RECONSTRUCTION OF HOLOCENE LAND USE POTENTIAL IN THE EGYPTIAN WESTERN DESERT

A. Bolten[1]*, O. Bubenzer[2], G. Bareth[1]
[1]Institute of Geography, University of Cologne, Albertus-Magnus-Platz, 50923 Cologne, Germany
[2]Geographical Institute, Heidelberg University, Im Neuenheimer Feld 348, 69120 Heidelberg
(a.bolten, g.bareth)@uni-koeln.de; olaf.bubenzer@geog.uni-heidelberg.de

ABSTRACT

For the study area in the Western Desert of Egypt, an open model is developed and applied for the derivation of Holocene land use potential. The model links geomorphometric with other available spatial data in a statistical analysis. Various findings about the Holocene land use potential of the Western Desert of Egypt could be extracted by the interdisciplinary investigation of two archaeological areas. Chronological to a hygric climate change during the Early- and Mid-Holocene (from 9,000 BC to 5,000 BC) assumes a modified land use of the prehistoric people. The types of artifacts and their situation changed concerning to their topographic position and to the potential water resources. Therefore, the paper presents methodological approaches for interdisciplinary research projects in the context of GIS, Remote Sensing, Geomorphology and Geoarchaeology.

1. INTRODUCTION

The archaeological and geomorphological field observations, generated during some 20 years of field research in the Western Desert of Egypt, were the starting point of this study. The spatial distribution of surficial archaeological sites, mainly of hunters and gatherers, shows a distinct pattern over a wide range of spatial scale. It seems to be that Early and Mid-Holocene sites are mainly found in characteristic geomorphological positions, namely in association with drainage lines and depressions which supply a surplus of water (Bubenzer and Riemer, 2007). To prove this hypothesis an archaeological data set from the two contrasting regions Djara (Egyptian Limestone Plateau) and Regenfeld (Great Sand Sea) were analyzed with GIS in combination with environmental information derived from topographical, hydrographical, and geological data sets.

2. GENERAL INFORMATION

In particular the present arid landscape of the Western Desert of Egypt presents an excellent test arrangement for research into the relation between man and environment. The multidisciplinary collaborative research center "Arid Climate, Adaptation and Cultural Innovation in Africa" (ACACIA) focuses on the interrelationship in arid Africa under changing climatic conditions during the Holocene. The project E1 "GIS-based atlas of Holocene land use potential for selected areas" aims at integrating the results of geoscientific disciplines with those of archaeology and social sciences (Bubenzer and Bolten, 2003; Bubenzer et al., 2007). For the purpose of this paper two archaeological study areas with different geomorphological settings were chosen. The geographical locations are displayed in Fig. 1.

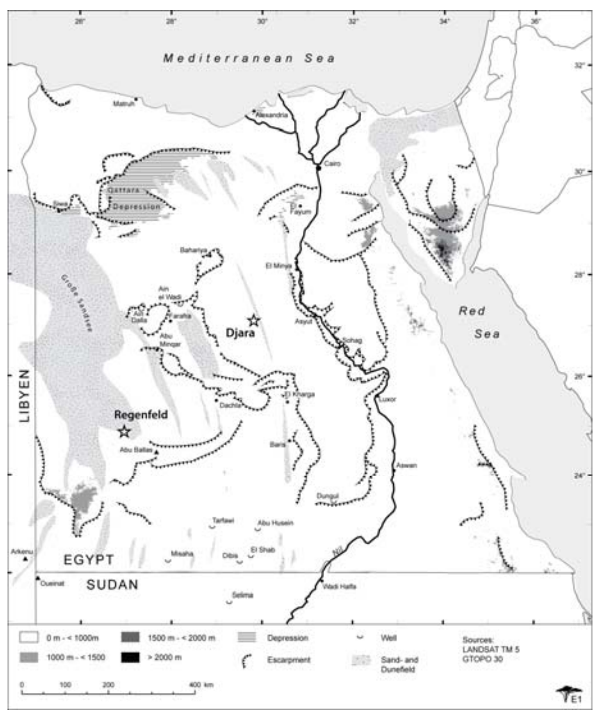

Fig. 1: Position of the investigation areas Djara and Regenfeld in Egypt.

* Corresponding author.

Fig. 2: Typical situation of the investigation region Djara (above) and Regenfeld (below).

2.1 Djara

The Djara region (approx. 200 m a.s.l.) is part of the hyper-arid Western Desert and lies in the center of the Egyptian Limestone Plateau (also named the Abu Muhariq Plateau) (Fig. 1,2,3). This plateau consists predominatly of eocene marine carbonate rocks with minor shale intercalations. Its strata and surface dip gently to NNE.

The relief documents a karstic landscape with rounded hill tops, flat depressions and drainage channels resulting from former wetter climate phases. The Pleistocene as well as modern hyperaridity led and leads to partly strong wind abrasion as well as dune formation (e.g. the famous “Abu Muhariq” dune belt), serir and hamada surfaces. The depressions and wadi channels are currently covered with sparse vegetation such as shrubs and a few tufts of grass and small herbs, which are independent of ground water and depend on rare precipitation events that cause runoff. In the Early to Mid-Holocene humid phase (approx. from 8,500 to 5,300 cal BC) precipitation amounted to 50-100 mm per annum. This led to an accumulation of water and playa sediments in the depressions. Until present, it is not clear whether rainfall was more common in winter or summer months but archaeobotanical findings support the idea of precipitation in both seasons (Kindermann et al., 2006).

The prehistoric settlement area of Djara embraces more than 150 archaeological sites, situated in a well defined area of 10 by 5 km. Most of these sites were found and surveyed next to shallow depressions, often with living vegetation on playa sediments. The radiocarbon dates, taken from anthropogenic features, give – except for an Early Holocene unit (7,700-6,700 cal BC) – evidence for a main settlement duration between 6,400 cal BC and 5,300 cal BC. Stone tools establish the largest group of artifacts in all inventories, whereas ceramic are remarkably rare. On the base of diagnostic tool types and additional 14C-dates two Mid-Holocene units, labeled as Djara A (6,400-5,900 cal BC) and Djara B (5,800-5,300 cal BC), are distinguishable (Gehlen, 2002; Kindermann, 2003; Kindermann et al., 2006).

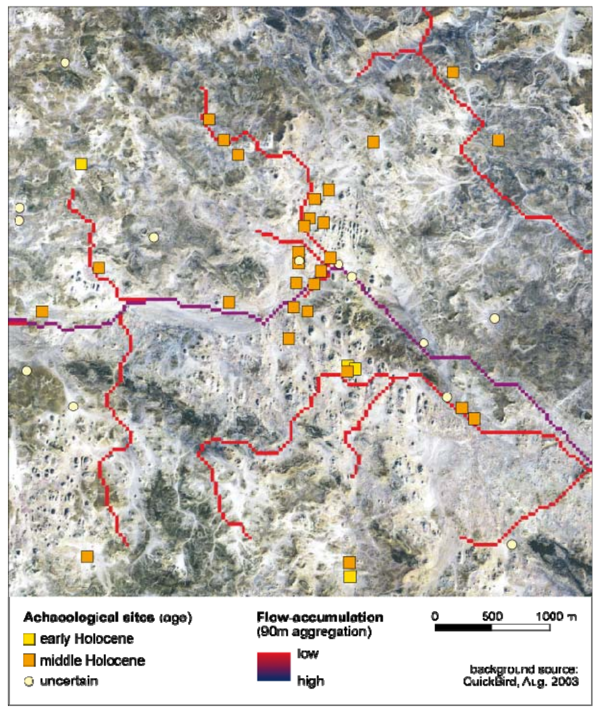

Fig. 3: A part of the Djara-region with archaeological sites and the derived flow-accumulation. Note, that the resolution of the QuickBird background is c. 100-times higher than the elevation model, which is the basis for the flow-accumulation.

2.2 Regenfeld

The Regenfeld area (approx. 400 m a.s.l.) is located in the southern part of the Great Sand Sea, Western Desert of Egypt (Fig. 1,2,4). The bedrock consists of Cretaceous shale, silt- and sandstones (Nubian Sandstone) dipping gently to the north. Besides the deflated Holocene playa, remnants in the corridors, Pleistocene mega dunes (draa with heights up to 70 m above the corridors) with riding recent longitudinal silk dune (height: approx. 15 m) are formative (Besler, 2002; Besler, 2007; Riemer, 2000). Actual vegetation (mostly Stipagrostis, spp.) is restricted to the lower dune flanks. From the geomorphological point of view the favorable situation of the Regenfeld area in the Holocene humid phase is based on a surplus of water from the megadunes and from a small sand sheet which reaches from the south into this area (Bubenzer and Bolten, 2007; Bubenzer and Riemer, 2007). These sand accumulations are able to store large quantities of water over a long time after a precipitation event. The annual amount of precipitation was approx. 100 mm (Bubenzer and Besler, 2005). The accumulation of playa sediments took place in the endorheic pans by sedimentation in seasonal or ephemeral lakes, which developed after surface runoff.

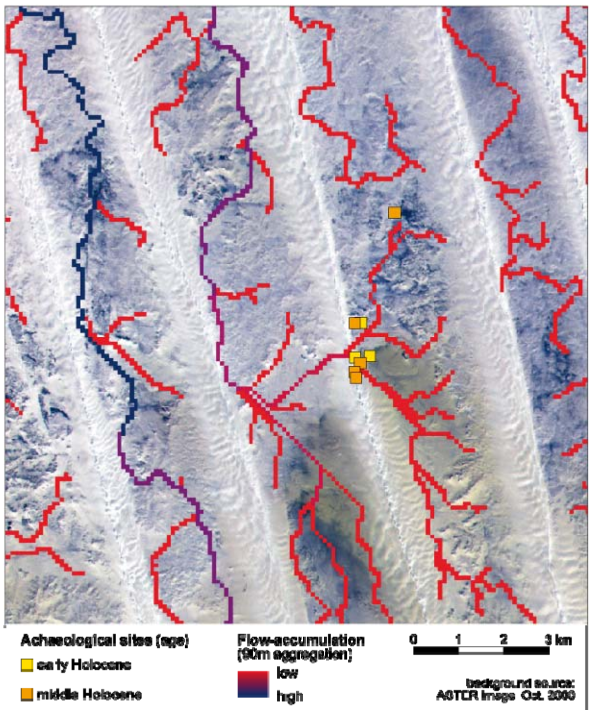

Fig. 4: Southern part of the Regenfeld-area. The longitudinal dunes are clearly visible Note, that just at the dune gap the archaeological findings are present.

After the mostly hyper-arid Pleistocene, human occupation started in the Western Desert of Egypt around 8,800-8,700 cal BC with the beginning of the Holocene humid phase (Kuper and Kropelin, 2006). The Regenfeld area can be subdivided into four archaeological phases, three Early Holocene units (Regenfeld A-C) and a Mid-Holocene one, labeled Regenfeld D (Gehlen et al. 2002). Whereas Regenfeld A-C units are distinguished by different lithic-tool kits, one of the most important characteristics of unit D (approx 6,500-5,400 cal BC) is the introduction of pottery and the abundance of grinding stones. All bones identified on the archaeological sites belong to wild animals and verify a hunter-gatherer subsistence.

3. DATA AND METHODS

The investigated dataset contains two, the geoscientific data and the archaeological data of the same region.

The geoscientific data is based on the information of a digital elevation model. Due to the lack of surveying and mapping data, like detailed topographic maps, only remote sensed information is available. The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) is a high spatial resolution, multispectral imager on the NASA spacecraft TERRA launched in 1999. Its spectral and geometric capabilities include 14 bands in different wavelengths, three bands in VNIR (visible and near infrared) with 15 m resolution, six bands in the SWIR (short-wave infrared) with 30 m and five bands in the TIR (thermal infrared) with 90 m, and a 15 m along-track stereo-band looking backwards with the same wavelength as band 3 (nadir) (Yamaguchi et al., 1998). The combination of the two stereo bands enables the generation of a 30 m digital elevation model (Abrams, 2000; Bolten and Bubenzer, 2006). The quality and usability in arid regions is proved by Bolten and Bubenzer (2006) for the use in an 1:50,000 scale range.

The first database contains the following information about the geoscientific setting of the two investigation regions (Tab. 1).

Tab. 1: Geoscientific parameters derived from the digital elevation model.

Parameter	Unit	Description
LAT	m	UTM 35
LONG	m	UTM 35N
ALT	m	Elevation
SLOPE	°	Slope
EXP_NoSo	-1…0…+1	Exposition in N-S-direction
EXP_OsWe	-1…0…+1	Exposition in E-W-direction
TOPO	Cipher > 0	Topographical index (Myburgh, 1974)
FLOAC	Pixels	‚flow-accumulation‘
FLOACX	Pixel sum	‚flow-accumulation‘ at the next drainage line
HYDRO	Pixel sum	Maximum ‚Flow-accumulation‘-value in an 7x7 pixel array
DIST	m	Distance to the next drainage line depending on the slope value

The topographical-index describes here the relative position to the surroundings in a lower or higher value. The hydro-index gives information of the potential supply with water. All information is derived using tools of ArcGIS SpatialAnalyst and the ArcHydro modul.

The second database contains the archaeological information about the investigation areas (Tab. 2).

Tab. 2: Archaeological parameters collected and processed by project archaeologists.

Parameter	Description	Category	Quantity Djara	Quantity Regenfeld
AGE	Age	Early Holocene Mid-Holocene uncertain	11 77 70	5 36 0
SIZE	Size of the site	low medium high	108 45 5	29 11 3
DENS	Density	isolated low high	90 41 27	16 20 7
BLANK	Blank product	existing / not existing	96	28
TOOL	Tool	existing / not existing	85	23
ARROW	Arrows	existing / not existing	16	10
ADZE	Adze	existing / not existing	26	0
GRIND	Grinding stone	existing / not existing	44	30
HEARTH	Hearths	existing / not existing	117	10
OES	Ostrich egg	existing / not existing	11	5

Using the geographical coordinates of the position of the archaeological findings as georeference, all information of the data tables are collected in one data matrix.

The multivariate ordination technique of the Canonical Correspondence Analysis (CCA) is used here to measure the connection between the two databases. The result of the CCA is shown in a bi- or triplot. The resulting ordination is a product of the variability of both, the environmental and the archaeological attribute data. Site scores and attribute scores are plotted on the same graph using different scales. The angle and length of the arrows show the direction and strength of the relationship between ordination scores and environmental variables. Its aim is to sort the variables and display their relations to identify dependencies between environmental and archaeological variables (ter Braak, 1994).

Another method to prove the dependency or independency of two datasets is to plot one geoscientific parameter against one archaeological parameter in comparison with the whole background (Fig. 5).

4. RESULTS

First of all we present frequency distributions of the topo- and the hydro-index against other data (Fig. 5). The topo-index against the Mid-Holocene sites shows a bimodal trend, different to the distribution against all other sites. Also the hydro-index gives a bimodal trend.

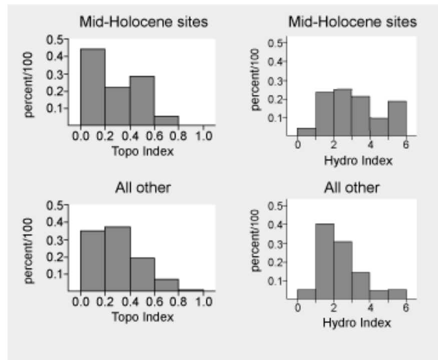

Fig. 5: Frequency diagram of topo- and hydro-index against all Mid-Holocene sites and against the whole background.

The biplot (Fig. 6), displays the hydro- and topo-index against the time position of the Djara and Regenfeld sites and gives the following results:

- The Variance of the data is described well with the two parameters hydro and topo. There is a vertical orientation of the vectors.
- Both parameters divide the plot into four regions with different time position and different parameter strength.

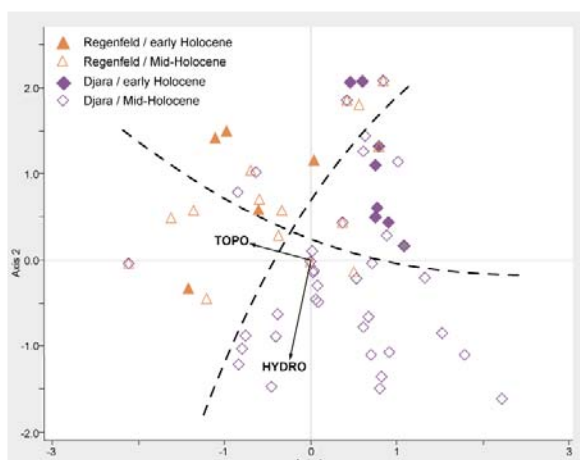

Fig. 6: Biplot of topo- and hydro-index against the time position of the archaeological sites Djara and Regenfeld.

In result, the topo-index separates the two investigation regions and the hydro-index separates the two time positions. Particularly for the Djara region this means the possible change of the land use potential of the highlands and the concentration of life to the more favorable hydro-positions.

The used technique, the combination of geoscientific and archaeological data in an interdisciplinary project can give an added value to the understanding of the man and environment interrelationship.

5. ACKNOWLEDGEMENTS

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