Institutionen för naturgeografi
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Stockholms
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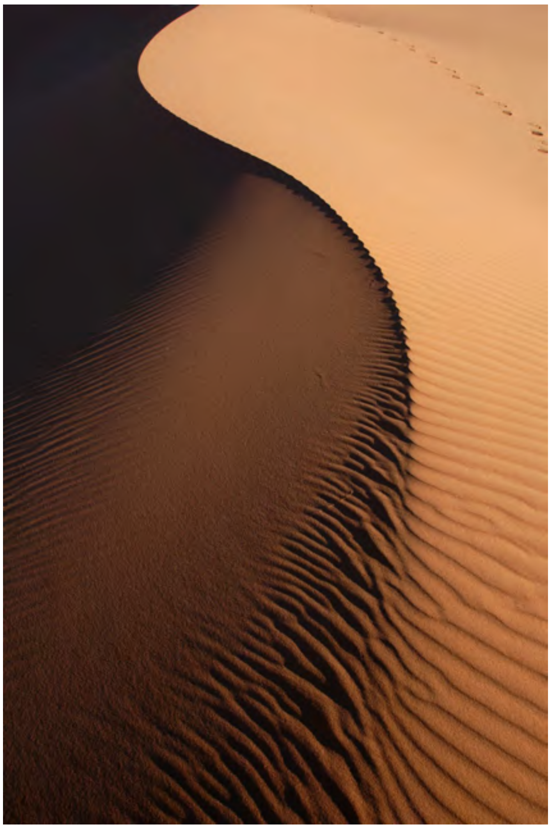
# Holocene Climate Variability and Cultural Changes at River Nile and Its Saharan Surroundings



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# Förord

Denna uppsats utgör Johanna Yletyinens examensarbete i geografi vid Institutionen för naturgeografi och kvartärgeologi, Stockholms universitet. Examensarbetet omfattar 15 högskolepoäng (ca 10 veckors heltidsstudier). Handledare har varit Karin Holmgren och biträdande handledare har varit Martin Finné, Institutionen för naturgeografi och kvartärgeologi, Stockholms universitet. Examinator för examensarbetet har varit Carl Christiansson, Institutionen för naturgeografi och kvartärgeologi, Stockholms universitet.

Författaren är ensam ansvarig för uppsatsens innehåll.

Stockholm, den 13 maj 2009

Clas Hättestrand
Studierektor

Holocene Climate Variability and Cultural Changes at
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**Summary**

**This literature-based study handles the climatic changes that took place during the Holocene in Egypt from 8500 BC to present, specializing on the years from 5000 to 2000 BC. During this time, the Sahara turned green and then dried gradually, ending in the present, hyperarid conditions, that were reached in 1500 BC. At the same time, people experienced the change from hunter-gatherers to urban citizens and Pharaohs, and pyramids were built. This study found out that climatic changes can be considered as drivers in the following cases: the birth of African pastoralism in c. 5300 BC, the availability of water resources acting as drivers for the patterns of the movement of the people in the 5$^{th}$ millennium BC, and the fall of the Old Kingdom being at least partially caused by the low Nile floods, as the unpredictable Nile floods have been shown to cause severe famine in Egypt. Although the causality of changes is hard to prove, it is proposed that the desiccation of Sahara has accelerated the development in Egypt. The study shows the significant importance of the river Nile for the state of Egypt as its unique, single water source. The geographical setting and history of the Nile region reveal the vulnerability of the state when facing the future climate changes.**

**FIGURES:**

# 1. INTRODUCTION

## *1.1. Purpose of the study*

In nature change is constant. What thousands of years ago used to be a green environment, providing a habitat for both wildlife and humans, is today a desert environment - one of the most hostile areas on earth for life - the Sahara desert. As the Sahara turned drier and drier thousands of years ago, the inhabitants had to move closer to the water sources for survival, many of them migrating to the River Nile. Unfortunately the Nile was not a stable system either; the extreme variations in the droughts and floods of the Nile strongly affected the life of people dependent on its water. Nile's flow results from the rains in its catchment area, which, in their turn, are for a remarkable portion due to African monsoon rains - another variable system. The shifting hydrological conditions in this large area have affected the lives of humans living along the Nile through time.

During the last thousands of years, not only nature has changed but the lifestyles of its people too. The history of people in the Sahara and by the Nile is breathtaking: they turned from hunter-gatherers to citizens of pharaoh empires, even constructing the pyramids, which keep on amazing even modern people. One can only wonder how and why did this process happen. Was it some kind of evolution of human mind, or did external forces, like for example environmental changes, cause it?

In general, severe or abrupt changes in climate are associated with interruptions to the progressive development of human societies, or changes in their developmental direction (Brooks, 2006). Also, according to Kuper and Kröpelin (2006), geological and archaeological evidence from the Sahara desert show dramatic climatic and environmental changes over the past 12 000 years. Maybe these changes have functioned as an external driver forcing the people, or giving them the possibility, to change their lifestyles.

To find answers on the questions of development and change, this study aims to explore the interactions between climate, environment and human societies in the surroundings of the River Nile during the Holocene, focusing on the time period between 5000 and 2000 BC.

The study aims to answer the following questions:

1. *What kind of variability has there been in climate, hydrology and social development?*
2. *Is it possible to recognize drivers and responses in the interaction of climate, environment and human actions? Can causality be found in these actions?*

## *1.2. Contribution to future studies*

The results of this study will contribute to ”*The Urban Mind. Cultural and Environmental Dynamics*” programme (Principal Investigator: Paul Sinclair, Uppsala University) and its sub-project ”*The Climate Dimension*” (co-ordinator Karin Holmgren).

## *1.3. Limitations*

### 1.3.1. Time period

The youngest time of Earth history is called The Holocene. It is the time when the Earth’s climate and environment took on their modern form (Oliver, 2005). The Holocene epoch began when the last glaciations ended, c. 8500 BC. As the remaining ice sheets over Scandinavia and Canada were melting away, the sea level rose to within a few meters of their present elevation in most parts of the world, and nature returned from its’ glacial refugia.

The changes in Holocene climate were often very rapid (Oliver, 2005, Williams & Nottage, 2006). There were abrupt transitions between humid and arid phases, punctuated by occasional extreme events.

This study covers the whole Holocene in a limited overview to create an understanding of the changes taking place in Egypt, and in detail concentrates on the period between 5000 and 2000 BC. The expanded time period, covering the whole Holocene for a less detailed overview, gives the reader a deeper understanding on the changing nature of the study area’s environment and culture during the Holocene, and the Egyptians’ continuous dependency on the Nile. The focus on the 3000 year long period was chosen because it includes many both environmentally and culturally important changes: varying floods in the Nile, the phases of both green Sahara sustaining life and the desiccation of Sahara, the establishment of pharaoh state and pyramid building, and the fall of the Old Kingdom of Egypt.

### 1.3.2. Study area

It would be impossible to study the Nile’s immediate surroundings without taking into account what was at the same time happening in the Sahara surrounding the river. The focus of the study will be on the river basin and the Nile delta, but also on the area’s interaction with its surroundings. As the Nile indeed flows through the Sahara, the Saharan people may have had a great impact on the Egyptian culture at the river delta. The development of the culture cannot be studied and described thoroughly if the possible roots of many cultural aspects and people are ignored.

Using the present political boundaries (as will be done throughout the whole thesis), the study area can be described to include the whole Egypt, northern areas of Sudan, and the easternmost part of Libya (*Figure 1*). The area appears remarkable large, but the intention has not been to study the whole area thoroughly. As the environmental aspects studied are happening at the macro level, the purpose is to find several case studies, which can be used as indicators for the environmental changes taking place in the area.

The same can be said about the mobility of the humans: as migration has happened, one cannot limit the study area to the Nile delta only.

The map in *Figure 1* shows the Nile basin area, but can also be used as a map of the study area. The studies included in this thesis are from the area including Egypt and Sudan northward from Khartoum to the Mediterranean Sea. To the east the area reaches to the coast of Red Sea, and to the west it covers eastern parts of Libya. This map is used here because it shows the Nile region as a whole: it includes the drainage source areas, i.e. Ethiopian Highlands and equatorial lakes. One can observe how the Blue and the White Nile meet in Khartoum and continue towards the Mediterranean Sea as a unified main Nile.

Also, as this thesis is based on several case studies, there are many locations appearing in the text. In *Table 1* there is a record of all the names mentioned in the study to be used as a complement to the map of study area. In addition, *Figure 2* can be useful especially when it comes to the geographical settings of the Nile.

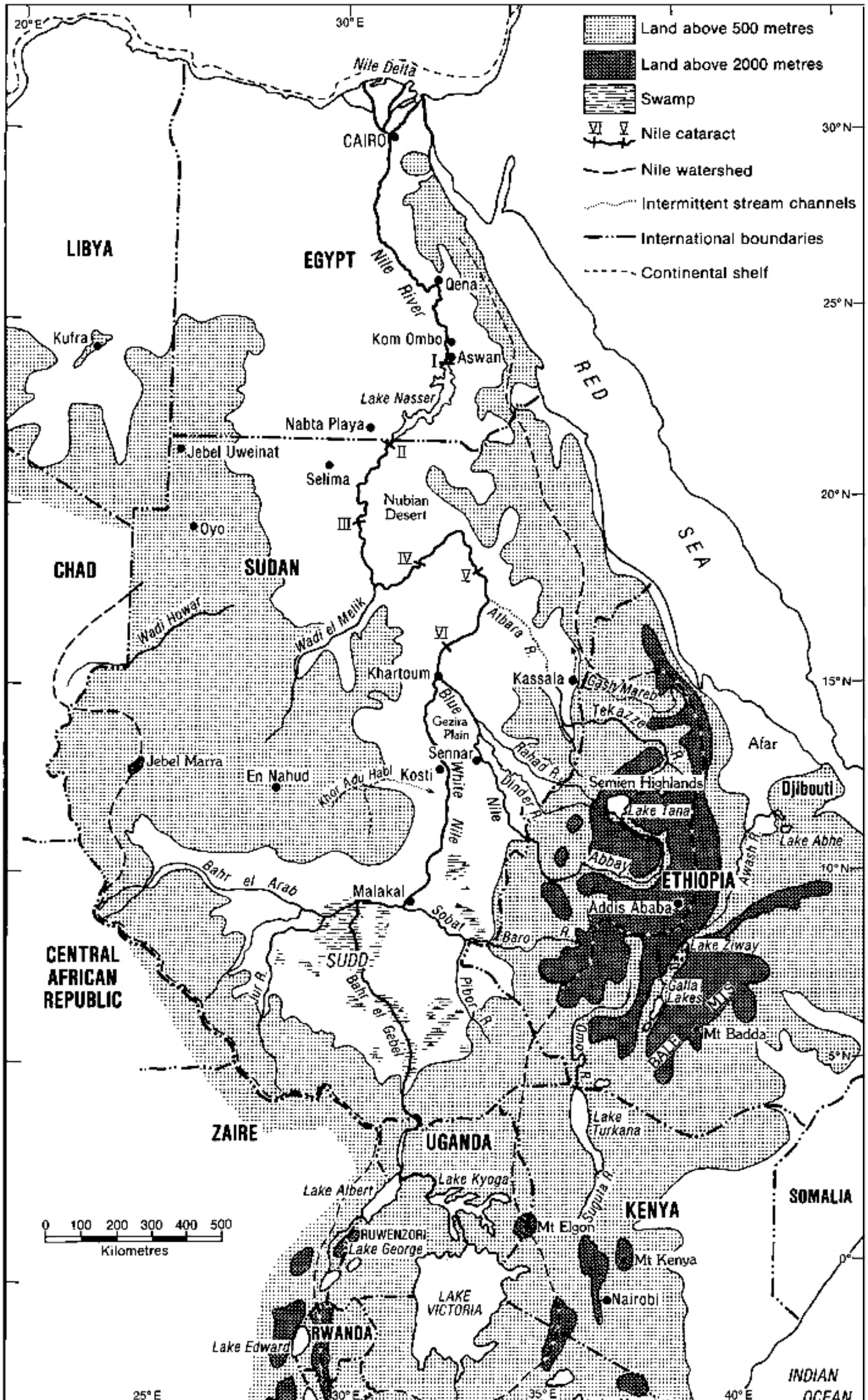


***Figure 1****. The Nile basin (Williams & Nottage, 2006).*

***Table 1****. List of locations appearing in the thesis to be used as a complement to the study area map.*

SHORT INTRODUCTION TO THE PLACES MENTIONED IN THE THESIS

- **Abydos:** A town located approx. 100 km north of Luxor. See *Figure 5*.
- **Badari:** An area of about 30 km stretching along the east bank of the Nile.
- **Bir Kiseiba:** Located approximately in between of Aswan and Gilf Kebir. One of the early settlement places with several early cultural developments (e.g. domestication of cattle) (Garcea, 2008).
- **Dakhla Oasis:** Located in the Western Desert, about 350 km from the Nile Valley.
- **Djara:** A cave located in the middle of the Western Desert. The surrounding area also called Djara is about 10 $km^2$.
- **El Kab:** An ancient settlement area, located across the Nile from the Hierakonpolis.
- **Farafra Oasis:** Located in the Libyan Desert, the Farafra Oasis has experienced several habitation phases (Garcea, 2008).
- **Fayum:** Located to the west of Nile Valley, south of Cairo. During the high Nile, there was a fresh water lake at Fayum.
- **Gebel Umm Hammad:** A 200 meters high hogback consisting of Limestone (Moeyerson *et al.*, 1999). With its valley, the Gebel Umm Hammad is more than 5 km wide and runs parallel to the Egyptian Red Sea coast.
- **Gilf Kebir:** Located in Egypt's Western Desert. An area of approx. 15 000 $km^2$ of extensive series of isolated flat-topped sandstone hills with near-vertical sides rising from 200 to 300 m above the surrounding plain (Wendorf *et al.*, 1976). The eastern side is cut by numerous deep wadis.
- **Great Sand Sea:** A desert region located in eastern Libya and western Egypt, stretching all the way to the Nile in the east. The Great Sand Sea has been called "the desert of all deserts" and has long dune chains (Besler, 2000)
- **Hierakonpolis:** An early center in the Upper Egypt. For the location, see *Figure 7*.
- **Khartoum:** Early settlement area, and the place where the White and Blue Nile join. For the location, see *Figure 1*.
- **Libyan desert**: The eastern Sahara of Libya, Egypt and Sudan (Kuper, 2006).
- **Memphis**: Capital of the first pharonic dynasty. See *Figure 5*.
- **Nabta Playa**: An area larger than 100 $km^2$, a deflation basin which is now filled with fossil dunes and clays. One of the early settlement places, Nabta Playa was almost continuously occupied. It is even said to have more organized cultural life than the Nile Valley. For the location, see *Figure 1*.
- **Nagada:** An early center in the Upper Egypt. For the location, see *Figure 5*.
- **Nubia:** An ancient region of southern Egypt and northern Sudan.
- **Saqqara:** Large burial ground of the town Memphis.
- **Shaheinab:** Located 60 km north of Khartoum.
- **Wadi Bakht:** Located in the southeastern margin of the Gilf Kebir.
- **Wadi Howar:** An active wadi in northern Sudan. It flowed into the Nile throughout the Early Holocene (Nicoll, 2004). For the location, see *Figure 1*.
- **Wadi (el) Melik:** An active wadi in northern Sudan. It flowed into the Nile throughout the Early Holocene (Nicoll, 2004). For the location, see *Figure 1*.
- **Wadi Soba:** Located about 22 km south from Khartoum, on the eastern side of Blue Nile. A settlement area e.g. during the Neolithic times.
- **Western Desert:** Eastern Sahara west of Nile.
- **West Nubian Palaeolake:** An ancient lake located in northwest Sudan.

## 1.4. Study method

### 1.4.1. Literature review

The thesis in hand is literature-based. Several studies on the subject have been reviewed, critically evaluated and compared.

Before the data search began, factors essential to be included to be able to study the subject in question were defined. These factors included for example migration, culture, trade, floods, precipitation, and vegetation change. Some other factors were left out from the beginning, for example changes in pottery styles, as they were considered to be too detailed either for the study question of change, or irrelevant for the causality analysis.

Research articles have been searched for in various science databases. Over 200 articles were browsed for selection, and those chosen for the study were selected based on their relevancy according to the chosen study limitations, (i.e. case studies concerning the Nile, Sudan or the surrounding Sahara, but not e.g. western Sahara, and some larger scale sources for basic information on e.g. monsoon pattern) and publishing date (no older than 1980s, preferably dating from 1990s or newer). Special emphasis was put on finding the newest research results available to be able to summarize and analyze today’s knowledge on the subject.

As the material accumulated, it was treated chronologically and placed on a timeline. Along this timeline, the data, i.e. the events found on climate and culture during the chosen time, were combined and compared for further analysis and conclusions. The thesis was then written based on the chronological timeline.

## 1.5. Theoretical approaches

### 1.5.1. Natural determinism

As this study deals with the causalities between environmental and social changes, it is appropriate to have a short discussion on the perspective of natural determinism. At one time in history, the relationship between the physical environment and the level of cultural human development was very intense (Oliver, 2005). In certain physical environments and climatic conditions it was easier for humans in their particular stage of socioeconomic and technical development to survive and multiply.

In some cases the relationship between humans and natural resources has been interpreted as deterministic. In this view, one factor (e.g. aridity) directly dominates over other aspects, and some players (e.g. humans) have been viewed as passive victims. It might be easy to explain social adaptations by natural determinism only, and draw a conclusion that natural phenomena of a region directly form the lives and lifestyles of its inhabitants, but one has to remember that there are usually many complicated causes and interactions acting on a social change. Adaptation strategies cannot be understood solely on the basis of environmental constraints (Bovin & Manger, 1990).

Both Di Lernia (2006) and Oliver (2005) stress the point that different people and cultural groups do not respond in the same way to the different climatic systems and changes they face. Even if the climatic changes have similar patterns, the social responses to these events can be different, with different paths and outcomes (Di Lernia, 2006). There are several aspects affecting the social change, for example conflicts, diseases, and interactions with other human groups (Bovin & Manger, 1990). One cannot forget that the inhabitants have never been completely isolated, not even if they live in the vast arid regions; nomads have moved, and there have often been networks of trade systems. Adaptation strategies can also be considered as a question of decision-making: people have had different interests and goals affecting the adaptation strategies, and people were in different strategical positions to reach their goals. Bovin and Manger (1990) suggest that one should look at adaptation as a process and focus on the mechanism of change.

So far it has been noted that as the habitat changes, the decisions people have to make result from many aspects of their lives. Further on, making the concept of change even more complicated, there are different levels and factors acting on changes. Factors causing change are often connected on causal chains. In these chains, different factors can intervene and connect even further variables to the change. Driving forces, or drivers as they are called in this study, are factors which - when applied - cause a change of state (Geist, 2006b). Drivers are not a simple concept either: they act on different levels, and it is important to distinguish not only the immediate agents of change but even underlying causes, i.e. the context in which agents of change operate (Geist, 2006b).

In summary, instead of focusing only on the environment as a driving force (i.e. natural determinism), it is necessary to remember that people under changing climate are not passive victims. Nonetheless, the environment certainly does have effect on social changes in certain regions and times, even though the relationship between humans and environment doesn't have to be – and shouldn't be viewed as - a simple cause-and-effect relationship. When analyzing the material for the recognition of drivers and responses, it is important to not over-simplify the situations.

Natural determinism has here been considered as a possible framework with the notion that the analysis of drivers and responses requires consideration, and the settings on which changes take place should be investigated as they are of great importance. Even if the skeleton of the study is the interaction between humans and environment, one cannot jump in to conclusions. The question "Can other reasons than environmental conditions have caused the change?" has to be kept in mind.

## 1.5.2. Political Ecology

Another perspective that can be named as the framework for analysis, and as the motivation for the chosen study time and area, is political ecology. Political ecology emphasizes the land use change to result from interactions between the society and the physical environment (Olson *et al.*, 2004). According to political ecology, these interactions occur at different scales and over time and space, and both environmental and social processes should be seen as active components of land use system.

Modern political ecology is increasingly stressing the importance of activism of people, situated knowledge and social movements as social aspects in change (Rocheleau, 2008). In the biophysical side (which in this study means environment including the climate), the important factors of change are ecology, the methods of science and complexity. What this means in practice is that the political ecologists are increasingly explaining the movements[1] as themselves: what are they about. When describing social movements, one has to recognize multiple factors, identities and rising cultural politics to be able to acknowledge the conflicts and differences between and inside the different groups of people.

In the biophysics, scientific methods are used increasingly for example by mapping the resources, and by defining the territories as sites of control over space, material resources and environmental conditions (Rocheleau, 2008). Complexity in political ecology refers to changing the focus from the linear causality chains to the complex webs of relations. According to Rocheleau (2008), the complexity is embraced, but "*without losing the explanatory power of structural relationships*". Both social and environmental changes are included in these networks, and scientific methods are indeed increasingly used to describe them.

Conflicts and differences between people bring us to the term of resistance. In political ecology, both direct and indirect resistance must be included in analysis (Rocheleau, 2008). Movements include resistance to environmental degradation or displacement, struggles with powerful individuals, hostile states or/and corporations for control of existing land and resources, and defense of existing land and resources.

Last, the political ecology approach emphasizes that the interactions should not be considered only over time but also in space: events in one area may affect other areas, e.g. migration and competition (Olson, *et al*., 2004). Historical time frame should be used to understand the current pattern between society and environment. There are different temporal characteristic for different processes: short-term, long-term, and some of sudden change.

What does the approach of political ecology mean to the study in hand? This thesis views the change in climate and culture both in time and space. The study area includes even the neighboring areas in search of change, and the time scale is viewed both for short-term and long-term changes. The changes in the physical environmental are measured scientifically in for example pollen, sediments, maps, and Nilometer readings,

[1] Rocheleau is referring to the movement as social movement, organizations and NGOs, but movement can also be seen as a group of people seeking alternative futures.

and the ecological communities of today are used to imagine the former landscapes of the Sahara.

In contrast to natural determinism, the modern political ecology emphasizes the activity of people. They have situated knowledge, and reaching for alternative future can group people together for a social movement with its very own identity. Grouping of people often gives birth to conflicts: people may respond to changes with resistance or with defense over their local natural resources. People in Egypt and Sahara did not only face the changes in environment, but even each others. Experiencing the change in natural resources also meant experiencing and creating one’s own identity and culture, for example in the form of pyramids.

# 2. GEOGRAPHICAL SETTING

In the chapter of theoretical framework it was pointed out that when looking for possible drivers for changes, it is necessary to be aware of the context in which agents of change operate. Also, the changes should be described as webs of relations instead of linear causalities. For these reasons, the study begins by describing the geographical settings of the climate and cultural changes, as the detailed description of the conditions in the study area is considered important for further analysis.

It is not difficult to understand the importance of the Nile to the ancient and modern Egyptians. In Nile, the water flows through the extremely arid regions of Egypt (See *Figure 2*), and makes life possible in the latitude where Earth's most hostile deserts are located. The floods have both extremely positive and negative effects on Egyptians. In ancient Egypt, society relied upon the Nile, as it was the sole source of water and soil fertility (Gawad, 2007).

## *2.1. The River Nile*

The Nile, one of the longest rivers on the Earth, flows some 6 671 kilometers through the parts of nine countries, and eventually flows into the Mediterranean Sea (Whittington & Guariso, 1983). The water originates from two main sources: The Ethiopian highlands and The Equatorial Plateau (Hassan, 2007). *Figure 1* of the study area can be reviewed throughout the following discussion, as it shows the river basin and the locations mentioned in the following text, as well as *Figure 2* for aridity zones. Nile's catchment area absorbs and channels all runoff from rainfall, and thus forms a system integrating the hydrological, ecological and socioeconomical components of the river basin (Geist, 2006a.). This way the catchment area supplies the resources for the area and regulates the environment.

The Ethiopian tributaries include the Blue Nile and the Atbara (Hassan, 2007). The Blue Nile originates from Lake Tana in Ethiopia, but only about 7% of the water flow of the Blue Nile comes from Lake Tana itself (Whittington & Guariso, 1983). As the Blue Nile flows through the Ethiopian mountains, it continually picks up water from several small tributaries and from its two main tributaries, the Rahad and Dinder Rivers (Whittington & Guariso, 1983).

The water in the White Nile originates from Lake Victoria and other equatorial lakes: from an area of heavy rainfall (See *Figure 2*) (Whittington & Guariso, 1983). The equatorial catchment area includes Kenya, Uganda, Rwanda, Burundi, Central African Republic and the Democratic Republic of Congo (Hassan, 2007). The White Nile also receives water of the River Sobat from the Ethiopian mountains (Whittington & Guariso, 1983).

The two rivers, White and Blue Nile, meet in Khartoum (Whittington & Guariso, 1983). The Blue Nile provides about 86%[2] of the annual flow of the main Nile. The long-term average annual flow of the Nile is 84 x $10^9$ $m^3$ (Omar, 2008).

The Nile does not only transfer water. It is also an important carrier of sediments. The sediments are deposited in low energy situations as, for example, in the delta region where it has built new land. The sediment deposition has provided fertile silt and clay for agricultural production (Sterling, 1999). The main source of nutrients for the farmland along the Nile - before the construction of Aswan Dam - was sediment deposition from seasonal flooding (Gawad, 2007). During the seasonal flooding, the sediment deposition increased, causing the farmland to be more fertile. Klemm and Klemm (2001) state that Egypt received its legendary reputation as “the land of milk and honey” thanks to the Nile as it was an excellent and everlasting source of fertilizers and water used by the agriculture. The Nile, therefore, determined of the resource availability for the inhabitants of the Nile Valley and Delta.

## *2.2. Climate in the Nile basin*

*Figure 2* presents the aridity zones of Africa. The Nile’s location in Africa can in this map be seen in relation to continent’s hydrological resources. Nile’s outstanding length and its location in North Africa makes Nile basin very interesting climatically. The variation on climate is huge.

The *Figure 2* shows the humid conditions of the source areas for the Nile’s water. On the opposite, north of Khartoum the rainfall is for the most part insignificant to Nile’s flow (Whittington & Guariso, 1983). For almost half of its length, 3087 km from Khartoum to the Mediterranean, the Nile flows through the extreme deserts of northern Sudan and Egypt. As the river flows northward, the rainfall decreases steadily. It shifts from the 1800 mm/yr by the Lake Victoria to less than 25 mm/yr in Egypt and predominantly arid Sudan.

[2] Because of the annual variation in water flow, the White Nile may contribute more than 75% of the main Nile’s total discharge by the Aswan during early summer, but, on the other hand, during the peak period of August, the White Nile may contribute only 6% of its discharge at Aswan (Whittington & Guariso, 1983). This way, the White Nile dampens the extreme fluctuations on the discharge of Blue Nile, and even provides Egypt with the majority of its summer water.

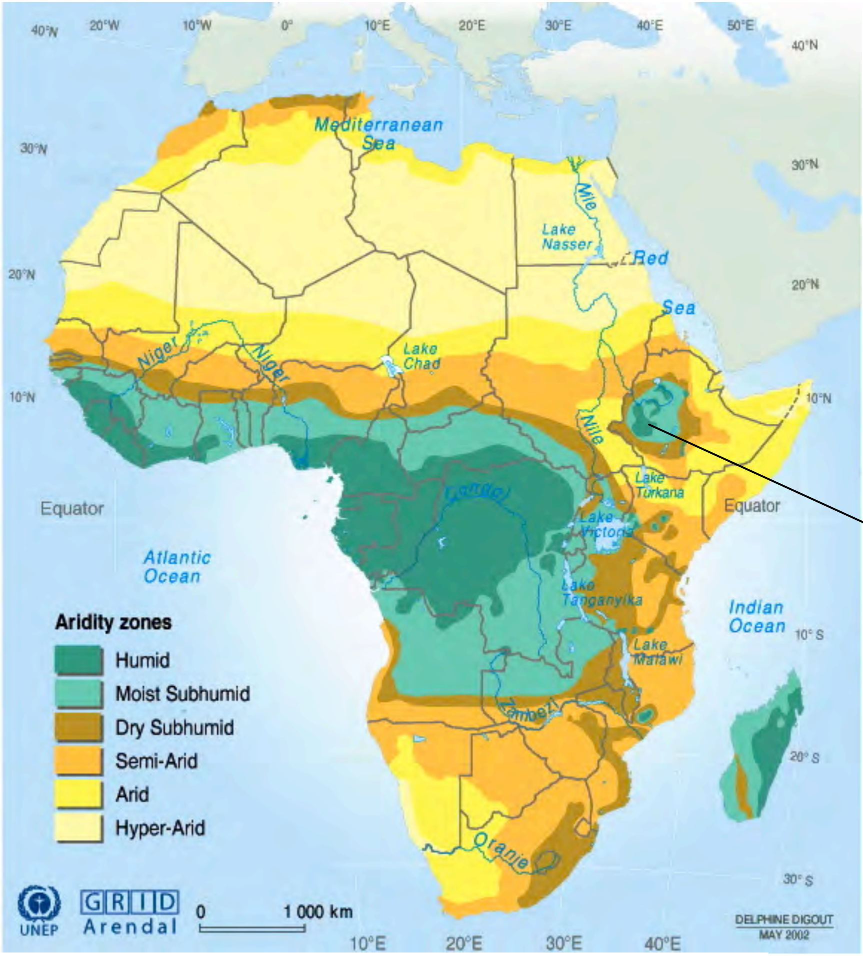


***Figure 2***. *Present aridity zones in Africa (WMO & UNEP, 2001).*

The Nile basin in the region of Egypt and Sudan can be divided in to two different climate types using Köppen's climate classification (Rudloff, 1981). Köppen's description of the dry and hot climate in the desert can be seen in the right hand column of *Table 2.* This study mostly concentrates on the inland area of the river basin, i.e. the right hand side of the table. Considering the information shown in the table, it becomes clear how significant Nile is for Egypt with its rare rains, very hot summers and desert environment. Without external water source, in this case in the form of river running through the area, the area would be mostly waterless.

***Table 2**. Two different climatic regions of Egypt according to Köppen's climatic classification (Rudloff, 1981)*

| | **Egyptian Mediterranean coast** | **Inland Egypt** |
|---|---|---|
| **Description of climate** | Steppe climate BS | Desert climate BW and desert mountain climate GBW. Coastal areas: marine desert climate BM. |
| **General heat conditions** | Summer hot, winter mild | Summer predominantly very hot, winter mild. |
| **Predominant form of general weather** | Generally dry and sunny, in winter frequent days with showers or rain. | Dry and sunny, rarely rain. |
| **Special weather phenomena** | Wind: occasional gales and dust storms. | Wind: occasional gales and dust-storms. |

### 2.2.1. Airstreams and precipitation

The climate in the study area is governed by several different climatic regimes. Dry continental air arrives from the Sahara, Arabian Peninsula and from the south as northeast monsoon (Buckle, 1996). In contrast, tropical maritime air from the Atlantic and south Indian Oceans bring precipitation to the source areas of the Nile as southeast monsoon. The movement of the Intertropical Convergence Zone (ITCZ) and the presence of the African monsoon system cause seasonality, which outcome is the rain season in Ethiopian highlands. Also, the northern part of the study area is located on the coast of the Mediterranean, affected by the coastal climate and Mediterranean front. On the most eastern part of the study area, airstreams even meet in the Red Sea convergence zone.

There are two sources for the dry continental air affecting the study area. Being a great desert, Sahara is the main source region of tropical continental air for Egypt. Located on global high-pressure cells, the air is dry, hot and very stable (Buckle, 1996). The upper air high-pressure limits cloud development and precipitation; because of the extremely low humidity, only dust storms are possible here. Another source of continental air is the African monsoon[3] system. From December to March, eastern Africa experiences the season of northeast monsoon. The map showing the dominating airstreams for January in *Figure 3* shows how the dry air of northeast monsoon affecting the study area comes from the dry deserts (Sahara and the Arabian Peninsula).

[3] When talking about African monsoons, it is worth noticing that the term *monsoon* is not accurate for the "monsoons" experienced in East Africa (Buckle, 1996). In East Africa, these seasonal airflows are not directly related to differential heating and cooling of continent and ocean. They are nevertheless part of the western edge of the Asian monsoon. In this thesis, however, they are generally referred as (African) monsoons, as this concept is widely used in the scientific papers on the subject, even if the term meteorologically would not be accurate.

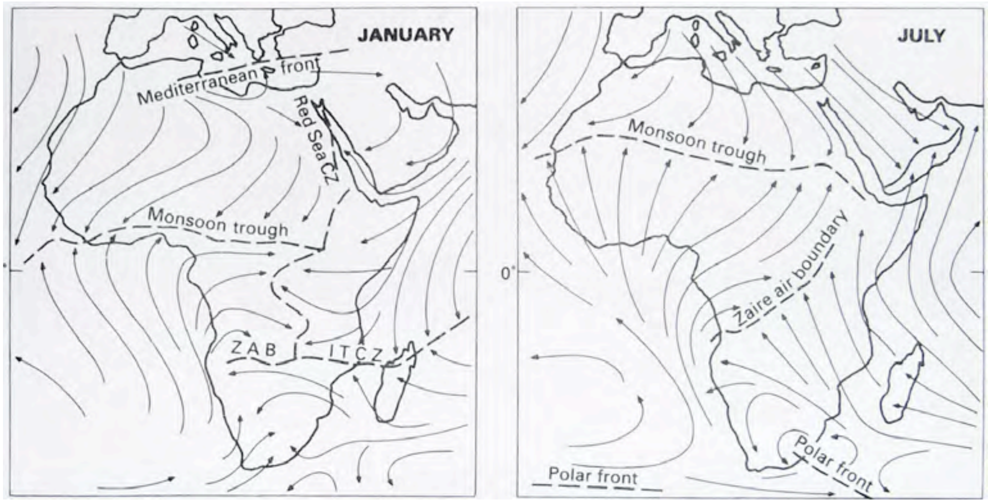

***Figure 3***. *Africa's major airstreams and air boundaries in January and July (Buckle, 1996).*

Rain is brought to Africa by tropical maritime air (Buckle, 1996). The source areas for the tropical maritime air are the subtropical highs of the Atlantic and south Indian Oceans. As the maritime air of the Atlantic nears the equator, it collects more and more moisture and is gradually transformed into the moist equatorial air of the ITCZ.

In July the mean position of the ITCZ lies a bit north of the equator. Seasonally it follows the path of the sun and the seasonal expansion and contraction of the subtropical highs (Buckle, 1996). The belt of maximum precipitation, the movement of ITCZ, roughly follows the movement of the sun overhead with the lag of four to six weeks. Over northern Africa, ITCZ's position and annual fluctuations are more influential than in southern Africa; this phenomenon is marked in the *Figure 3* as Monsoon trough.

As earlier outlined, most of the Nile's water originates from the Ethiopian highlands. This area experiences one main rain season: from late June to early October (Buckle, 1996). In July, the ITCZ Monsoon trough is located over the southern border of the Sahara bringing with it precipitation (Rudloff, 1981). During this season, the moist southwesterly and southern air moves north across Ethiopia (*Figure 3*). Varying in the amount of precipitation, these air masses bring rain to different parts of Africa and are known as the southeast monsoon (Monsoon trough). During the dry season, air flows to the Ethiopian highlands from the Saharan and Arabian areas (Northeast monsoon). Some small rains develop even during the dry season.

To put it short, seasonal precipitation in the study area is governed by the African monsoon. Looking at the whole African continent in summer, as seen in *Figure 3*, wind blows inland from the cooler oceans toward the warm continents, and to the opposite directions in winter (Oliver, 2005). Therefore the summer monsoons are wet and winter monsoons dry; the most important manifestation of the monsoon circulation is indeed the seasonal rainfall, although not as remarkable as for Asian monsoon. According to Buckle (1996), the precipitation brought by monsoon is not, in today's climatic circulation system, striking to the precipitation pattern of the study area. Oliver (2005), however, and the authors of most studies reviewed for this study, argue that it indeed is the monsoon winds that bring the precipitation to the Ethiopian highlands.

There have been variations in the strength of the monsoon, as will be often referred in this study. Monsoons experience different irregular phases (onset, active period, withdrawal, breaks), which cause variation in the timing of onset and withdrawal, duration and intensity of precipitation (Oliver, 2005). The past seasonal pattern of monsoon precipitation in the Ethiopian highlands can be seen in the consequent Nile floods. There have been, and still are, shifts in the monsoonal systems with consequent effects on the affected region's precipitation and, further on, on Nile's flow.

Two smaller air boundaries affecting the climate of the study area are the Mediterranean front and the Red Sea convergence zone (see *Figure 3*). The Mediterranean front forms during the northern hemisphere winter (Buckle, 1996). It is a boundary formed when the maritime air warmed over the Mediterranean meets the hot dry Saharan air. Comparing the location of the front to climate presented on *Figure 3*, the effect of the Mediterranean front can be seen in the different climate on the northern part of the study area, the Mediterranean coast (left hand side in *Figure 3*). Even the coastal location affects the climate. The Red Sea Convergence Zone affects the coastal parts of the Red Sea and Ethiopian highlands, but the effect is not remarkable enough to be included in this study.

## *2.3. Nile floods*

A flood is a period of high flow in the Nile occurring during the late summer and fall (Whittington & Guariso, 1983). The Nile has two peaks each year (Oliver, 2005). The high summer peak reflects the northern hemisphere summer monsoonal rains in Ethiopia. The water travels down the Blue Nile and the Atbara in the early summer, and arrives in Egypt during mid-July, August, September and October (Whittington & Guariso, 1983). Water level reaches its peak by the middle of the August, and the Nile level remains stationary for about three weeks (Hassan, 2007). The floodwater level may rise as much as seven meters from May to September. By the end of October the water begins to subside and the Nile has sunk to its lowest level by May. The winter low peak reflects the equatorial rains in East-Africa and the overflow of Lake Victoria (Oliver, 2005).

The knowledge of the water levels has been of crucial importance for the ancient Egyptians, and they invented a gauge to measure and record the floods: the so-called Nilometer in Roda. The Nilometer was used between the AD 7$^{th}$ and the 15$^{th}$ centuries to annually record the fluctuating levels of the Nile (Fein & Stephens, 1987). The water level was gauged twice a year in connection with the peak flood and the winter low. The Roda Nilometer has a record of 1300 years.

Major droughts or severe floods can at their worst have catastrophic effects on human societies (Williams & Nottage, 2006). Unusually high or long floods had negative impacts: plant parasites, water-logged fields delaying planting, inundated settlements, demolished flood-control devices and promoted epidemic diseases (Sterling, 1999; Williams & Nottage, 2006). In events of low or no floods, people died of starvation (Williams & Nottage, 2006). Low or short floods also generated a smaller amount of silt and clay, decreasing the agricultural productivity (Sterling, 1999). *Figure 4* shows the so-called real world interpretations of the Nile floods. In this figure, the river levels are presented as cubic meters from 12 to 18. As the exact measure of cubic meters has varied through time, they are not used in this study as a definition, but this figure is still worth observing, as it highlights the direct relationship between Egyptian life and the river Nile.

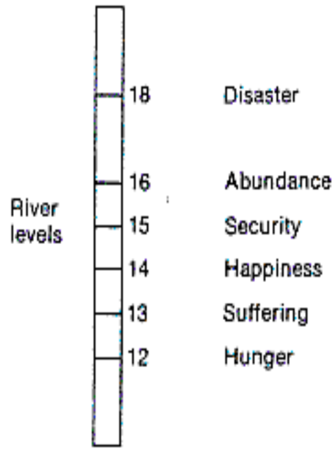


***Figure 4****. The so-called real world interpretation of the Nilometer readings (Hansen, 2008).*

As *Figure 4* shows, the fluctuations of Nile levels had extreme consequences on both ends: a change of two cubic meters from 14 to 12 meant famine, and an increase of three cubic meters from the level of “security” meant disaster. It can be concluded that the Nile was at its best for Egyptians when it was stable, but as soon as the floods got too high or low, the balance of life was severely disturbed. This remarkable effect of flood fluctuations on the society can be seen, in more detail, in *Table 3*, which compares Nile levels to social incidents for about 600 years period.

# 3. LITERATURE REVIEW

In this chapter, the results of the literature review are dealt with in periods of 500 years for the sake of chronological clarity. The following chapter is a description of cultural and environmental changes taking place during the time period covered by this study, presenting the case studies, which together form a common image of the conditions in the study area. A short summary of the most important events is presented in the beginning of the each 500-year period. In the following chapter, the main changes are discussed and analyzed more qualitatively.

All the years below are approximations and they have been rounded off to the nearest hundred for practical reasons. The division to Early, Middle and Late Holocene is based on the same division as in the study of Kuper and Kröpelin (2006). Even if the Early Holocene started earlier, the review here begins from the year 8500 BC.

## *3.1. Early Holocene 8500 – 7000 BC*

### 3.1.1. 8500 BC: Green Sahara supporting humans and fauna, Nile Valley probably uninhabited

*During the first period of the studied time scale, the Sahara turned from being a hyperarid desert to a savannah-like environment, where wildlife and humans were able to live, and where rivers and lakes formed. The Nile valley, on the contrary, was inhospitable to humans.*

In the beginning of the Early Holocene, the Sahara went from being a hyperarid desert to a savannah-type vegetation (Brooks, 2006). In 8500 BC, the onset of semi-arid conditions in the north, and semi-humid conditions in the south, has been found in the geological and archeological archives of the Eastern Sahara (Kuper & Kröpelin, 2006). The climate was monsoon-controlled with short but violent summer rains, and because of the monsoonal rains, the desert margin shifted up to 800 km north to latitude 24°N within only a few centuries. The region, today covered by desert, was well vegetated (Brooks, 2006)! Lakes and temporary rivers were formed because of rising water tables (Nicoll, 2004; Kuper & Kröpelin, 2006).

The change made Sahara able to support faunal and human populations (Brooks, 2006). As the environmental conditions strikingly improved, the spread of wild fauna was rapid and there was a swift occupation of the entire Eastern Sahara by prehistoric populations (Kuper & Kröpelin, 2006).

From where these first people arrived is unclear: Nile dwellers might have left the inhospitable swampy (Nile) valley, or groups from the south, already adapted to savannah ecology, might have followed their traditional way of life (Kuper & Kröpelin, 2006). People were hunter-gatherers, who in certain regions probably already practiced some animal husbandry. As already mentioned, the occupation of the eastern Sahara at this time must have proceeded rather quickly up to the far northwest of Egypt, since settlement is occurring in the central Great Sand Sea already before 8000 BC. The Libyan Desert was occupied during 8500 – 7000 BC (Kuper, 2006).

During this time period there is almost a complete lack of evidence for any occupation of the Egyptian Nile valley. Only the site of El Kab shows evidence for the presence of people during this time (Kuper & Kröpelin, 2006). It is not known whether this pattern reflects a historical reality caused by unsafe living conditions in the swampy valley, or whether it is because sites are undetectable under several meters of river sediments.

### 3.1.2. 8400 – 8000 BC: The Nile Valley as a wooded steppe

*During the second oldest time period, the case studies show that the monsoon rains were heavier than today and even the Great Sand Sea, nowadays called the desert of all the deserts, was probably vegetated. People living in the study region were pastoralists and at Khartoum, the Early Khartoum Tradition flourished.*

Evidence from Gilf Kebir suggests that from 8400 to 4400 BC, the climate was arid with rare heavy rainfalls (on an average four events per 100 years) (Linstädter & Kröpelin, 2004). The monsoonal summer rains can be considered significant, since they enabled the beginning of soil formation and sparse plant growth in areas around the temporary rain pools in Gilf Kebir.

There are many findings supporting the vegetated conditions. The Great Sand Sea may have supported a grass cover during the moist conditions of the Early – Middle Holocene (Nicoll, 2004). Possible evidence for local pastoralism has been found within its southern part. Even the Nile valley immediately north of Khartoum was probably covered in wooded steppe around and after 8000 BC (Williams & Nottage, 2006). Olago (2001) also suggests that there was a maximum expression of vegetation adapted to humid conditions between 8000 - 6000 BC, further underpinning the availability of moisture.

As well as in the findings of the Great Sand Sea, some of the art scenes found in Sahara from this time picture humans as pastoralists with herds of cattle and carnivores (Nicoll, 2004; Olago, 2001). Excavations have yielded evidence of stone-built “house” structures, and it has been shown that Saharan people intensively exploited local food cereals (Nicoll, 2004).

Dated 8000 - 4900 BC, The Early Khartoum Tradition[4], a highly successful food-gathering lifestyle, flourished in Khartoum (Krzyzaniak, 1991; Williams & Nottage, 2006). It spread on the Early Holocene savannah to the north of the tropical rainforests (Krzyzaniak, 1991). The Early Khartoum Tradition specialized in the exploitation of water-side resources by fishing, hunting and collecting mollusks and plants (sometimes referred to as "*African aqualithic*"). At 8000 BC, the Neolithic period started.

[4] *Early Khartoum* is a Mesolithic culture with some bone and stone workings.

### 3.1.3. 7900 – 7500 BC: Semi-aridity

*During the last 500 years of the 8$^{th}$ millennium, the conditions stayed humid.*

During the Early to Middle Holocene, Sahara was continually characterized by numerous water bodies (Brooks, 2006). It still supported an abundant humid-climate flora and fauna and significant human populations. The rainfall was probably at least 500 mm/year, probably even higher during the time when the Early Khartoum tradition flourished. Farther south in Sudan, there were actually swampy conditions with crocodiles (Nicoll, 2004).

Conditions were humid also in Nabta Playa and at various locations in the Great Sand Sea (Nicoll, 2004). There were several wadis, and in some locations, springs and artesian-fed lakes existed.

### 3.1.4. 7400 – 7000 BC: Semi-arid to arid environment

*The first half of the millennium of 7000 BC marked the start of the change to aridity. The precipitation was still higher than today's. There were lakes, wadis, tributaries to Nile, and the bones from great fauna indicate the presence of tree vegetation. The landscape of Eastern Sahara consisted of a mosaic of different vegetations.*

The change had started in the Middle Holocene, around 7000 BC: the general environment was semi-arid across southern Egypt and northern Sudan (Nicoll, 2004). There were seasonal grassy plains, shrubs and trees especially around wadis, lakes and springs, but now the pattern of surface water storage, vegetation and fauna started to show a gradient of decreasing moisture from south to north, and rainfall isohyets actually shifted northward.

The surface waters attracted wildlife and people (Nicoll, 2004). Identified fauna from e.g. the Great Sand Sea area are hare, gazelle, rodents and some carnivores. Other findings in rock art and sediments in Sahara include e.g. elephant, lion, and giraffe. The distribution of giraffe bones along the Egypt-Sudan border implies that the sufficient tree vegetation was at least occasionally present. With other words, Sahara was still able to support a great fauna!

In northern Sudan, lake sediments and pollen records have permitted detailed reconstructions of the paleoenviroment for the Early Middle Holocene (Nicoll, 2004). This reconstruction reveals a zonation of vegetation from wooded savannahs to sparsely vegetated steppes in a 500 km wide belt in northwest Sudan. Farther south, there were rain-fed lakes and an Acacia-tall grass community west of Khartoum. Nicoll (2004) points out that this Acacia-tall grass community west of Khartoum must have required twice the amount of present rainfall. In the Eastern Sahara during the Middle Holocene, the savannah and sahelian shrub vegetation seem to have formed mosaics in the landscape in a way that is not seen today (Mercuri, 2008). According to these two sources, the study region included more environmental variations in the form of "mosaics" than it does today.

Hydrologically, Wadi Howar and Wali Melik were active in northern Sudan and flowed into the Nile throughout the Early Holocene (Nicoll, 2004). Nile's discharge had increased and there was a Nile-controlled lake close to Fayum. The White Nile had floods about 3 meters above the modern maximum flood stage. The humid conditions along the Nile caused depositions of silts, mud and gravels. Nicoll (2004) points out that this Acacia-tall grass community west of Khartoum must have required twice the amount of present rainfall.

## *3.2. Middle Holocene 7000 - 3500 BC*

### 3.2.1. 6900 – 6500 BC: Well established human settlement in Libyan Desert

*The precipitation in some places came periodically, instead of falling continuously, during this 500-year period. Humans were well established all over the Libyan Desert, and social changes include changes in economy and technology, and according to some sources, introduction of domesticated livestock.*

A more humid period at Gebel Umm Hammad took place during the transition from the 7th to the 8th millennium, but Moeyersons *et al.* (1999) point out that there is no evidence for a permanent wet and green environment in the area, only of periodic floods. Wadi sediments at Gebel Umm Hammad show that extremely heavy rainstorms occurred at this time. The high water stages indicated by the stratigraphy of the area can only represent individual flash floods and not seasonal or permanent rain situations.

After 7000 BC, human settlement became well established all over the Libyan Desert (Kuper, 2006). There had been economical and technological adaptation to the local ecological requirements. In the northern Libyan Desert there was a complete change in the stone tool kit, that can be followed up into the later Predynastic cultures of the Nile valley.

Another cultural change at this time was the first appearance of domesticated livestock (Kuper, 2006). Cattle might have been domesticated locally but the precise timing of the introduction of domesticated animals is uncertain.

### 3.2.2. 6400 – 6000 BC: High Nile floods

*Humid conditions caused high Nile floods.*

The archeological excavations at Khartoum and its surroundings have revealed that the Nile flood levels were very much higher than today, causing at least 10 m of channel incision over the last 8000 years (Williams & Nottage, 2006). The reason for flooding could certainly be the fact that the Blue Nile area experienced humid conditions (Lario *et al.*, 1997). The fauna from these early to middle Holocene archeological sites is consistent with swampier conditions, also referring to the humid conditions.

According to some sources, the time when tame animals initially appear in the Egyptian archeological record was between 6000 and 5000 BC (Sterling, 1999; Garcea, 2008). According to both Kuper (2006) and Garcea (2008), domestic caprines were originally introduced from the Near East to North Africa.

### 3.2.3. 5900 – 5500 BC: Decrease in humidity, Predynastic period begins

*The second half of the 5000 years BC was characterized by the beginning of the end of the humid period as shown in several case studies. People started to abandon the drying places and it seems that many people moved from the Sahara to the Nile valley. Small independent agricultural villages in the Nile valley developed.*

The evidence of humid conditions during this time period increases: at Gilf Kebir the joint occurrence of plant species (e.g. *Tamarix articulata*, *Ziziphus mauritiana* and *Maerua crassifolia)* indicate wet conditions around 5800 BC (Linstädter & Kröpelin, 2004). However, at the same time, the evidence of the humid period coming to its end is found elsewhere: Brooks (2006) notes the start of drying of the northernmost rainwater-fed playas in Egypt in 5800 BC, and Di Lernia (2006) notes a dramatic decrease in the rainfall in 5500 BC. Between 6100 and 5100 BC, a drop in the flooding levels of the Nile records a reduction of humidity, although there is still evidence for some seasonal floods (Lario *et al.*, 1997). In addition, the decrease in the humidity was shown in the diminishing lakes (Pachur and Hoelzmann, 2000; Linstädter & Kröpelin, 2004).

The spread of settlements developed under the "Mesolithic Optimum" i.e. the optimum climatic conditions (Lario *et al.*, 1997). The settlements were widespread along the Wadi Soba area and the Nile riverside, where the seasonal floods probably were unable to reach. A comparison between the distribution of human settlement around 6000 and 4000 BC suggests that an exodus from Sahara coincides with the rise of the first settled communities in the Nile Valley during the Predynastic Period (Kuper, 2006).

The Predynastic Period took place between 5500 and 3100 BC. This was a critical time for the development of social and political complexity in Egypt (Savage, 1997). At the beginning of the period, the Nile valley was dotted with small, independent agricultural villages that followed essentially a Neolithic type of agricultural economy.

### 3.2.4. 5400 – 5000 BC: Multiresource pastoralism, cattle burials and the termination of monsoon rains

*As the regular monsoon rains decreases, the aridification developed further. People moved to refugia, and migration and regionalization caused humans not only to make lifestyle changes by moving to another environment, but they even went through adaptations to the new environment, for example in the form of adapting multiresource pastoralism.*

No later than 5300 BC, the regular monsoon rains had ceased to reach the Egyptian Sahara (Kuper & Kröpelin, 2006). Effective moisture conditions in northern Sudan and southern Egypt waned (Nicoll, 2004). This happened to different degrees in different locations. As aridity set in, vegetation decreased and aeolian sands were mobilized in the lack of vegetation. After the Middle Holocene, the aridification progressed rapidly over much of the region. Fauna and flora were either destroyed or were pushed into certain areas. Similar phenomena are suggested to have happened in northern Sudan and the Great Sand Sea. Tributaries of the Nile stopped flowing. Wadi Melik became dry.

Most rainwater-fed playas in Egypt became less extensive after about 5000 BC (Brooks, 2006). There was an arid period in 5100 - 3700 BC, and throughout the whole 5th millennium BC, numerous hydrological indicators point to progressive desiccation in Egypt. However, the Nile still seems to have been under a wetter regime, e.g. Sterling (1999) states that from 5000 to 3700 BC Nile floods were high. Also Williams and Nottage (2006) state that the archeological excavations at Khartoum and its surroundings revealed the early Holocene Nile flood levels to have been very much higher than today.

Because of the increasing aridity, humans who were settled in the vast plains of the Egyptian Eastern Sahara, moved to the oasis depressions of for example Dakhla and Farafra, to the Nile, or to Gilf Kebir during the millennia of 5000 and 4000 BC (Linstädter & Kröpelin, 2004). After the onset of the actual arid phase about 5000 BC, the Saharan cattle keepers gradually migrated towards the Nile (Kuper, 2006). This process of migration may have lasted 1000 years (Kuper, 2006).

A significant decline of data in the core desert of the Great Sand Sea indicates a break of settlement in 5300 BC (Kuper, 2006; Kuper & Kröpelin, 2006). The retreat took place from the desertificating regions into areas with permanent water and sufficient rainfall (to the ecological niches like for example the Gilf Kebir Plateau or to the plains further south) (Kuper, 2006). For example, the dates of findings at Djara with those of Fayum and Dakhla oasis support the supposed migration and its direction (Kuper & Kröpelin, 2006). Large savannah animals and humans were able to migrate along the palaeodrainages into the lowlands, which became hunting grounds and were suitable for cattle herding between 5500 and 1700 BC (Pachur & Hoelzmann, 2000).

There are only a few archeological findings beyond the year 5300 BC belonging to the sites relatively close to permanent water (Kuper & Kröpelin, 2006). This might reflect episodic visits by small stock herders from the Nile valley, or it might result from occasional grazing from the oases region (Kuper, 2006).

The regionalization caused by the migration fostered more regional cultural development (Kuper, 2006). The first Neolithic groups, starting with fully developed agriculture in Fayum and Merimde around 5000 BC, with wheat and barley as the economic base, are clearly rooted in the Near-Eastern Neolithic (Kuper, 2006; Kuper & Kröpelin, 2006). By migrating to Egypt, the Saharan cattle keepers contributed their cultural heritage to Predynastic Egypt and Saharan traditions of cattle pastoralism became an essential component of Neolithic life in the Nile valley (Kuper & Kröpelin, 2006). Essential social and cognitive aspects can be traced back to Saharan cattle herders and their spiritual heritage. The pattern of the settlements of the earliest agriculture in the Nile valley indicates the presence of African livestock enclosures and of a rather mobile existence.

Garcea (2008) notes the first of three main occupation phases in the Farafra Oasis during 5700 - 5300 BC. At Nabta Playa and Bir Kiseiba, between 6100 and 5400 BC, a new economy of intensive plant collection started to exist. Archeological findings suggest intensive exploitation and preservation of fruits, tubers and seeds. In 5300 BC, multiresource pastoralism appears to have become the vital human subsistence strategy in the Egyptian Sahara, while at the same time, the first farming communities developed in Fayum (Kuper & Kröpelin, 2006). Pastoralism became the predominant subsistence base in the Eastern Sahara and was extended to caprine herding at 5200 - 4700 BC (Garcea, 2008). According to Hassan (2008), agriculture was introduced to Egypt in 5000 BC.

There was also a rise of specialized cattle pastoralism. Cow burials already existed among cattle keepers of the Eastern Sahara before 5000 BC (Hassan, 2008).

### 3.2.5. 4900 – 4500 BC: Increased aridity and mobility

*The next 500-year period faced the change to further aridity, and people followed the water if it was not available on their habitats.*

The years 4900 to 4500 BC were generally characterized by climatic instability in Sahara (Linstädter & Kröpelin, 2004). From 4800 to 3800 BC in Gilf Kebir, the arid conditions tended toward moderate aridity (Linstädter & Kröpelin, 2004). The climate can be defined as a West-wind induced climatic type with occasional, yet steady winter rainfall.

Where were people living in this environment of increasing aridity? In the far east of the Sahara, the pastoral groups followed localized rainfall from the end of the 4000 BC, and congregated in highland areas and areas around shrinking water bodies (Brooks, 2006). During the 5$^{th}$ millennium BC, the level of West Nubia Palaeolake was declining, and the settlements increased on the lower ground of the fringes of the lake with the retreating shorelines. In spite of the increasing aridity, in Gilf Kebir, the upper reaches of the wadis still supplied people with adequate water as a result of increased seasonal or episodic rainfall accumulating behind the dunes, which hydrologically blocked the valleys Gilf Kebir (Linstädter & Kröpelin, 2004). This was actually the apparent main phase of Neolithic settlement in the wadis of Gilf Kebir. 4800 BC was the time of the second of the three main occupation phases at Farafra (Garcea, 2008).

### 3.2.6. 4400 – 4000 BC: Spread of cattle cult, food-producing communities on the Nile, environment turning hostile

*The period of 4400 – 4000 BC meant increasing aridity, and humans abandoned several locations. Pastoralism was switched for agriculture, and small agricultural communities were born in the Nile valley. Cattle cult was spreading in Sahara.*

The aridity increased. In 4400 to 4100 BC there was an arid spell with patchy distribution and length (Di Lernia, 2006). Generally, the landscape became progressively more arid and inhospitable (Nicoll, 2004). As has been noticed, the desert regions surrounding the Nile Valley and the Delta had started to go through the transition from wetter conditions already before 4200 BC (Hassan, 2008). In 4000 BC full desert conditions were evident in southern Egypt except for some oases and wadis (Brooks, 2006). Around 4200 BC the modern phase of hyperaridity began in the Eastern Sahara.

Not surprisingly, the aridity influenced human activities. Hand-dug wells at many of the playa sites around this time are indicative of the falling water tables (Nicoll, 2004). As the aridification developed further, the human settlement stayed, until even the playa basins were sanded in.

Humans had to abandon many locations in southern Egypt because of the drying conditions. An area around the Nabta Playa in Eastern Sahara was abandoned in 4200 BC (Brooks, 2006). The area inhabited during the main phase of settlement in Gilf Kebir region was now abandoned (Nicoll, 2004). At Gift Kebir, the climatic transition in 4400 BC appears to have induced a remarkable environmental change (Linstädter & Kröpelin, 2004). The change resulted in different patterns of human behavior, economy and land use in the canyon-like valleys and on the plains surrounding the plateau. Even thought the residents of the desert regions surrounding the Nile Valley and the Delta struggled through the transition from wetter conditions before 6200 to 4100 BC. Hassan (2008) considers it likely that the residents at this time might have been forced to attack the prosperous villages in the Nile Valley and the Delta for survival in the new environment. On the contrary to other regions, this time was the third of Farafra Oasis' occupation phases (Garcea, 2008).

Abandoning the habitats caused another significant cultural change to take place. Accelerating movement of human settlements from the desert toward the Nile Valley brought with it the relative abandonment of pastoralism, and the adoption of intensified agriculture based on increasingly systematic artificial irrigation (Brooks, 2006). In 4500 - 3900 BC, small, somewhat self-sufficient farming communities were located on the margins of the floodplain, levees, and the near-by desert (Nichols *et al*., 2008). In Upper Egypt, the earliest food-producing communities were located in the Badari region where small encampments, probably of herders, date back to 4400 - 4200 BC (Hassan, 2008). Around 4000 BC there were intensive settlements along the Nile (Oliver, 2005). This intensification was associated with the breathtaking rise of building, engineering, and irrigation skills.

The production of food seems to have been a part of a broader process of the geographical expansion of lifestyle change in North-eastern Africa (Krzyzaniak, 1991). The food production had spread all along the Nile reaching from the delta in the north to south of Khartoum by 4000 BC. The earliest production of food near Khartoum was composed of mixture of cultigens.

Hydrologically, Lindstädter's and Kröpelin's (2004) studies show that the seasonal rainfall distribution on cultural landscapes in arid regions is of more importance than the annual precipitation rates. Mid-Holocene rainfall pattern produced more favorable conditions in Gilf Kebir than the short summer monsoonal precipitation pattern earlier. The 4400 - 3500 BC winter rains were rather continuous and therefore had different effect on the surface runoff, evaporation and soil infiltration of the water than the summer rains 8400 - 4400 BC. All this meant a transition from an African monsoonal type of climate to a Mediterranean climate with quantatively lower amounts of precipitation, but more continuous winter rainfall.

The effect of hydrological change can be seen, according to Linstädter and Kröpelin (2004), in the cultural change. They distinguish a fundamental transition in land use in the surroundings of Wadi Bakht, Gilf Kebir, before and during the general climatic deterioration in Eastern Sahara. First of all, there was a change in the settlement and land use. Earlier, the land use was characterized by central campsites in the wadis and exploitation of raw material at plateau rims. During the climatic deterioration, the campsites were distributed net-like in the wadis and on the plateau. Now the plateau was the main habitant. Later on, the use of the plateau seems to have become less important. Linstädter and Kröpelin (2004) suggest that the first settlers were hunter-gatherers, but the later settlers were pastoral groups, as the altered conditions on the plateau provided a suitable habitant for this kind of activity. Before the climatic deterioration, the fauna included only wild game, whereas later sheep or goat and cattle are included.

The food production and migration were not the only cultural phenomena during this time; trade and cattle cult flourished too. In Khartoum, trade was already developed by 4000 BC and is well documented by the marine shells and malachite/amazonite objects found in the graves (Krzyzaniak, 1991). Trade had probably the direction of north - south, most probably along the Nile. The spread of the Cattle Cult occurred in the Sahara at the end of the 5$^{th}$th millennium BC (Di Lernia, 2006). The earliest evidence of cattle burials seems evident over a large territory from around 4400 BC. The sites share strictly similar ritual, but at more than 3000 km from each other. The rate of dispersal is not known, but Di Lernia (2006) finds apparent similarity in the duration and chronological placing of the arid climate interval and the very initial spread of cattle-burial.

### 3.2.7. 3900 – 3500 BC: Unpredictable Nile floods, small cities, no evidence of people in Sahara

*The wet phase came to its end: rains ceased in the so far safe sites, and more and more places had to be abandoned. Agriculture was intensified in the Nile Valley – which might have turned attractive only now, when the increasing aridity changed its environment drier – and small towns were born there.*

Agriculture intensified further in the Upper Egypt by 3800 BC and became the dominant subsistence system (Sterling, 1999). By this time the individuals of cultivated areas were dependent on the flooding of the Nile for subsistence. Thus, the environmental perturbations of 4000-3700 BC were experienced in the form of unpredictable Nile flood volumes (Sterling, 1999). According to Hassan (2008), there was a severe famine in Egypt from 4000 to 3000 BC. Nile flood levels first fell briefly after 3700 BC, followed by a long episode of high floods until 3000 BC (Sterling, 1999). The Egyptians had received relatively and consistently high floods for almost 1300 years (5000-3700 BC), but the subsequent 700-years period marked an era of fluctuating flood levels. In 3300 BC, the Egyptians began keeping records of individual Nile flood events. The unpredictable Nile flood volumes constrained the amount of land available for farming and Sterling (1999) suggests that there is a coupling between the unpredictable Nile floods and the cultural elaborations that developed over the coming two thousands years.

The Naqada I[5] period took place in 3900 - 3500 BC (Nichols *et al*., 2008). Small towns, perhaps centers for craft activities, involved in regional exchange, characterized this period. These towns were located along the edge of the floodplain and on the levees. They were usually associated with cemeteries that began to exhibit signs of social differentiation. Naqada I also marks the Middle Predynastic period, which dates from 3900 to 3600 BC (Hassan, 2008). The Middle Predynastic was a period of incipient state formation at a regional scale. There were at least two prominent states or petty kingdoms named Hierakonpolis and Nagada in Upper Egypt, and perhaps several town-principalities in the Delta. Progressive transformation of social organization and increased complexity appears to have taken place in Upper Egypt.

An exodus from the Nubian Desert took place around 3600 BC (Brooks, 2006). A minimum of evidence for human occupation in Sahara can be found south of 23°N in 4000 BC (Brooks, 2006 and Kuper & Kröpelin, 2006). It is likely that at least some of the cattle rearing groups in the far east of the Sahara would have headed towards the Nile Valley, as the last refugia dried (Brooks, 2006). Humans may have been stimulated by the social differentiation and cultural complexity in Predynastic Upper Egypt, or by the limitations of the subsistence options for groups, which already spent at least some of the year in the Nile Valley itself. These latter mentioned populations, which might earlier have practiced seasonal migration between the Nile Valley and the summer savannah (in the area of present Egypt's Eastern Desert), were now forced to settle permanently in the Nile Valley as a result of the cessation of summer rainfall.

The use of astronomical knowledge, devices to predict solar events and an emphasis on cattle in religious beliefs appeared suddenly in the Nile valley in 3500 BC (Young, 2007). In the Nabta Playa, all these elements had already existed for a long time, proving that it wasn’t just people that spread to the Nile valley from the desert.

It is possible that before 3500 BC, the Nile valley was simply too marshy to offer a good permanent residence (Young, 2007). When the climate began to dry, the valley became increasingly fertile and attractive. In 3500 BC, even in the ecological niches like the Gilf Kebir, the rains ceased and permanent occupation is only proved from areas further south in northern Sudan (Kuper, 2006). In 3500 BC there was a sudden increase in land-eroded dust deposits in deep-sea sediments downwind from the Sahara, indicating the further aridification of the environment (Kröpelin *et al.,* 2008). After the end of the wet phase, there has been no significant revival of the rains over the Egyptian desert (Linstädter & Kröpelin, 2004).

[5] For *Naqada I* and *Naqada II*, see chapter “Urbanization” further on.

## *3.3. Late Holocene 3500 BC to present*

### 3.3.1. 3400 – 3000 BC: Final desiccation of the Sahara, emergence of Egyptian state

*This time period witnessed the abandonment of even the last environmental refugia, as the aridification spread. Nile floods began to decrease. Hierakonpolis gained more power. Unification of Egypt and the emergence of Egyptian state took place, and the elite started to be buried in special burial monuments. The graves of the cattle turned to the graves of the people.*

The late Holocene paleoclimate of the northern Nile delta was characterized by arid conditions with short moist episodes (Zalat & Vildary, 2006). These moist intervals are mostly indicated by studies of freshwater diatoms, whereas other studied ecological groups suggest to arid to sub-arid climate.

The final desiccation of the Eastern Sahara happened around 3300 BC, when even Gilf Kebir was abandoned (Linstädter & Kröpelin, 2004). The region around the West Nubia Paleolake shore was in intensive use by cattle rearing groups between 3300 - 2500 BC, after which the area was abandoned (Brooks, 2006). Dramatic climatic deterioration took place in 3000 BC (Di Lernia, 2006; Brooks, 2006). Desertified wadis, which had offered refuges to people in the Sahara, were abandoned in 3200 BC (Brooks, 2006).

The droughts became more prevalent, as the Nile flood discharge began to diminish 3300 -3200 BC (Hassan, 2008). Increased population density resulted from the decrease in habitable or productive land in the late Predynastic period (Brooks, 2006). By 3000 BC, people were modifying the flood basins of the Nile by breaching the natural levees, diverging overflow channels and digging short irrigation channels (Sterling, 1999). Other adaptation strategies were used too. According to Brooks (2006), there had been an attempt to combine the maintenance of herds with increased sedentism. This may have been done through an increase in artificial feeding with cultivated grain. Brooks (2006) states that this phenomenon shows, that social change was associated with environmental drivers: the settlement of pastoral groups in the Nile Valley was caused by the declining water and pasture in the neighboring deserts.

At Hierakonpolis the population was gradually squeezed into the confines of the alluvial plain (Brooks, 2006). By about 3300 BC, Hierakonpolis had extended its power over Nagada so that it started to dominate the area north of Nagada from a new stronghold at Abydos (Hassan, 2008). This way, Hierakonpolis established a far more suitable strategic geopolitical position: it now had a shorter distance to Middle Egypt and the Delta. Considering the narrow floodplain at Hierakonpolis and access to a more extensive floodplain north of Abydos, the leaders of Hierakonpolis also buffered themselves from droughts.

The emergence of the Egyptian state and the unification of Egypt took place around 3200 BC (Brooks, 2006). The Dynastian civilization of Egypt emerged at a time of increasing aridity. The first pharaonic dynasty was founded some time around 3100 BC

(Young, 2007). This kingdom stretched southwards along the Nile valley all the way to Aswan, and had a capital at Memphis. An emerging elite controlled the trade in raw materials (Brooks, 2006). A class of skilled workers gained elevated social status through its association with the "royal" authority of early Pharaohs.

During Naqada II, the elite segregated their burial grounds from those of the commoners: their graves were larger and well endowed with grave goods (Hassan, 2008). The megalithic architecture monuments had cultural transformation from animal to human burial somewhere around 3000 BC (Di Lernia, 2006).

### 3.3.2. 2900 – 2500 BC: Old Kingdom period begins, construction of pyramids

*Egypt was a state, and ruled by the Pharaohs. Pyramids were built.*

Radiocarbon-dated lake levels and stream discharges from central Sudan, Ethiopia, Kenya Rift, Chad Basin, and southern Sahara indicate a downward trend in Nile floods just after 3000 BC (Sterling, 1999). Nile flood levels dropped during 3100 - 2500 BC. In 3000 BC Nile flood levels varied from 1 to 4 m above the baseline.

Communities settled along the banks of the Nile, from the border with Nubia to the shores of the Mediterranean, were brought together to form a single state under the rule of powerful kings, Pharaohs (Hassan, 2008). The Pharaonic empire was well established after 3000 BC (Kuper & Kröpelin, 2006). The Old Kingdom period started in 2700 BC (to 2100 BC) (Sterling, 1999).

The first monumental stone structure was erected for a King at Saqqara in 2600 BC (Hikade, 2008). Khufu Pyramid at Giza was built about 2900 BC, Unas Pyramid in 2700 and other big pyramids in 2700 to 2500 BC (Sterling, 1999 and Cheers, 1999). According to Sterling (1999), there is a correlation between severe and unpredictable environmental perturbations (and consequent Nile flood patterns) and increased energy-costly stone-building events in Egypt between 3000 and 2600 BC (Sterling, 1999).

Earlier it was mentioned that the desert was emptied of people, but according to Kuper (2006), recent discoveries have provided evidence for the presence of people over a wide range of the Western Desert around 3000 BC. People had special technique to cope with the demands of growing aridity. Even in the outskirts of the desert there was widespread human activity, among others Pharaonic expeditions to the western Desert, which may have been caused by the trade.

### 3.3.3. 2400 – 2000 BC: Extremely low Nile floods, end of Old Kingdom

*The study area reached its present environmental conditions: Sahara was once again hyperarid. Low floods caused famines. Old Kingdom fell and chaos prevailed.*

The onset of extreme aridity took place (Brooks, 2006). Drying climate resulted in decreased rainfall to equatorial Africa and a consequent drop in discharge down the Nile

Valley (Catto & Catto, 2004). A general decline culminates in extremely low floods between 2200 and 2000 BC. According to Gawad (2007), there was a low discharge in the Nile between 2500 and 2200 BC. During the millennium of 2000 BC the Sahara reached a state similar to that existing today (Brooks, 2006). Vegetation types and distribution that were established at that time remain today (Olago, 2001).

The diminished Nile flow and aridification has been linked to the end of the Old Kingdom Period (Nicoll, 2004 and Catto & Catto, 2004). The fall of the Akkadian Empire and the end of the Egyptian Old Kingdom were experienced in 2000 BC (Brooks, 2006). The lack of floodwaters, which would normally provide fertile fields, led successively to starvation, military weakness, and political instability. Local adaptations and effective management by local governors replaced the weakened central authority (Catto & Catto, 2004). Between the first and the second Dynasty (2152 - 2040 BC) periods of chaos prevailed (Oliver, 2005).

### 3.3.4. 1900 – 1500 BC: Middle Kingdom, global decline of ancient civilizations

*The world experienced a global decline of ancient civilizations.*

The Middle Kingdom existed between 2000 and 1600 BC (Hikade, 2008). A decline of ancient civilizations happened globally in 1500 BC (Oliver, 2005). Many of the ancient civilizations were not able to continue living successfully in the valleys along the rivers because increasingly drier climates caused limited crop production. The agricultural areas had been greatly reduced and the decreased rainfall caused less production.

## *3.4. The Egyptian state after 2000 BC: a short overview*

As the environment reached its modern hyperarid state and vegetation pattern in about 2000 BC, changes are no further discussed detailed other than for the short discussion of variability in Nile floods for the 600 –year period, and for the changes in the political level. *Table 4* shows some of the environmental changes of the 20th century. The discussion of the future of the Nile and its people can be found in the Results section.

### 3.4.1. The Nile floods during the AD 622 – 1250

Records on Nile floods have been kept with the Roda Nilometer since AD 622 with some gaps caused by social upheavals (Oliver, 2005). So far, the variations of Nile floods have been marked in the chronological presentation of events, and the importance of the Nile floods for the Egyptian society was discussed in the "Geographical setting" chapter. The effects of the fluctuations of the Nile floods could have horrifying consequences on the life of ancient Egyptians. As has been mentioned, Egyptians were, and still are, dependent on the river Nile as it is their sole source of water in the otherwise arid environment.

*Table 3* is mostly based on Hassan's (2007) study on flood's effects on Egyptian society. It is somewhat simplified from his earlier study (Hassan, 1981) of the flood fluctuations. The table presents information on the effects of low or high floods for the 600-year period, compared to the severe consequences floods had on society.

***Table 3.*** *The effect of Nile floods during the 600-year long time time measured in Roda Nilometer.*

| Years (AD) | Nile level | Human life |
|---|---|---|
| 622 | Before the year 650, the Nile floods were generally low (Hassan, 1981). | |
| 700 - 827 | Very low incident of devastating floods (Hassan, 2007). | |
| 827 - 848 | Very low Nile floods 827-848 (Oliver, 2005 and Hassan, 1981). | |
| 828 - 832 | In 828-832 the Nile is reported to have frozen over (presumable in the delta) (Oliver, 2005). | |
| 930 - | Disastrously low and high floods (Hassan, 2007; Williams & Nottage, 2006). | Severe famine (Hassan, 2007). |
| 951 | Low Nile (Hassan, 2007). | Inflation (Hassan, 2007). |
| 953 | Low Nile (Hassan, 2007). | Distress and inflation, increases in the prices of grain and pulses (Hassan, 2007). |
| 962 - 967 | Low floods (Hassan, 2007). | Low floods and famine forced people to eat dogs and cats until they was a shortage of dogs (Hassan, 2007). As conditions worsened, people ate each other. |
| 963 | Nile less intensive (Hassan, 2007). | Inflation for the nine following years (Hassan, 2007). |
| 965 | Flood, then rapidly subsided (Hassan, 2007). | |
| 965/6 | Subsided rapidly (Hassan, 2007). | |
| 967 | Subsided rapidly (Hassan, 2007). | |
| 967 | Severe drought (Hassan, 2007). | Inflation lasting until 971, called Kafour el-Ikhshid crisis (Hassan, 2007). |
| 997 | Low Nile (Hassan, 2007). | Increase in prices (Hassan, 2007). |
| 1005 | Low Nile (Hassan, 2007). | People irrigating some of the land (Hassan, 2007). |
| 1006 | Low Nile (Hassan, 2007). | People irrigating the fields twice (Hassan, 2007). |
| 1007 - 1008 | Subsided rapidly (Hassan, 2007). | Increase in prices (Hassan, 2007). |
| 1031 | Subsided, then rose (Hassan, 2007). | |
| 1052 - 1055 | Low Nile (Hassan, 2007). | Increase in prices (Hassan, 2007). |
| 1056 | Inundation was cut short (Hassan, 2007). | Pestilences and famine (Hassan, 2007). |
| 1059 | Nile subsided (Hassan, 2007). | Great famine, caused by Nile drought, that lasted for seven years (called "Al-Mustansir Crisis") (Hassan, 2007). One third of the population died. |
| 1067 | | Inflation and famine (Hassan, 2007). |
| 1088 | A devastating high flood (Hassan, 2007). | |
| 1099 | Subsided rapidly (Hassan, 2007). | |
| 1122-1124 | Subsided rapidly (Hassan, 2007). | Increase in prices (Hassan, 2007). |
| 1148 | High Nile floods (Hassan, 2007). | |

| | | |
|---|---|---|
| 1164 | A very high flood (Hassan, 2007). | High flood made walls collapse, orchards drown and wells overflow with water (Hassan, 2007). |
| 1070 - 1180 | Disastrously low floods still persisting, interrupted by two occasions of extremely high floods (Hassan, 2007). | |
| 1180 - 1350 | The number of high floods increased at the expense of extremely low floods (Hassan, 2007). The percentage of extremely high and low floods decreased progressively from 20% to 14% from AD 930 - 1359. | |
| 1181 | Very low flood (Hassan, 2007). | Pestilences caused the death of 75% of the population (Hassan, 2007). |
| 1882 | A severe flood (Hassan, 2007). | Walls collapsed, orchards drowned (Hassan, 2007). |
| 1183- 1184 | A severe flood (Hassan, 2007). | |
| 1184 | | Famine (Hassan, 2007). |
| 1191 | Low Nile lasting for three years (Hassan, 2007). | The increase in prices led to the death of one-third of the population (Hassan, 2007). |
| 1200 | | Land un-irrigated, an increase in prices and distress, famine (Hassan, 2007). Appalling famine and frightful mortality: The poor ate carrion, corpses, dogs, excrement and the filth of animals, then began to eat little children. The population was devastated by the famine. From Cairo they carried away between 100 and 500 dead bodies each day. In Old Cairo, the number of the dead was so high they could not bury the dead but just threw them outside the city. Over period of 22 months, 111 000 people were dead (excluding those eaten or died in other parts of Egypt). |
| 1201 | Nile stopped rising, subsided rapidly (Hassan, 2007). | Famine, death, emigration (Hassan, 2007). |
| 1211 | Low flood (Hassan, 2007). | |
| 1212 | Very high Nile (Hassan, 2007). | |
| 1230 - 1231 | Nile subsided (Hassan, 2007). | Increase in prices (Hassan, 2007). |
| 1231-1232 | Nile rose (Hassan, 2007). | A severe increase in prices (Hassan, 2007). |
| 1233 | A severe flood (Hassan, 2007). | |
| 1250 | Increase in frequency of high Nile floods after ca. AD 1250 (Williams & Nottage, 2006). | |

As the table shows, the floods controlled to the large extent,the well-being of the Egyptian society. The fluctuations caused inflation, famines so severe that people started eating each others, death, and destruction of infrastructure. For example the Al Mustansir Crisis in AD 1059 killed one third of the population and it is stated to be caused by the Nile drought.

### 3.4.2. State-level political changes

The Middle Kingdom dates c. 2100 - 1700 BC (Hikade, 2008). Egypt was reunified and had new capital. There were ministries for e.g. cattle and fields, crops and labor. An irrigation program in the Fayum Oasis was created for new cultivation. Old Kingdom tradition of pyramid building was continued along the desert edge west of Nile Valley. The Middle Kingdom ended in fragmentation under the pressure from Asiatic rulers in the eastern Nile Delta. During the time of Middle Kingdom, the environment of Nile reached its' modern state of aridity, as has been mentioned for the time of 2000 BC.

During the time 1650 – 1550 BC, several kings reigned in quick succession, some of them of Asian origin (Hikade, 2008). Royal mortuary cults for the kings ceased. Central government fragmented, and small kingdoms in the Nile delta emerged under the authority of several rulers. There was a liberation war at the 16$^{th}$ millennium during which the Asiatic rulers were driven out of Egypt.

The New Kingdom emerged c. 1550 – 1069 BC (Hikade, 2008). One of the most powerful states in the Eastern Mediterranean and the Near East was created, when Egypt occupied foreign territories. Gold was mined in the eastern desert of Upper Egypt, and trade was maintained throughout the Mediterranean. In 1400 BC, Egypt has its' highpoint, but already in 1153 BC the Egyptian power was weakened by corruption, murder of pharaoh, and internal conflicts (Cheers, 1999). These internal conflicts and economic problems caused Egypt to lose its international power (Hikade, 2008).

During the 1069 to 664 BC, Libyans played a dominant role in Egypt (Hikade, 2008). Egypt was unified again at least for some time, but this period is poorly known. Egypt was conquered by people from the Kush (located on the northern part of present Sudan), who ruled Egypt c. 715-656 BC.

In 332 BC Egypt was conquered by the Alexander the Great and became part of Alexandria (Cheers, 2008). Later on, in 31 BC, it was taken over by Rome. After that, c. AD 642, eastern Egypt was lost to Arabian control, and at AD 1517 to the Osmanian Turks. *Table 3* shows the dramatic conditions Egyptian experienced as a result of Nile's low floods at AD 622 – 1250. In AD 1798 Napoleon conquers Egypt and France overcame the country. AD 1801 British and Osmanian groups take control over Egypt. AD 1922 Egypt was applied nominal independence, and 1953 it became a republic.

### 3.4.3. Environmental changes in the 20$^{th}$ century

The modern environmental variability is presented in *Table 4*, in which environmental changes are marked on the right hand side, and time on the left hand side. This table will be further discussed in the chapter concerning the future of the Nile people, but is presented already here for the continuity of the chronology.

***Table 4.*** *The 20$^{th}$ century and modern climatic changes in the Nile basin. The time periods of the time scale are not regular but run according to the years of the events.*

| | |
|---|---|
| *20$^{th}$ century* | *The continent of Africa is warmer today than it was 100 years ago (Hulme et al., 2001). Warming through the 20$^{th}$ centrury has been at the rate of about 0.5°C century.* |
| *1905-1965* | *Annual rainfall anomalies over the source areas of the Blue and White Niles: a slight increasing trend in the Blue Nile basin between 1905-1965 (Conway, 2005).* |
| *1909* | *Mean annual Blue Nile flows are 45.9km$^3$ 1961-1990 (Conway, 2005). The flow has ranged from 20.6km$^3$ in 1913 to 79.0km$^3$ in 1909.* |

| | |
|---|---|
| *1910s* | *The periods of most rapid warming in Africa: 1910s and 1930s, and the post 1970s (the same as global) (Hulme et al., 2001). Severe and widespread droughts in Africa (Nicholson, 2001 and Oliver, 2005).* |
| *1920 - 1930* | *In the 1920s and 1930s there were indications of wetter conditions, and Nile discharge rose with 35% (Oliver, 2005).* |
| *1930* | *The second period of the most rapid warming in Africa: 1930s (Hulme et al., 2001).* |
| *1931-1960* | *A relatively wet 30-year period in Sudan: The mean annual rainfall at Khartoum amounted to 164mm at 1931-1960 (Williams & Nottage, 2006). In the 57-year period 1900-1957 the rainfall ranged from 48 to 380 mm, but only in 5 years did it exceed 250 mm. Rainfall over much of Lake Victoria's catchment area increased by roughly 8% between 1931-1960 and 1961-1990 (Conway, 2005).* |
| *1946-1975* | *Regional temperature trends shows warming of +0.2-0.3°C/decade or 0.5°C/century from 1946 to 1975 (Conway, 2005).* |
| *1950* | *Multi-decadal drought in Sudan since 1950s (Hulme et al., 2001).* |
| *1960* | *Annual rainfall anomalies over the source areas of the Blue and White Niles: a moderate increasing trend up to 1960 followed by a prolonged increase in annual rainfall due to a combination of extremely wet years, e.g. 1961, 1963, 1977 and smaller increases in some other years (Conway, 2005).* |
| *1961 - 1990* | *Lake Victoria outflows roughly doubled between 1931-1960 and 1961-1990 (Conway, 2005).* |
| *1965* | *Since emplacement of the Aswan Dam in 1965, Nile Delta lake level fell while salinity and nitrate concentration increased (Zalat & Vildary, 2006). Since the Nile flood water stopped reaching the delta lake after 1965, massive amounts of chemicals from the various drains entered the Delta lakes.* |
| *1972/3* | *Major drought and famine in Ethiopia (Conway, 2005).* |
| *1978-1987* | *Low Nile flows lasting from around 1978-1987, unprecedented in the historical record back to 1870 (Conway, 2005). Although Egypt is fairly well secured against the effects of interannual variability by over a year's storage in the Aswan Dam, the 1980s showed it's vulnerability to interdecadal variability.* |
| *post 1970s* | *The third period of most rapid warming in Africa: the post 1970s (Hulme et al., 2001).* |
| *1983-1984* | *Near continent-wide droughts 1983 and 1984 (Hulme et al., 2001).* |
| *1984* | *Nile flows reached their second lowest point in 1984 (Conway, 2005). Annual rainfall anomalies over the source areas of the Blue and White Niles: a slight increasing trend in the Blue Nile basin between 1905-1965 followed by a prolonged decline which bottomed out in 1984.* |
| *1984/5* | *Major drough and famine in Ethiopia (Conway, 2005).* |
| *1988* | *The warmest year in Africa (Hulme et al., 2001). And at the same time, exceptionally wet year (Williams & Nottage, 2006). The rain of 200mm storm in Sudan of 4-5 August 1988 was "unprecedented in its magnitude" and estimated to have a return period of between 400 and 700 years. By summer 1988 Egypt was very close to a major water shortage initiated by a set of responses and anticipatory planning to cope with future such situations (Conway, 2005). The timely high flow later in 1988 removed the immediate threat of severe shortage and since then Nile flows have been sufficient to maintain releases at 55.5km$^3$ and increase storage.* |
| *1990s* | *The recovery of rainfall in the Blue Nile region during the 1990s is also reflected in the increased Nile flows during this period (Conway, 2005).* |
| *1993* | *The River Nile system has been so modified, that nearly all water is diverted by a dense network of irrigation channels throughout the valley and delta, causing no fresh water to reach the sea (Stanley & Warne, 1993). The little water now approaching the coast is polluted agricultural runoff and industrial-municipal waste, that spills into the four coastal lagoons. The Nile Delta is no longer an active delta but rather a completely wave-dominated coastal plain.* |

| | |
|---|---|
| *mid-1990s* | *Nile flows returned to higher levels and Lake Nasser (See* Figure 2*) levels were recovering (Conway, 2005).* |
| *1998* | *Heavy and persistent rain in the Ethiopian uplands resulted in above average runoff in the Blue Nile (Williams & Nottage, 2006).* |
| *1999* | *Lake Nasser's levels reached their highest point since the Aswan Dam was completed (Conway, 2005). The year 1999 was an exceptionally wet year in many regions globally, and very high flow in the Nile and its major tributaries (Williams & Nottage, 2006). In the Sudan, the July rainfall was unusually early and heavy, and persistant rains throughout August and September caused severe floods in much of the central Sudan, including Khartoum. On 16th August 1999, Khartoum received as much rain in 6h as it normally receives in the entire year. These rains were intense and often highly localized downpours. The storm was exceptional in magnitude.* |
| *2000* | *The lowest Nile flood of the 20th century; similar low extremes were reported all across Africa (Oliver, 2005).* |
| *2008* | *On the canal banks, trees and shrubs are often planted as soil retainers (Newton & Midant-Reynes, 2007). There are even other salt-tolerant and stabilizing plants, palms and other plants. Many of the taxa are naturalized and/or cultivated. Gilf Kebir Plateau represents the core of Eastern Sahara today: the largest hyperarid region on earth. It receives less than 2mm of average annual rainfall. (Linstädter &Kröpelin, 2004)* |
| *Present* | *Today rainfall over much of the Egypt is minimal, less than 100 mm mean annual precipitation, and is inadequate to sustain wadi flow or playa lakes (Nicoll, 2004). Groundwater is not being recharged at the rate it is being removed by inhabitants of the New Valley. Wells in the New Valley and watering places have become progressively deeper and brackish. As the water table has dropped, watering places have dried up, trees in oases have died, etc. The modern desert is largely lifeless, with the populations limited to the hardiest desert-adapted plants, animals and passers-through.* |

## 3.4.4. Modern population distribution in the Nile basin

The importance of the Nile can be seen in the population pattern of Egypt. Today the majority of Egypt's population is concentrated on the fertile banks of the river Nile, especially in the cities of Cairo and Alexandria, within the Delta and the *Suez Canal* region. This area, the Nile Valley and Delta, represents less than 4% of the total land area. With other words, even in today's modern world, the livelihood of Egypt's people and the stability of the society are intimately linked to the Nile (Stanley &Warne, 1993). All of the farming land along the Nile valley and delta must be irrigated. Stanley and Warne (1993) see the Nile valley and delta as a vulnerable oasis in the vast, inhabitable Sahara. As the majority of forcefully increasing population lives in the 4 per cent of land, 4 per cent of which the Nile delta constitutes two thirds, the functionality of the Nile is crucial for the Egyptians. Egypt is still dependent on a single water source: the river Nile.

# 4. THE RELATION BETWEEN CULTURE, CLIMATE AND ENVIRONMENT

The chronological presentation of the literature review was presented in the previous chapter. This whole chapter – unless otherwise marked in the reference information – is based on the data of the previous chapter, and intends to closer examine the following cultural phenomena in relation to environmental changes: pastoralism, cattle burials, pyramid building, the rise of the state, and the fall of the Old Kingdom. Although the order is basically chronological, the text here concentrates on the description of the phenomena and environmental conditions, for the exact years of the events, one can always go back to the previous chapter.

## *4.1. The abruptness of the termination of the Saharan humid period*

During the early Holocene, the subtropical North Africa provided a habitat for human populations and fauna including giraffe, antelope, elephant and hippopotamus (deMenocal *et al*., 2000). There were small and large lakes, and vegetation consisted of grasses and shrubs. Quite a different environmental setting in comparison to today's hyperarid Sahara. The rate of the shift from humid to hyperarid is of interest, since the social response is assumedly dependent on how dramatically the change occurred. The science world has not agreed on whether the swift was abrupt or gradual in spite of many diatom, sediment and geological studies.

Linstädter and Kröpelin (2004) state that the Holocene drying of Sahara was an abrupt event, completed within a few hundred years. One example of the studies implicating the abruptness of the termination of the humid period is that of eolian sediment layers by deMenocal *et al*. (2000). They conclude that the collapse of the African humid period was so striking, that they suggest the term "climatic crisis" to be used for the event. The magnitude and spatial scale were remarkable, and the shift from the green, lake-dotted, populated landscape to uninhabited hyperarid desert took place extremely abruptly, within a few decades to centuries.

At the same time, other studies suggest that the precipitation changed more gradually (Holmes, 2008 and Liu *et al.*, 2007). Holmes points out a fresh study of Kröpelin *et al*. (*Science* 320/2008, 765) on a continuous and well-dated pollen record, which suggests a gradual reduction in vegetation cover.

On top of this ongoing debate, Liu *et al.* (2007) question the use of the strong positive vegetation – climate feedback, on which many studies are based. They state that the dominant vegetation change in the North Africa occurs as an abrupt collapse in ca. 3000 BC, but that local rainfall change is much less abrupt. The vegetation might have collapsed because of the increased variability in the climate - instead of decreased precipitation.

It is clear that at the moment the science world cannot answer the question of the type of shift Sahara experienced. Holmes (2008) concludes that the question might even stay unanswered, as the suitable sites for further studies probably don't exist. More studies – if possible - are needed to be certain about the rate of change, and there are naturally geographical differences in the timing and rate of aridification, but one thing is sure: a significant drying trend took place after the Mid-Holocene, turning the Sahara to its modern, arid form.

## *4.2. Neolithic revolution*

During the Early Holocene, Sahara experienced remarkable changes in conditions as was highlighted in the previous chapter. The environmental conditions strikingly improved, and Sahara was able to provide a habitat for people and wildlife. The Neolithic Period started in Sahara around 8000 BC. Human settlement was well established in the Libyan Desert, and the Early Khartoum Tradition was born in the swampy environment of Khartoum.

During the period of 5900 to 5500 BC there was a dramatic decrease in the precipitation. Mesolithic settlement was widespread in the Nile Valley, and the Predynastic period began in 5500 BC. In 5300 BC the aridity had already increased. The first farming communities were established, as was multiresource pastoralism. At the Great Sand Sea, people retreated to the sites close to water.

Although farming and multiresource pastoralism already existed, sedentism[6] as a common lifestyle took place before the year 5000 BC in North Africa, for example in Nabta Playa and Bir Kiseiba (Garcea, 2008). It was a typical strategy adopted for the exploitation of a broad spectrum of wild resources, and it made it possible for people to continually occupy the same sites for long periods of time, as there were sufficient food and water resources available. Intensification of resource exploitation and scheduled consumption with considerable investments of capital, labor, and skills made sedentism a particularly efficient practice, as it allowed people to cope with irregular precipitations and to manage drier periods (Garcea, 2008).

The scheduled consumption of sedentism increased awareness of predictable access to locally available food resources and development of storage facilities (Garcea, 2008). But this strategy had disadvantages too, especially when the environment started turning drier: the local wild resources became unable to sustain the increased needs of people. Consequently, North African dwellers switched to nomadic pastoralism as the only sustainable form of food production in their environment. In the Eastern Sahara this happened about 5200 – 4600 BC.

At the same time, an almost similar change can be recognized at the Nile region in Sudan. A warm, dry phase between 6000 and 4000 BC in Sudan is coincident with the regional Mesolithic-Neolithic transition from the Nile-dependent farming and fishing populations towards cattle raising and sheepherding (Lario *et al.*, 1997). Lario *et al.* (1997) argue that the warm, dry period might have been responsible for the change in

[6] I.e. the transition from nomadic to permanent, year-round settlement.

living habits. The later, humid period also allowed the development of Acacia forests and highly vegetated areas close to the Nile, favoring the spreading of Neolithic populations.

According to Tafuri *et al.* (2006), the dramatic oscillations of climate during the Holocene make the development of pastoralism in the Saharan Africa unique in the prehistory of food production. African pastoralism is indeed believed to originate in the Sahara, in parts of the Nile Valley, and along the Mediterranean coast (McDonald, 1998). The specialty of the African pastoralism can be identified when comparing the Saharan way with the traditional Near-Eastern model of Neolithisation. The basic transition from the nomadic hunter/gatherer to nomadic cattle herders usually goes via the phase of sedentary, pottery producing farmer and stock keeper societies. The specific African variant of this basic cultural change is that in Africa, the relatively stationary pottery producing hunter/fisher groups were skipped, and the nomadic hunter/gatherers were instead directly replaced by nomadic cattle herders (Kuper, 2006; Kuper & Kröpelin, 2006). Kuper and Kröpelin (2006) suggest that the widespread farming obviously was not part of the so-called "*Neolithic revolution*" in Sahara, because the desert-savannah kept on offering wild growing grain, fruits and tubers.

Another reason making the development of pastoralism in Saharan Africa unique is the mobility of people (Tafuri *et al.*, 2006). Because the climatic changes and progressive desertification were so intense, the societies and economies came to be based on movement of people and resources. The mobility in itself became a resource. Both Di Lernia (2006) and Tafuri *et al.* (2006) point out that according to the ethnography and ethnoarchaeology of African pastoral societies, the idea of movement seems to be an obliged condition, and not a free and deliberate choice. In the absence of significant demographic growth, people appear to avoid movement, or at very least to dislike movement other than seasonal. But this time, because of the aridity and possibly even other push factors, the seasonal movement must have become significant.

The desiccation of the environment developed further and more social adaptation were required. The later phase of pastoralism took place: the food security was now based even on the herding of animals better adapted to dry climate (sheep, goats) (Tafuri *et al.*, 2006; Garcea, 2008). The presence of a social system permitted the control of labor when excavating the deep wells in the drying areas (Wendorf & Schildt, 1998).

With further drying, the access to natural resources, in this case water and pastures, became critical (Wendorf & Schildt, 1998). The digging of deep wells made the water available, and thus occupation of the desert was possible at least for a part of the dry season. But even if there were water in the wells, the cattle needed grazing lands. The impoverished environment in the Eastern Sahara reflected in the significant reduction of living sites (Garcea, 2008). Narrowed resources may also have led to intra-group competition (Tafuri *et al.*, 2006).

With other words, the sum of the worsened conditions forced herders to increasingly rely on intensive mobility together with widening and diversifying their relationship with the surrounding environment (Garcea, 2008; Tafuri *et al.,* 2006; Wendorf & Schildt, 1998). The herders supplemented their diet with the gathering of tubers and fruits (Garcea, 2008 and Wendorf & Schildt, 1998). As the medium and large size herbivores decreased, gazelle hunting was reduced. Gazelles could no longer be the major source of meat.

Where could the refugia be found? The climatic deterioration started earlier in the far north than in the south (Pachur & Hoelzmann, 2000). According to Wendorf & Schildt (1998), in the Sahara the mobility generally meant north-south pattern of movement, as there was more rainfall in the southern parts of most areas. The pastoralists moved to the wetter areas during the driest time of the year, and send their herds northward at the onset of the summer rains. The pastoralists at Nabta had another option: moving to the Nile valley during the dry season.

The change in lifestyle even changed the social organization in the herding groups: Tafuri *et al.* (2006) recognize the transformation of social organization from matricentric to patricentric. The shift in animal use is witnessed by the adoption of megalithic monuments as burial places, a change which will be discussed later in this thesis. Tafuri *et al. (2006)* state that:

> "*With the abandonment of cattle as the main resource, megaliths are no longer used as cultural milieus related to African cattle cult, but rather as the site where social elites express their relation with the landscape*".

They conclude that the onset of desert conditions changed the way people approached the resources and also their way to organize themselves.

## *4.3. Emergence of the state*

The process of state formation begins with the mobility; increasing number of people moving to the Nile. The small, independent agricultural villages begin to exist along the Nile (Savage, 1997). First cities emerge. State formation continues through a process of military, economic, political and ideological reinforcement by different groups, which had accumulated power. The process of consolidation ended when the Old Kingdom was created. The ideological, political and economic foundations had been clearly crystallized; the foundations of the state of Egypt were created.

### 4.3.1. Urbanization

As was concluded in the previous chapter, the mobility was the key to survival in the desiccating Sahara. Mobility drove prehistoric societies from foraging to multi-resource economy and specialized pastoralism (Kuper & Kröpelin, 2006). It wasn't just ideas that "migrated" to the Nile Valley from the desert (Young, 2007). Astronomical knowledge, devices to predict solar events, and an emphasis on cattle in religious beliefs are some of the ideas that migrated to the Nile Valley

During the 4000 BC there was a progressive desiccation in Sahara, and at the same time, more and more people moved to the Nile Valley and oasis depressions. Full desert conditions were now experienced in Southern Egypt except for some wadis and oasis. Earliest food producing communities rose in the Upper Egypt. Movement to Nile Valley accelerated as time passed. The Nabta basin had one of the longest and most complete sequences of Holocene occupations known in the Sahara.

People abandoned pastoralism, and agriculture increased. Eventually, the production of food reached the whole Nile. The intensive settlement increase along the Nile brought with it building, irrigation and engineering skills. In 3600 BC the exodus from Nubian Desert takes place. Finally, even the seasonally migrating populations were forced to settle in Nile Valley.

A shift of the settlements near the Nile's floodplain occurred, maybe partly due to ecological and economic reasons, or as linked to the Nile's role as the major communication and trade route (Newton & Midant-Reynes, 2007). Nile floodplain provided the initial infrastructure for the artificial irrigation technology in the form of natural floods (Sterling, 1999). Settlement sites for much of Egypt's early agriculture period were concentrated on the margins of desert hills. The wet, fertile soil of the flood basins was used for planting crops after the floods receded. Minimum artificial manipulation was needed thanks to the annual flooding of the Nile (Sterling, 1999). The conditions Nile provided make it easy to join Di Lernia's (2006) question about the Holocene mobility: "*Did people move to escape aridity or to follow moisture*?"

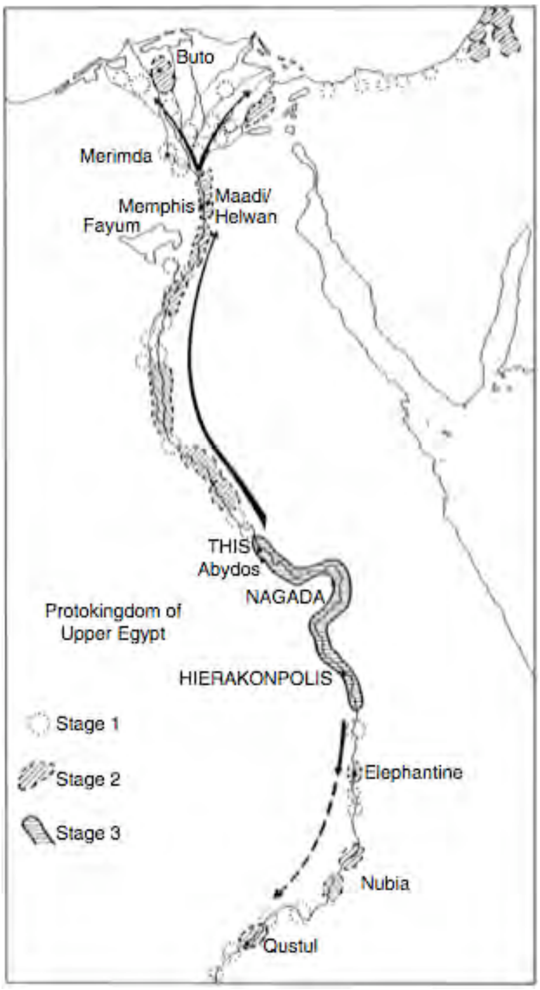


***Figure 5**. Three phases of settlement (Nichols et al., 2008).*

The migration had an important impact on the contemporaneous origin of the pharaonic civilization in the Nile valley: Immigration fueled the rapid growth of the earliest cities and helped sustaining them (Nichols *et al.*, 2008). People moving into the region created a need for greater social organization, and provided workers for the monumental construction projects and armies of the pharaohs' (Young, 2007).

The small communities developed into well-organized communities. In Upper Egypt, the earliest food-producing communities were in the Badari region where small encampments, probably of herders, date back to 4400-4200 BC (Hassan, 2008).

Egypt has been called "the civilization without cities" because of the lack of evidence for major urban centers dating to the earlier part of Egyptian history (Nichols *et al.*, 2008). This may be caused by the heavy sedimentation or later human activities destroying the sites. Also, the first cities did not necessarily develop gradually: some centers grew explosively when regional populations relocated to them.

These transformations were not always peaceful.

For the time of c. 4500 – 3100 BC three patterns of settlement development can be distinguished. These phases are marked with different patterns in the *Figure 5*. The settlements can be described as below by Nichols *et al*. (2008):

> *"Phase 1:* ***Tasian - Badarian period*** *(c. 4500 - 3900 BC). Small, more or less self-sufficient farming communities were located on the margins of the floodplain, levees, and the low desert to avoid annual flooding, but to have easy access to rich alluvium left behind by the Nile.*
>
> *Phase 2:* ***Amratian or Naqada I period*** *(c. 3900 - 3500 BC). Small towns, perhaps centers for craft activities, involved in regional exchange, were located along the edge of the floodplain and on the levees. These towns were usually associated with cemeteries that began to exhibit signs of social differentiation.*
>
> *Phase 3:* ***Gerzean or Naqada II period*** *(c. 3500 - 3200 BC). Small cities that housed protokingdoms exercised control over a stretch of the floodplain and towns and villages within it."*

The Early Egyptian cities were population centers, contrasting with less densely occupied countryside (Nichols *et al*., 2008). In the cities centered elites, governance, social institutions, ideologies, production, distribution of wealth, and political and ritual activities. They were also places where social innovations were materialized. The growth of cities and urbanism in itself was affected by economics, role of markets and merchants, and role of technology especially in forms of transportation, politics and rural-urban relations. Cities were dependent on rural villages for labor and immigrants, food, goods and raw materials.

Hierakonpolis was perhaps the most important center in Upper Egypt at the time, and archeological excavations in the Hierakonpolis have indicated an accelerated process of social differentiation as the time passed (Nichols *et al.*, 2008).

By the Naqada II period, people from Upper Egypt began expanding northward into Lower Egypt (Nichols *et al*., 2008). The archeological evidence suggests that military campaigns through several generations were needed for the political unification of Upper and Lower Egypt.

Memphis was Egypt's capital during Early Dynastic and Old Kingdom times, and the most important political and cultural center of the land (Nichols *et al*., 2008). It was the royal city for the court and high officials, whereas the common people lived in small towns and villages along the Nile. With the fall of the Old Kingdom and integration of the central government, Memphis' time as a capital was over.

## 4.3.2. State level society

There are many explanations for the emergence of the state. The first one discussed here is simply based on the need of a system to feed the citizens. As discussed above, the Nile valley received more and more inhabitants, and pastoralism was abandoned for the agriculture. Oliver (2005) suggests that the rise of Egypt as a state and the organized cultivation of the Nile valley (by the use of early floods for irrigation) may have been necessary because of the increased food demand in the Nile Valley. This would mean that the civilization came about through the need to organize irrigation systems to produce food for the increased population. Taking this thought further, it would mean that the disruption of established ways, which the climatic events caused, provided the challenge and stimulus for undertaking deliberate cultivation and invention of new tools.

This theory, however, is not suggested by Sterling (1999). He states that the need of irrigation and thus agriculture does not necessarily result in a stable food supply. Even though agriculture provides more food per unit area, it also decreases the variability of food sources. Depending on fewer food sources means that the high-yield years alternate with low-yield years, and the consequences of low-yield years can be severe, especially with the increased population. According to the historical documents, it is more likely, that the temple complexes relied on satellite agriculture villages for subsistence (Sterling, 1999).

The second theory discussed is provided by Hassan (2008). The large political entities have several advantages compared to small entities, which set the trend for example for Hierakonpolis to get bigger by annexing smaller communities. The small communities could be used for defense, and as food security against droughts and food shortages. Also, as the tendency of elites to strengthen their position through bigger tombs increased, more and more costly grave goods of rare materials and better artisanship could be achieved from the small communities. It was earlier noted that the unification demanded violence, but Hassan (2008) thinks it might have demanded little or no use of force, as the alliance with larger power may have been considered as beneficial to small polities. This way, the transition to multiregional complexity took place. The transition required synchronizing religious ideologies and politics, and in this process: synchronizing people. This might have been done even with the help of inter-regional royal marriages, which would explain the important role of royal wives in Egypt.

The third theory is very similar to the process described in Urbanization - episode. According to Brooks (2006), the first complex, highly organized, state-level societies emerged in the Afro-Asiatic monsoon belt and northern South America during the period of profound climatic and environmental change, i.e. widespread aridification. Socio-cultural change is seen as a response to enhanced aridity. The populations agglomerate in environmental refugia characterized by the presence of surface water. Brooks (2006) argues that

> *"There is a widespread and increasingly abundant evidence that pronounced increase in social complexity in the Middle Holocene coincided with climatic and environmental deterioration, and in particular with increased aridity".*

The emergence of the Egyptian Dynastic may be viewed as a result of adaptation to increased aridity throughout the 4$^{th}$ millennium BC (Brooks, 2006). Migrant groups arriving in the Nile Valley were likely either to have come into conflict with existing populations, or to have formed disadvantaged groups. The groups with lower status would have provided a pool of labor for military purposes and the monumental building projects.

The fourth theory explains the creation of an Egyptian state as a side effect. Savage (1997) states that the creation was not the initial intention of such a move, but the domination of the Nile Valley and Delta and the control of the trade routes with southwest Asia were the real reasons for the changes. Throughout the first two dynasties a series of actions was taken to accomplish these goals. These actions ultimately resulted in what is called “a state”. According to this theory, the intentions were not political but economical.

As the science world debates on the reasons of the state building, all of these theories suggest that the state was created by the interaction of cities (or other dense populations of people) with their surrounding areas, i.e. Sahara, as listed below.

1. The state emerged to feed the Saharan people who arrived to Nile Valley.
2. The communities networked with other regions to create a better security against outer forces like droughts.
3. Aridification caused people to agglomerate in refugia, in this case Nile Valley, where socio-cultural changes take place.
4. State was built as a side effect to the intention to control the trade routes.

Whatever the motivation was, or whether it was all of the above, it can be agreed that the communities were brought together to form a single state under the rule of Pharaohs, and that the Egyptian state was depended on the agricultural productivity of Nile Valley (Hassan, 2008).

Earlier it was noted that it wasn’t only people who migrated, but even their social organization, ideas and inventions. This role of social organization impacts from Sahara in the rise of Egyptian civilization is complicated (Wendorf & Schildt, 1998). The social complexity is not something borrowed or diffused from one area to other, but something that develops from local causes when people meet. As cattle have played a weighty role in the history of Nile and Egyptian so far (referring to the causes of mobility for the Nomadic cattleherders), the cultural impact studied in this thesis is chosen to be cattle burials.

## *4.4. From cattle burials…*

Cows are important in herding community (Hassan, 2008). The management of domestic livestock must have been a severe challenge for pastoralists of arid lands with highly variable and unpredictable precipitation, especially when they migrated in unfamiliar environments (Di Lernia, 2006).

The pastoral communities in Nabta had experienced increasing social complexity, and the late Neolithic communities had ranked societies, in which cattle played a crucial role symbolizing status and power – and were ritually buried (Di Lernia, 2006). *Figure 8* shows a cow lying in its' megalithic grave, the walls being build with different layers. Nabta is not the only site where evidence of cattle burials has been found. They are found even in Central Sahara. There are sites strongly resembling the evidence known at Nabta where one can find cattle bones dedicated to complex rituals, cattle sacrifices depicted on the wadi walls, sacred fires and building of labour-demanding monuments.

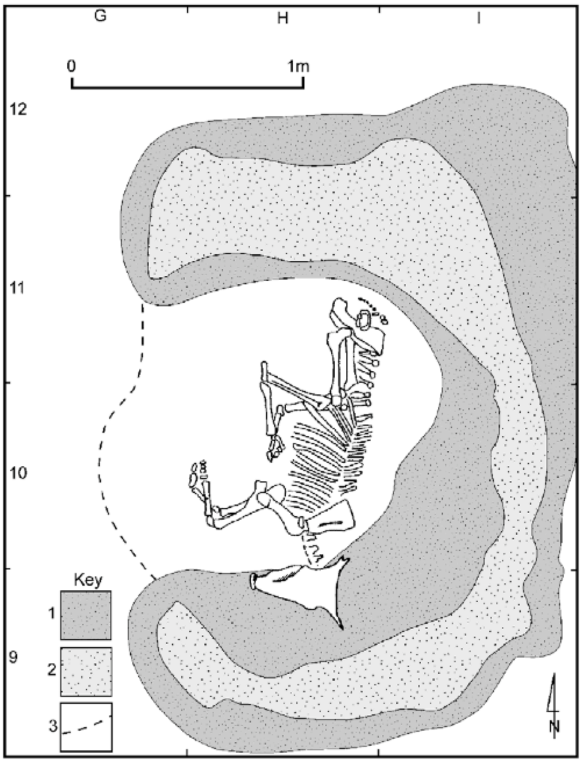


***Figure 6.*** *The settings of cow burials indicate that they were used as rituals (not because of, for example, hygienic reasons); for example the head of the cow was always pointing to the east (Di Lernia, 2006)*

The earliest evidence of the ritual cattle burials comes from around 4000 BC: there are sites sharing strictly similar ritual, but at more than 3000 km from each other (Di Lernia, 2006). It is not likely that a population increase was the reason for the spread of this "cattle cult" from the Egyptian desert, where the oldest cattle burials are located, to the central Sahara. Analysis on the rapid rate of expansion of small livestock in Africa shows that it is unlikely to see the spreading as an advancing wave or a frontier. Instead, it could have rather been a "leap-frog" movement by small groups, a movement that might have been caused by the high inter-annual variability in rainfall and increasing droughts. Moving in unfamiliar environment may have raised the people's need to mark the new environment.

The second half of the 5$^{th}$ millennium BC was characterized by increasing aridity (Di Lernia, S., 2006). Di Lernia (2006) considers the emergence of a cattle cult as a social response to cope with the increasing aridity: Droughts and famine were faced by using a precious resource, cattle, as offering to superhuman entities. Cattle burials are seen as part of complex ritual scenario. This type of rite – slaughtering of precious domestic livestock – reveals people having a shared identity in coping with catastrophic episodes. Cattle served as mediators between group, territory and superhuman forces.

Dramatic climatic deterioration in 3000 BC causes a further major social shift in the cattle burial ritual: the monuments became human burials (Di Lernia, 2006). The stone tumuli of the cattle turned to human tombs, changing their symbolic function, as the monuments no longer belonged to the group of common identity and group wealth, but to the smaller clan members or extended families. The cattle symbolize social power. The change from "cattle burials" to monuments with identical stone architecture (but containing human inhumations) transmits even the symbolic meaning. Di Lernia (2006) states that it is evident that the cattle burials and megalithic human tombs are strictly connected as far as monumental features are concerned:

> *"Deep social and economic changes will be later evident in the use of megalithic tombs for people, where a process of social differentiation develops in the use of these structures as away of affirming personal identity".*

Cattle still dominates the lives of modern herders living along the Upper Nile (Di Lernia, 2006). Cows are their primary wealth today, and used to pay bride-payments and blood fines. They are the basis for prestige. Particularly relevant among these groups are the rain-maker religious figures. Cattle are still used in ritual butchering in Niger, and as cultural tool in $19^{th}$ century Masai culture. Di Lernia (2006) states that cattle cult could be seen as an African legacy, rooted in the Holocene prehistory, and mediated through time and places with different social meanings.

## *4.5. …to pyramids.*

Pyramids are found in many ancient, great civilizations. They were constructed in Egypt during the period of 2900 to 2500 BC, characterizing the Old Kingdom. Egyptian pyramids were stairways to heaven for the deceased kings (Hikade, 2008).

Massive monumental constructions are considered a to be a proof of complexity, because they indicate large-scale group co-operation and, by extension, a hierarchical social structure that coordinated or compelled construction activities (Sterling, 1999). Egypt's first monumental stone structure was build at Saqqaea (Hikade, 2008). This monument was enlarged twice before it was altered into a four-step, and later six-step, pyramid. The construction began as a "*mastaba*", the "bench" in Arabic, which the tomb looked like. When finished, the funerary complex included the pyramid and ceremonial buildings.

The design of the pyramid building was very standardized (Hikade, 2008). The majority of the Egyptians were of course buried in simple pits in the desert sands, but the wealthier could afford rock-cut or mastaba tombs. Nile's clay-rich mud and building stones were main raw construction material in ancient Egypt (Klemm & Klemm, 2001). The mud was easily accessible along the Nile valley, but the stones required systematic quarrying organization. Apart from the temples and sacral monuments, the other architecture was almost solely built of the sun-dried Nile mud bricks. Therefore, it can be said that the Nile mud was the most important raw material in ancient Egypt. It formed along the river valley during floods.

Unlike the mundane architecture (including dwellings of the nobility and royal palaces), the temples, pyramids and tombs were built to last and therefore of primary stone materials (Klemm & Klemm, 2001). If needed, the required stone material was transported from remote sites thousands of kilometers from the construction sites. The Nile and its man-made channels often served as ideal shipping routes for heavy stone loads.

The building of pyramids required strong royal power to arrange the labor and efforts for these magnificent construction projects (Klemm & Klemm, 2001). During the periods of weak government, there was almost none remarkable building activity.

It has been thought that the surplus production of resources (e.g. food produced in agriculture) drives to monumental construction to restrict the access to surplus resources (Sterling, 1999). Several studies show, on the contrary, that the history of monumental constructions do not often correlate to the periods of surplus production of food, but instead to the times of environmental stress, for example unpredictable environmental productivity. The onset of fluctuations of the Nile corresponds roughly with the Predynastic period around 4000 BC. Large-scale stone monumental architecture appears about 1000 years later with the pyramids at Saqqara and Giza. Sterling (1999) argues that the pyramid construction follows the onset of fluctuating and gradually declining Nile flood volumes. She states that there is a correlation between severe and unpredictable environmental perturbations as reflected in Nile flood patterns, and stone-building events in Egypt between 3000 and 2600 BC. Consequently, pyramids were not built at the time of surplus production in agriculture.

The opposite is suggested by Scott and Collins (1996), who state that the end of pyramid building coincides exactly with the Mid-Holocene cooling event in climate, taking place at around 2200 BC globally. The cooling caused drought and, according to Scott and Collins, the pyramid building stopped, showing the direct link between climate deterioration and changes in human activities.

But why where the pyramids built?

Klemm and Klemm (2001) picture the life in ancient Egypt: because of the annual flood, for nearly three months each year working in the fields was impossible. The sowing was easily done and did not take much time. Another two or three month's minimal labor took place until harvest time, when intensive male employment was required. This means, that a large portion of the male population was free of regular daily work for almost 5 months a year. The administration was legendary well organized in Egypt, but the unemployment could have become a problem for the state: There could have been local separatist movements or rebellions. Steady occupation of the population was necessary. The construction projects gave jobs to a significant number of citizens, and a suitable daily supply system had to be guaranteed by the government. In other words, the pyramid building provided a complex interplay of governmental care, continuous daily duties in honor of Pharaoh. As long as it worked, the ancient Egyptian world was kept in order – anything else caused chaos, according to their beliefs.

Another perspective on the reasons for pyramid building is suggested by Sterling (1999). She uses the laws of ecology: trade-offs and bet-hedging models, in which an organism has a finite energy budget. When using less energy on reproduction, there is more energy available on non-reproductive pursuits. She suggests that monumental construction was ordered so that the Egyptians would use less energy in reproduction. In her study she found out that the cultural development (pyramid building) correlates with the environmental unpredictability. The mortality patterns had a shift between 3800 BC to AD 300, to a population in which individuals lived longer and had less juvenile mortality than earlier. With this kind of population pyramid, the population growth rate would slow down, and the smaller population size would be advantageous in uncertain environment. Whether individuals do take the decision of reproduction trade-off consciously is not known.

There is no disagreement about the fact that the pyramids are extraordinary constructions, and very showy. Hassan (2008) states that the pyramids, having unprecedented dimensions as royal tombs, were clear indication that mighty Pharaoh ruled over a state society. Not only showing their power, the elite was even embedded in a religious ideology linked with mortuary rituals and therefore required pyramids. Generally, the cultural importance of the pyramids cannot be underestimated (Sterling, 1999). Pyramids also prove the considerable aesthetic and architectural sophistication of the Egyptian population.

## *4.6. The fall of the Old Kingdom*

*"And there was famine in the land: And Abram went down into Egypt to sojourn there: For the famine was grievous in all the land."*

-Abram's journey into Egypt, Genesis 12 (Prentice, 2005).

The Old Kingdom was a time of long, uninterrupted economic prosperity and political stability (Hikade, 2008). The central administration was at the capital of Memphis, and trade was maintained with for example Nubia. A system of palaces, temples, royal domains and mortuary complexes served as centers for redistributive economy: agrarian products were collected, stored and distributed. More than a dozen pyramids, stairways to heaven for the kings, were built.

The fall of Akkadian Empire and the end of the Egyptian Old Kingdom takes place in ca. 2000 BC (Brooks, 2006). Prentice (2005) present the following quotes from around 2000 BC.

> The sepulchers of Ankhtifi[7]: "*All of Upper Egypt was dying of hunger, to such a degree that everyone had come to eating his children... The entire country has become like a starved grasshopper".*
>
> Chiselled into Egyptian rock: "*I am mourning on my high throne for the vast misfortune, because the Nile flood in my time has not come for seven years. Light is the grain; there is a lack of crops and of all kinds of food. Each man has become a thief to his neighbor. They desire to hasten and cannot walk. The counsel of the great ones in the court is but emptiness. Torn open are the chests of provisions, but instead of contents there is air. Everything is exhausted."*
>
> Middle Kingdom Hymn to Nile: "*If there be a cutting down of the food offerings of the gods, then a million men perish among mortals, covetousness is practiced, the entire land is in a fury, and great and small are on the exectution block."*

[7] A nomarch of Hierakonpolis.

The quotes indicate that the effects of the low Nile floods were very similar to those shown in *Table 3.* As was described earlier in this thesis, there were unpredictable Nile floods, which then, in 2400 to 2000 BC turned to low floods (Gawad gives an approximation of low discharge from Nile to years c. 2500 – 2200 BC). According to Hassan (2007), clusters of extreme floods closely spaced at times of climatic transition are likely to exceed the ability of social systems to cope successfully.

If the conditions at the time of the Old Kingdom's fall were similar to those described in the *Table 3*, the fall of the Old Kingdom society could easily be imagined to be caused by the failing Nile flooding. This view is shared in several articels. For example Nicoll (2004) and Gawad (2007) state that the diminished Nile flow and aridification are coincident with the fall of Old Kingdom Period. The worsened climatic conditions caused droughts and famine, probably contributing to the fragmentation of centralized regime (Hikade, 2008). The lack of floodwaters, which would normally provide fertile fields, led successively to starvation, military weakness, and political instability (Catto & Catto, 2004). The power ended in the hands of the smaller regions (Hikade, 2008). Hikade (2008) does not however blame the enironment only. He states that the long reign of *Pepi II* (c. 2278-2184) has generally been seen as the time of stagnation and decline, bringing down the regime of central government.

The following political reorganization of Egypt under the Theban Pharaohs was made possible by the return of regular, predictable Nile floods (Catto & Catto, 2004).

## *4.7. The future of the Nile people*

In about 2000 – 1500 BC, the environment of the Sahara and the Nile reached its' present state, and has not faced remarkable changes after that. Analysis of the record of Nile flood levels throughout the late Holocene reveals several short, recurrent episodes of high and low floods (Zalat & Vildary, 2006 and Williams & Nottage, 2006). There has been, for example, a period of high flows prior to 1899, and a drought at 1968 - 1972 (Williams & Nottage, 2006). The different phases of floods seem to reflect climatic influences of global extent. *Table 4* is presenting the environmental changes that the study region is facing in the modern world.

The impacts of changes in the hydrological system of the Nile still, in the world of 2$^{nd}$ millennium, require adaptive responses in the human communities and water management institutions (Conway, 2005). The construction of Aswan Dam changed the hydrological system of the Nile north of the dam, as from time to time showed in the *Table 4*, and during the 20$^{th}$ century there has not been obvious correlation between rainfall over the source area and the river flow. Neither is the short nor decadal variability of the rainfall fully understood nowadays. Instead of nature driven changes, people even have to deal with anthropogenic hydrological changes. On top of that, they have to deal with problems brought by alternating flooding (periodic, prolonged) within other environmental and social events including drought, health problems, insecurity and increases in taxes (which, when compared to *Table 3*, is nothing new). Another aspect on the Sahara's desiccation is that still today, many conflicts in Africa are rooted in environmental deterioration (Kuper & Kröpelin, 2006).

In the *Table 4*, one can see that during the summer of 1988 Egypt was close to a major water shortage (Conway, 2005). The Aswan High Dam storage was sufficient to meet the needs of Egyptians, but the government understood the need for emergency plans against future droughts. The state of Egypt counters the variability of Nile by adapting the irrigation systems, improving early warnings of Nile flows, measuring and estimating the water supply and demand, and by building capacity to handle the multi-year episodes of high and low floods. Nationally, water is not yet a limiting resource, except for some areas due to the inadequate local supplies or capacity constraints in delivery system. Conway (2005) points out that this water security could easily be wiped out by climate variability or change.

*Table 4* even marks the rising temperatures. The continent of Africa is warmer today than it was 100 years ago (Hulme *et al.*, 2001). Warming through the 20th century has been at the rate of about 0.5°C century. Today Egypt is climatically located in the arid and semi arid – Mediterranean region, and will be strongly affected by climatic changes of the global warming (Zalat & Vildary, 2006). It is possible that the future climatic changes increase the magnitude and frequency of extreme climatic events such as floods, droughts and heat waves during the 21$^{st}$ century (Williams & Nottage, 2006). If the present trends continue, the regions of the world already experiencing large variations in precipitation from year to year are thought likely to experience an even higher degree of variablity. The areas most affected by climatic changes will be the arid, semi-arid and dry sub-humid regions of the world. Most at the risk will be the poorer communities in regions already vulnerable to land degredation and desertification. Egypt meets many of these characters.

Model based predictions of future greenhouse gas-induced climate change for the Africa as a continent clearly suggest that the warming will continue, and accelerate so that the continent on average could be between 2 and 6°C warmer in 100 years time (Hulme *et al.,* 2001). The magnitude and direction of regional rainfall changes in Africa are uncertain.

Another danger that Egypt is facing is the global rise of the sea level. *Figure 7* shows two possible scenarios for the effect of sea level rise, one for the rise of 50cm and another for the rise of 1 meter. It is worth remembering that the majority of Egypt's population lives on the Nile delta, and that only a few percent of Egypt's land is suitable for agriculture – most of this land in the Nile delta.
The consequences of the sea level rise would be severe for Egypt. The population density at the Nile delta is very high, up to 1600 inhabitants per km$^2$ (Simonett *et al.* 2008b). The area is protected against flooding only by sand belts (See *Figure 7*), the weak parts of which would be destroyed by the rising sea level. The rising sea level would among other consequences salinate the groundwater, threaten the habitat of millions of people, inundate valuable agricultural lands, change the fish communities in the Delta lagoons (today the lagoons provide one third of Egypt's fish catches) and endanger the beaches supporting Egyptian tourism industry.

In Scientific American (Feb. 2001), Peter H. Gleick (director of the Pacific Institute for Studies in Development, Environment and Security) made the following statement "*The* *history of human civilization is entwined with the history of the ways we have learned to manipulate water resources.*" The history of Egypt, and the future climatic predictions of Africa due to changes caused by global warming, seems to show that history repeats itself: the future of Egyptians is closely entwined to the ways they can manipulate water resources. Hulme *et al.* (2001) conclude that the adaptation to existing climate variability should be iproved by reducing vulnerability to adverse climate events and increasing capacity to adapt to short-term and seasonal weather conditions and climatic variability.

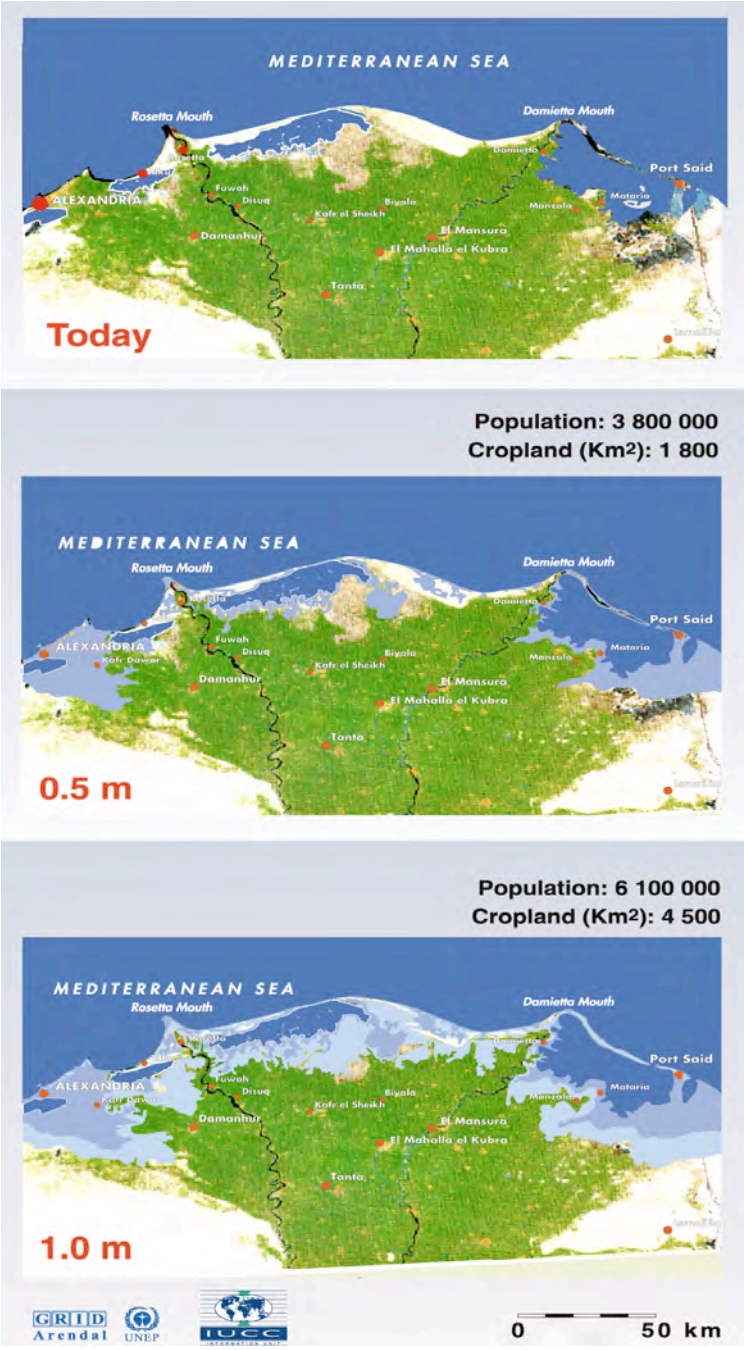


***Figure 7****. Possible effects of global sea level rise of 0.5 or 1.0 meters on Nile Delta (Simonett, et al. 2008a). The population and cropland numbers on the upper right hand corners of the maps show the number of people living in the area which then would be under water (i.e. turn inhabitable), resp. the area of cropland lost on the sea level rise.*

# 5. DISCUSSION AND CONCLUSIONS

## *5.1. Climate induced changes*

The purpose of this study was to find out what kind of environmental and social changes took place in the Nile environment during the Holocene, especially during the 3000 year period between 5000 and 2000 BC, to recognize drivers and responses, and to see if the causality could be find between the environmental and cultural events. According to the chosen theoretical framework, the study took into account the geographical setting of the study area and prolonged time scale (viewing the study question over time and space).

The theoretical framework for the study has been natural determinism (with the note that critical judgment has to be used when viewing the drivers and responses) and political ecology. It was noted that the existence of drivers cannot be simply concluded, and that the responses are dependent on several aspects. Changes cannot be viewed as simple linear causalities but as a web of variabilities. Simply put, real life is more complicated than causality models.

Studying the results of this study, it seems that the comparison of climate and social changes does show a few causalities, which would be difficult to explain to have taken place for other reasons. This applies to the following changes:

1. The lifestyle change around year 5300 BC, when regular monsoon rains ceased and aridity increased, giving birth to the unique African pastoralism. The intensified mobility, and because Sahara still could provide enough vegetables for food, caused cultural development to skip the usual phase of stationary pottery-producing lifestyle.
2. The progressive desiccation at the 5$^{th}$ millennium BC forcing people to move. The movement can be seen in the abandonment of several Saharan sites, if not all, and as the intense settlements along the Nile. This way, climate affected the population distribution in the study area.
3. The unpredictable Nile floods in 3700 – 4000 BC, 2200 – 2000 and ca AD 600 - 1200 caused severe famine in Egypt.
4. The low floods of 2200 to 2000 BC and the extreme aridity may have been partial reason to the fall of the Old Kingdom.

For the major time of the study, urbanization had not yet happened in Egypt. People were hunter-gatherers or herders and therefore dependent on their environment. For them, the drivers for social changes are the availability of water, the diversity of fauna and flora to be used as food (e.g. cereals) and grazing land for cattle for herders. Their response to changes was modifying their lifestyle, and finally, moving to areas where they needs were met. But, on my opinion, one cannot conclude that without the aridification of Sahara, these above-mentioned changes would not have happened. Political ecology press the importance of the activism of the people. Even if there are studies showing that people prefer to *not* move, the human curiosity, competition, conflicts, meeting new groups, some disease or new inventions might have resulted in the same kind of changes and social movements even without the climatic deterioration.

The migration patterns of the 4000 BC, on the contrary, are in my opinion showed to be too widespread and have such a clear direction, that they cannot be explained by anything else than the simultaneous environmental aridification as push factor, and the green environment and the availability to water at the Nile as pull factor.

The population distribution on the Nile Valley increased exponentially, leading to the formation of cities, and further to the formation of state of Egypt. Four different theories about the state formation were presented, all of them showing the importance of interaction between the Nile Valley and Sahara. Three of them are based on environmental changes as drivers to state-building: Oliver's food producing theory, Hassan's networking for security theory, and Brooks' theory of state-building or increasing social complexity as a response to aridity. As there is no common statement of what triggered the creation of the Egyptian state, I leave the question open. Also, since there are many possible theories, a simple environmental driver – social response equation appears unlikely.

Cattle burials, which were mostly discussed based on Di Lernia's study, were taken with on the purpose to study the cultural impact of Sahara to the urban Egypt at Nile Valley. Di Lernia states that the aridification turned the megalithic constructions to human tombs. Although it wasn't put in words, it is easy to draw a line from the cattle burials to other megalithic structures: the pyramids. The change of the resting place of cows to humans coincident with the climatic deterioration but once again, I think the driver-response relationship is not direct nor simple enough to be able to say that it would not have happened without the climate change. The web of relations around both the cattle burials and the reason of building the pyramids is probably much more complicated than what this study has the possibility to present. Egyptian identity and rising cultural politics are surely at least as important drivers for this cultural change than what the climate alone could be.

Sterling's study on pyramids provides surprising information of their construction to have taken place during the unpredictable environmental conditions, especially Nile flooding. It is on my opinion amazing that these huge constructions were possible to build during the time when the state was not under secure food producing conditions. This study somehow speaks against the dependency of Egyptian people on the stability of Nile. With common sense, it would be easier to accept the theory of pyramid building stopping when the droughts arrived. As the governance has been presented to be another factor affecting the building projects, and since the studies don't agree on the causality between pyramid building and hydrological changes, there is no reasons to see the climate as the driving force in this question.

The impacts of low Nile floods are discussed with the fall of the Old Kingdom taking place simultaneously. Referring to the catastrophic events of the c. AD 600 – 1200 of low Nile floods, and to the quotes of the 2000 BC people of Old Kingdom, it could be concluded that the Old Kingdom society suffered from the lack of water creating conditions similar to those AD 600 - 1200. Many papers judged the low Nile floods to be the reason for the fall of the Old Kingdom. The discussion of the effect of low floods is rather difficult to take with the little information found for the study, but I would imagine it to be at least a partial (possible combined with the less powerful rulers) explanation for the weakened state.

Summarizing the results, the aridification of Sahara seems to have had remarkable impact on pushing the development of the social change further. It could be said that the climatic deterioration accelerated the pace of social events; the fast change from hunter-gatherers to nomadic herders, the movement of people to Nile Valley at the same period of time certainly accelerated the birth of the cities, and thus formation of the state, to happen earlier than what it would have done, if the aridity had not "send" people to the river. The relationship between famines and failure of Nile floods is very direct. Unfortunately, to this driving force, the Egyptians had not very many possible responses - other than eating animals, corpses and children.

The presentation, even if simple in this study, of the modern changes at the Nile proves that the interaction between climate and culture is not a question of the ancient history. The flow of Nile still varies. On top of natural changes, humans themselves have become essential force of causing natural deterioration. The construction of Aswan Dam has changed the natural balance of the river system and lands depending on it, and the global warming is changing the environment for the whole continent, and even globally. Most of the Egyptians are concentrated on the river delta, which has been showed to be a fragile environment. Rising sea levels would have devastating effects on the economy, culture and common everyday life of the Egyptians. In today's world, and especially on the urban environments, it is easy to forget how dependent people still are on their natural environment.

## *5.2."The Nile is Egypt."*

As was discussed in the Introduction chapter, linear causal chains can seldom be recognized in changes. If the perspective is moved from questioning the changes to the general view on the relationship between the history and existence of Egypt, this study has showed that "The Nile is Egypt".

The Nile flows through the hyperarid Sahara creating a zone of life in the desert for Egyptians. The flow of the river has carried sediments and created land for agriculture, even building material for their most magnificent cultural manifestation, and it has created the delta and river banks, where most of the people of Egypt live nowadays. The floods have brought with them national misery when they have been too high or too low, or non-existing. They have also become part of the cultural history in the form of Nilometers, connecting several generations to the measurements of flood levels. As the environmental deterioration took place on the Sahara, Nile Valley was the refugia for the people. At the Nile valley, the first cities emerged, pyramids were built, and the river was used as a communication and trade route. It was also Nile, at least partially, that fell the Old Kingdom by low floods. Still today, Egypt has a water reserve because of the unpredictable Nile flow and its' economy in the form of e.g. agriculture and tourism are dependent on Nile or Egypt's history entwined in Nile.

The importance of the river Nile is significant for the whole of Egypt. It hasn't only created habitable regions in the arid desert or affected Egypt's history, but it has even formed the identity of the Egypt as a state. In a way, one could say that the Nile is the driving force for what Egypt is.

## *5.3. Suggestions for future studies and criticism on methods*

Throughout the study, some questions has been suggested as future study subjects. One of them is the abruptness of desiccation of the Sahara, but as has been stated, there might not be sufficient enough study sites to find the answers to the question.

Another interesting question is the reason for pyramid building. As one of the most amazing human constructions, it is surprising that there were not more studies on the subject. It would be highly interesting to know if the pyramids were built on the time of rich or poor natural resources. If they indeed were built on the time when the society had lack of everything including the water, the ability to construct the massive monuments would be even more remarkable.

The status of the cattle is also something that seems to continue throughout the Saharan history. Even today, cattle are highly appreciated in some African cultures, and I consider it interesting how unchangeable some traditions can stay for centuries.

The difficulties met when doing this study were mostly problems of finding information on all aspects, especially the longer back data goes in time, and dealing with different units. The information limitation has caused some further limitations to the study question, but as a whole, the question itself has not been changed. Because of the long time scale, even if the majority of the sources are modern studies, carefulness was needed for the units. Cubic meters for example have changed in size and were thus left out as a measure for flood volumes. There were some complications with comparability between data, especially between climatic and archaeological data, and especially on age determinations when different units were used. Great consideration has been used to deal with the age determinations and I strongly hope that some day the international science world agrees to use one system only.

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