belonging to this group, claim that they are able to stop the climatic change simply by their signature of international agreements and through the controlled sale of the emission permits.

Minor group, formed mostly by introvert professionals, contradicts that nothing is wrong with present climate and any impact of man in that matter is negligible. According to them the climate will remain stable in the future and costly control measures are futile.

The situation is even more complicated owing to the fact that serious professional polemics have been distorted by interference of non-professionals such as journalists, music stars and show business celebrities, influencing general public in layman's terms.

Instead of giving support to the above groups it is more feasible to analyze the climate development in the past and learn what can be anticipated in the future. No doubt that the arid regions, particularly Sahara and Arabian Peninsula are most convenient for such analysis. The history of climatic changes can be easily traced in those regions, while in the other environments it remains hidden under the impact of other phenomena.

The fluctuation of wet and dry periods in Sahara has been related to so called pluvial and inter-pluvial. The pluvial has been associated with faunal and floral development as well as the cultural history advancement. Therefore the reconstruction of past trends in ecologic and climatic development has been a significant part of Quaternary archaeology in the arid lands. The shifts of the vegetation and faunal zones were conceivably extensive. In last 40 000 years or so the Sahara desert was invaded several times by the Mediterranean flora

down to the southern limits. Such shifts required up to 700 mm of annual rainfall and temperate conditions in areas which today are true deserts.

Information on the climate variability is also supported by the groundwater dating. Total volume of the groundwater resources under Sahara is estimated by 600,000 km³ and water has been gradually stored within last 42,000 years. In course of so called "pluvial maxima" the conditions became favorable for the groundwater recharge as well as the extension of pastures and formation of the lakes. Artifacts such as harpoons, bones and even massive anchor were discovered along former lakes. The depth of former lakes was estimated between 3 and 9 meters.

During the wet periods the conditions also became favorable for the invasion of fauna, particularly the game. Extended river network, traces of which presently exist as wadí, facilitated fauna expansion. Thus land became repeatedly hospitable for the human settlements and cultural development. This has been proved elsewhere in Sahara on the overlapped layers of rock paintings.

Another proof of the climatic variability has been based on author's periodical analysis of the Nile maximum and minimum level sequences, compiled by the Arab historians Taghri Birdi and Al-Hijazi.

Presence of wet and dry periods in course of Roman times was also identified along the northern outskirts of Sahara. Discussed results are based on author's hydrological survey in Algeria.

Present dryness in the region can be compared with the climate around 20,000 BC, however, in course of last 40 000 years Sahara experienced at least five humid and arid periods - not because the climate, fauna and flora had been changed by man, but on the contrary fauna, flora and people had to adapt themselves to the climate changes. No doubt that similar process can be identified in other global ecosystems, however, they are not pronounced so markedly as in the arid environments.

In the absence of man's influence first we need to ask what has been the actual cause of former climate changes. Some might have been produced by the air and sea current shifts in continental scale. Very likely, in African and Asian arid regions the shifts of monsoons and trade winds may have played major role. In a geological scale perhaps even geomorphologic uplifts contributed toward the climate destabilization.

However, most important role has been played by slowly changing impact of the Sun radiation on the Earth surface. This can be explained by changing periodic superposition of three dominant astronomic components, namely the decline of Earth's equator to the eclipse level, eccentricity of the Earth's elliptic trajectory and the perihelion status. Periodical components 13,000 to 114,000 years are involved in those astronomical features and therefore such kind of impacts occurs rather slowly.

It can be concluded that we cannot expect stable climate in the future. On the contrary, we should prepare scenarios and strategies for the survival of mankind under the conditions of forthcoming global warming or global cooling. In addition, so called catastrophic scenario should not be omitted. It is based on the presumption of the climate change under sudden impact of the cataclysmic

event, such as the Earth's collision with an asteroid, massive earthquake or super-volcanic explosion.

Throughout the ages people have been compelled to settle in the regions with hostile climate and deficient water. Man's endeavors to achieve better relations with changing climate and environment have helped to form his skills and character. Thus throughout the history it has been the Nature and not humans who played the decisive role in bringing about climatic changes.

Keywords: Arid Environment, Sahara, Climate Change History, Pluvial, Inter-Pluvial.

Introduction

Once quiet scientific discipline as climatology used to be, it has become a matter of conflict and dispute between scientists, politicians and non-governmental activists. Since the Kyoto conference in 1997 the impacts of man on the climate change have been emphasized together with the proposals solving the climate change reduction if not elimination. A major group of scientists and politicians claims that the climate has been rapidly changing because man and his industrial and other activities are responsible for the climate whims such as hurricanes, droughts, floods, etc. Politicians, who belong to this group, believe that they are able to stop the climatic change simply by the signature of various international agreements and through controlled sale of the emission permits.

Minor group, formed mostly by the introvert professionals, contradicts that nothing is wrong with present climate and any impact of man in that matter is negligible. According to them the climate will remain stable in the future and therefore control measures, requiring large financial injections, are futile. The situation is even more complicated because attempts to lead serious professional polemic have been distorted by frequent interference of non-professionals such as journalists, music stars and show business celebrities trying to influence public opinion in their own interest.

Instead of giving support to any of the above groups it appears to be more effective to analyze the climate development in the history of mankind and learn what can be anticipated in the future. No doubt that the arid regions, particularly Sahara and Arabian Peninsula are very convenient for the analysis of the climatic variability. History of the climatic changes can be more easily traced in arid environments, while in the other ones the changes remain hidden under the impact of other phenomena.

Climate variability traced in the arid environments.

The fluctuation of wet and dry periods in Sahara has been associated with so called pluvials and inter-pluvials. The pluvials have been often related to the advancement of cultural history and faunal development. Therefore the reconstruction of past trends in ecologic and climatic history has become a significant part of Quaternary archaeology in the arid lands. The shifts of the vegetation and faunal zones were conceivably extensive. In course of last 40,000 years or so the Sahara desert was invaded several times by the

Mediterranean flora down to the southern limits. Such shifts required up to 700 mm of annual rainfall and temperate conditions in the regions which at present are true deserts.

Indication of historical climate variability is supported by the results of groundwater dating. Total volume of the groundwater resources under Sahara was estimated by 600,000 km³. A large volume of subsurface water was stored in course of last 30,000-42,000 years. It has been commonly agreed that another considerable recharge occurred prior to 20000 BCE. The recharge estimates for the period between 20000–11000 BCE are contradictory and the interpretations range widely from arid to humid climate. It is also expected that after cold and arid period 11 000–8 000 BCE another significant recharge occurred in course of the Neolithic pluvial.

During the so-called “pluvial maxima” the conditions became favorable for the groundwater recharge as well as the extension of pastures and formation of the lakes in Sahara and Arabian Peninsula. Very likely, during wet periods monsoonal rains covered a great part of Sahara and the annual precipitation reached 270–600 mm.

The first settlements in Western desert were already identified for the period around 40000 BCE. Along former Nile river bed the first settlements were developed between the years 19000 and 10000 BCE. Artifacts such as various remnants of the settlements, harpoons, bones and even massive anchor were discovered along once extensive lakes. The depth of newly formed temporary lakes was estimated between 3 and 9 meters. In course of the extensive wet epoch, short but extremely dry periods were identified in eastern Sahara between the years 5300-5100 BCE and 4700–4500 BCE. According to Butzer (1959) shorter periods of dry climate in the basin, associated with so called fauna breaks, occurred around 2350-500 BCE, 300-800 CE, 1200-1400 CE and 1700 CE onwards. Present dryness in Sahara has been compared with the common dryness around 20,000 BCE.

In presently driest part of Saudi Arabia, known as the Empty Quarter, several wet periods were also identified. They contributed to the formation of so called Rub'al-Khali lakes. Findings of the hippopotami, buffalo and other fossils indicated that the depth of those lakes had been between 2 -10 meters. The lake system was formed at least twice prior to 5000 BCE. Extensive swamps were also formed in northern Sudan between 6,400–5,300 BCE.

During the wet periods the conditions became favorable for the invasion and extension of fauna, particularly the game. Expanding river network, remnants of which have been preserved as wadis, facilitated fauna expansion and former arid lands became repeatedly hospitable for the human settlements and cultural development. This has been proved elsewhere in Sahara on the overlapped layers of rock paintings with the figures of both people and animals. The eldest paintings were dated prior to 10000 BCE. Corresponding annual rainfall, supporting both people and fauna, was estimated by 200-800 mm.

Climate variability identified in the river Nile regime.

The river Nile has its sources in Ethiopia and East Africa. Exogenous sources of the river have a special significance for the arid environment. Distinct

changes in the re-distribution of the water resources can be traced back to the end of the Middle Paleolithic period. Since then, after the decline of precipitation regime, the basin became attached to the drainage system of the Ethiopian Highlands. Later on, more or less regular regime of annual floods was established, however, the river channel became fully stabilized much later. The floods brought the first mud deposits and the flood level was higher than at present. Some authors concluded that between 6500–6000 BCE the flood maximum level was 3 meters higher (Malkowski, 2005) and around 1,400 BCE it was 7 meters higher (Reisner et al., 1960) than at present. From time to time some wadis such as Howar and Melik, drained into the Nile from Sudan, used to be perennial rivers. Such regime was proved for the years 5700 – 4000 BCE.

More or less regular flood regime of the Nile basin was accompanied by the sedimentation. For instance, the deposits contributed to the formation of so called Selbian silts. Certain irregularities in the hydrologic regime occurred before the Neolithic sub-pluvial, which probably lasted in Egypt from the early Neolithic period until the Old Kingdom (about 3240 BCE). Only after 3000 BCE the Nile's bed has become more or less stable and has achieved present form.

As another proof of once wet conditions serve the constructions of dams in the Nile basin. Herodotus who came to Egypt in the 5th century BCE, found then still existing dam, built south of Memphis around 3000 BCE. So far, exact location of that dam has not been identified. Existing remnants of the world's oldest dam are found in Wadi el Garawi, south of Cairo. It was built probably between 2700–2600 BCE, unfortunately great part of still unfinished dam was washed away by a flood. Also during the Middle Kingdom, around 2 000 BCE, several artificial reservoirs were constructed in the Nile basin.

Extensive hydraulic works are also known from the Arabian Peninsula. A dam of Marib in Yemen was built and reconstructed several times between 750 BCE and 575 CE. Other dams are known from Saudi Arabia, like renowned construction Qasr al-Bint, believed to be founded during the period of the Queen of Sheba.

No doubt that such engineering works indicate then more favorable climatic and hydrologic conditions than nowadays (Balek, 1990).

Another proof of the climatic variability already in CE was based on the statistical analysis of the periodicity in the sequences of Nile maximum and minimum levels, compiled by the Arab historians Taghri Birdi and Al-Hijazi.

Basic set of Arabic data from the period after 646 CE was published by Prince Omar Toussun (1925). They stem from data gathered by Al-Hidjazi and collected in an unpublished manuscript "Nail aR-Ra idmin an-Nil az-Za'id" (Bibliothèque Nationale, Arabic MS 2261). Some missing data were supplemented from the sources compiled by Taghri Birdi in "An-Nudjum az – Zahira" (Langles 1810) (Tab.1). The source of Al-Hidjazi's data is not known

Tab.1. Records of nilometric readings commencing the year 646, compiled from the Arabian sources

YEAR S	TAGHRI BIRDI		AL-HIJAZI	
	Minimum	Maximum	Minimum	Maximum
663		849	849	849

Andel and Verner (1971) compiled and unified the records and through the stochastic approach analyzed periodic components in the river regime (Tab.2).

In the modern records. periods of 7, 22 and 84 years were found as statistically significant. The results testify about short-term runoff fluctuation under corresponding impact of the climate variability, possibly influenced by the occurrence of solar spots (Balek 1990).

Tab. 2. Periodical components in the sequences.

Periods in years	Taghri Birdi		Toussun	
	Min	Max	Min	Max
	440	556	282	282
	221	282	106	141
	7	141	14	18

An impact of the climate changes on the Sahelian environment.

Relatively frequent droughts and floods have been recorded in Sahel since the 17th century CE. Very likely they occurred as a consequence of regional to continental climate disturbances. In the years 1616-1617 CE flooded Niger destroyed the crops along the river. Immediately after the flood, rainless years and severe drought were accompanied by an extensive famine. A considerable drought was experienced southwest of Timbuktu in 1633. Another event, locally known as “hungry war” and responsible for the death of thousands people, was recorded in the years 1696-1697 around Agadez.

Prolonged droughts have been extremely severe. The drought northwest of Timbuktu between 1738-1756 was responsible for at least ten thousand of deaths. More than 300,000 people became the victims of 1866-1868 catastrophic drought in Algeria. Another catastrophic drought was experienced in Algeria in 1945-1946. Then 80 % of the nomads' herds perished at once.

Since the 17th century short droughts have occurred in Algeria in span of 5-10 years. Therefore, when author designed the storage reservoirs to be replenished by occasional floods in Algerian dry river beds, it was necessary to design sufficient water storage allowing to overcome one dry year out of five.

Recent severe drought lasted in southern Sahel from late 1960 till 1984. Among other it had a very negative impact on the regime of the Lake Chad. Till 1960s Lake Chad was the fourth largest lake in Africa. However, as a consequence of that drought the lake area was reduced to one tenth of its original size. Some specialists, emphasizing man-made impacts on the climate, ascribed the lake shrinking to the overgrazing, deforestation and poor land and water management. However, it is known that other serious Lake Chad reduction events were identified for the years around 8500 BCE, 5500 BCE, 2000 BCE and 100 CE. Certainly then the decisive and negative role was not played by the population but by a wide scale impact of continental droughts developed by such phenomena like changing sea surface temperature and irregular fluctuation of the ITCZ.

Valuable information about the climate variability during the Roman times was obtained from the analysis of the water balance of drying saline lakes called chotts. They are situated along the rims of northern Sahara in Algeria and Tunisia. The chotts have been connected with ephemeral to intermittent wadis locally called les oueds. It was proved that during Roman times the chotts used to be regular lakes. Their original size was assessed from the position of the Roman farm ruins, situated along former lake shores. Complex water balance, which was calculated as a case study for the chott Boulhilet in search for another promising dam site (Balek, 1988), can be given as an example of climatic analysis in the region. At present the size of the Boulhilet basin is 28 km², mean annual precipitation 340 mm, mean annual runoff 16.4 mm and mean annual evapotranspiration 326.6 mm. Taking into account the location of neighboring Roman ruins, the former lake size was assessed by 520 km², the precipitation 1,250 mm, mean annual runoff 486 mm and mean annual evapotranspiration 764 mm. Similar climatic conditions exist these days far away in the vicinity of the tropical Lake Kyoga in East Africa. Obviously since the beginning of our common era Romans had to leave once flourishing farms because the climatic transformation was followed by permanent depletion of lake water, much needed in the agriculture.

Search for the origin of the climate changes.

From what has been said is clear that since the earliest stages of human settlement in arid environments, man was not responsible for the climate change. On the contrary, it was man who had to adapt himself to changing climate and worse living conditions.

Rejecting man's influence as a major reason of the climate changes, we have to look for another reason of their occurrence. Some role might have been played by the air and sea current shifts in the continental scale. Very likely, in African and Asian arid regions the shifts of monsoons and trade winds might have contributed toward changing situation. Also irregular fluctuation of the Inter-Tropical Convergence Zone (ITCZ) can be considered as another factor.

Some climatologists ascribe the shift of African monsoon to changing sea surface temperature. It is one possible reason. However, in a wider geological scale perhaps even geomorphologic uplifts and displacements of the Earth's crust such as slow steady expansion of the planet radius and fluctuation of the magnetic field, might have contributed toward such type of the destabilization.

According to some astronomers (Moore, 1988), changing impact of the Sun radiation on the Earth's surface has been another decisive factor of the historical climate changes. Major role has been played by changing periodic superposition of three astronomic phenomena, namely the decline of the Earth's equator to the ecliptic level, eccentricity of the Earth's elliptic trajectory, and the perihelion status during the autumn equinox. Another significant role can be played by the precession and so called nutation of the Earth axis. The latter one describes the Moon's position in relation to the Earth axis (Balek, 2006).

Very likely those exogenous forces play major role in long-term fluctuation of the climate. This is because the Earth's reaction to the variability of the incoming Sun radiation is rather slow, delayed and nonlinear. With the

exception of the nutation, having the periodicity 18 years, the oscillation of other periodic components varies between 13,000 and 114,000 years.

Needless to say in this context that the historical phenomena like deforestation, overgrazing and primitive land and water management have been of secondary importance.

How can we protect ourselves against the climatic changes?

It is clear that the climate has never been stable and therefore we cannot expect stabilized climate in the future. On the contrary, climate changes of variable intensity can be also anticipated in the future. Under such circumstances we should prepare corresponding scenarios and strategies for the survival of mankind under the conditions of continental and global warming or global cooling. Another important factor is an unspecified occurrence of catastrophic events. Similarly like in other strategic studies, positive, negative and catastrophic scenarios should be cautiously set up and preventive measures taken well in advance.

For the sake of complexity we should initiate our considerations with so called positive but rather hypothetical scenario under which the negative impact of man's activity will be slowed down, perhaps stopped and eliminated administratively by a series of international agreements and protocols. However, hardly we can assume that international political negotiations can stop astronomic and large scale global impacts so that the climatic and hydrologic extremes could be eliminated forever. Political negotiations can have only a minor influence on the climate, if any at all. Under very special circumstances only effect of the regional climate change can be moderately modified, for instance, by transfer of large amount of exogenous water into the desert.

For rather pessimistic but more realistic scenarios of slow but steady global warming or global cooling, preventive measures should be prepared well in advance with the aim to facilitate man's survival and basic living comfort under the consequence of changing climatic conditions.

The Lake Chad Master Plan can be given as an example of initial preventive measure against the impact of the climate change accompanied by prolonged droughts. The first version of the Plan was prepared by the Lake Chad Basin Commission (LCBC) and UNEP at the end of 20th century. It was a response to prolonged drought in the lake basin (Anon.,1989). As it was obviously impossible to change local climatic conditions and impact of other serious droughts in the future, series of preventive programs was set up with the aim to remedy the drought negative impacts on the population and ecosystems. The author of this paper co-operated on the first version of the Master Plan and proposed the realisation of following major sub-projects:

Particular attention should be given to the long-range water transfer from the Upper Ubangi river, situated in the Congo Basin, into the Lake Chad. Prior to the realization of such extensive project it would be necessary to prepare an assessment of all environmental and socio-economic effects.

Another project was proposed on the effective and environmentally sound water management system of two major natural tributaries Chari and

Logone. This will include an assessment of existing irrigation systems in relation to the conjunctive use of surface and groundwater resources.

As a prevention of occasional and spontaneous diversion of the Lake Chad waters into the River Benue, a special study was recommended, accompanied by a proposal for more effective utilization of overexploited groundwater resources. Improvements of the groundwater recharge and groundwater reservation for dry periods were also considered.

Other suggested sub-projects were concerned with the improvement of observation network, food preparedness combining irrigated agriculture, food processing, preservation and storage, together with improved protection of the wetlands, fisheries and biosphere reserves. Special program for endangered faunal species was also proposed. Last but not least, attention was paid to the establishment of relevant educational programs, early warning system, improvement of the transportation network and basin-wide microwave communication.

A realization of the above proposals would be much useful for the initial improvement of living conditions in case of future droughts. Unfortunately, till nowadays the proposed sub-programs are far from being accomplished. As major constraints have been identified inadequate funding, inadequate qualified manpower, inadequate equipment and insufficient donors assistance (Anon., 2005). Needless to say that similar constraint is common elsewhere in the developing countries.

It should be mentioned that even positive consequences of climate change can produce negative impacts. For instance, some climatologists predict that the wide scale temperature rise will produce higher precipitation and introduction of savanna in some parts of formerly arid environment. Very likely, this can be accompanied by an uncontrolled migration of the pastoralists from the regions which have remained arid. Another inland invasion of the population can be expected from the coastal regions, owing to the rising sea level. In other words, land ownership disputes and civil strifes can be expected as negative consequences of such climate change.

Talking about various climate change alternatives, so called catastrophic scenario should not be omitted. It stems from the expectation of the climate change under sudden impact of the cataclysmic event, such as the Earth's collision with an asteroid, massive tectonic disturbance or super-volcanic explosion. Such possibilities are not hypothetical. Only in course of last twenty years the Earth was three times at the brink of the collision with an asteroid. Unfortunately those events, particularly their magnitude and location, cannot be sufficiently predicted in advance. However, such catastrophic alternative is not very popular on the international political scene because so far adequate preventive measures cannot be reasonably proposed by the politicians, claiming their ability to control all kinds of the climate change.

Throughout history, it has been the Nature and not humans who played the decisive role in bringing about climatic changes. Nevertheless, we should be optimistic for the future because throughout the ages man has always been compelled to settle in the regions with hostile climate and deficient water. Remarkably, man's endeavors to achieve better relations with changing climate and environment have helped him to form and adjust his skills and character.

References

- Andel, J., Balek, J. and Verner, M., 1971, An analysis of historical sequences of the Nile maxima and minima. ECA/WMO Conference on the Role of Hydrology and Hydromet. In the Economic Development of Africa. Addis Ababa, WMO No.301, Geneve
- Anon., 1989, Master Plan for the development and environmentally sound management natural resources of the Lake Chad conventional Basin. UNEP-UNSO Nairobi.51 p.
- Anon., 2005, Management Water Resource of the Lake Chad Basin. ICID Conf. Beijing, 38 p.
- Balek, J., 1988, Le regime hydrologique du Bulhilet. Interim report to Hydroproject Est, Algeria.
- Balek, J., 1990, Assessment of histor. changes in aquatic environment under climatic impacts. Water Res. Devel. Vol.6, No.3, s.178-186
- Balek, J., 2006, Hydrological consequences of the climatic changes. J. Hydrol. Hydromech., 54, 2006,4,357-370.
- Butzer, K.W., 1959, Some recent geological deposits in the Egyptian Nile Valley. Geographical Journal, Vol.125,pp 75-79.
- Langles, L., 1810, Table chronologique des crues du Nil les plus remarquables depuis l'an 23 de l'hegire. Notices et extraites des manuscrits de la Bibliothèque Imperiale.
- Malkowski, E., 2005, Before the Pharaohs, Bear & Comp. USA, 390 p.
- Moore, P., 1988, The new Atlas of the Universe. Chancellor Press, London, 271 p.
- Reisner, G.A., et al., 1960, Second Cataract Forts, Boston Univ. Press, Boston MA, Vol.1.
- Toussun, O., 1925, Mémoires sur l'histoire du Nil, Vol. II, Memoires presentés à la Societé archéologique d'Alexandria, Museum Cairo.