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The Aswan high dam impact on the downstream Wadi Allaqi (Egypt): A multitemporal analysis based on Corona, Landsat ETM$^+$ and Aster images

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ABSTRACT: From August 1964 on, an important part of the millennia long preserved Nubian landscape along the Nile, with its typical Nubian villages and archaeological remnants, gradually disappeared. This was due to the creation of Lake Nasser, one of the world's biggest artificial lakes that stretches 500 km south from the High Dam at Aswan (Egypt). The lake reached its foreseen dimensions by 1975 and submerged the whole southern Egyptian and part of the northern Sudanian Nile valley. As a consequence, approximately 60,000 Nubians lost their homes and lands and many archaeological relicts disappeared under the water. Studies of the former landscape were thus not possible anymore, until recently. In 1995 the CORONA intelligence imagery of the United States, made during the sixties and early seventies, were declassified and fortunately images of the study area dating from before august 1964 were found available. After the image developing and digital processing, the landscape was mapped by on screen interpretation and digitalisation.
To follow the further evolution in the study area CORONA images from 1967 and 1971 and a Landsat ETM$^+$ image from 1999 were used. By on screen digitising of the lake borders, the evolution of Lake Nasser could be followed in time.
To complete the picture, the new landscape on the shores of the lake was considered. With the Landsat ETM$^+$ image from 1999 and an ASTER image from 2001 the newly created roads, agricultural lands and irrigation canals could be detected.
The major outcomes of this work are evolution maps of the landscape between 1963 and 2001, and the positioning of some archaeological features based on the CORONA data.

1 INTRODUCTION

With the formation of Lake Nasser the old Nubian landscape along the Nile with its typical Nubian houses and archaeological remnants gradually disappeared under water, making any further investigations of the area (archaeology, geomorphology, etc.) impossible. Almost three decades later, in 1995, the doors for investigation of old landscapes were opened by the declassification of the CORONA intelligence imagery of the USA. These black and white photonegative images were made in the sixties and early seventies and thus make it possible to 'look into the past'. As this period coincides with the building period of the High Dam, the images give the opportunity to study the landscape behind the dam before and during the filling of the lake. Fortunately the whole Lake Nasser area was photographed before the Nile flood of 1964 (start filling of the lake) and the area was also registered at later moments. These conditions were ideal to:

- investigate the disappeared landscape
- follow the evolution of Lake Nasser in the beginning period of its existence

After the lake was filled (1975) and its dimensions stabilised, the uprooted Nubian population started to come back to their 'homeland' and colonised the lakeshores. In order to study this newly created cultural landscape, as well as to get an idea of the current confines of the lake, a Landsat ETM$^+$ and an ASTER image were used, dating from 1999 and 2001, respectively.

The five considered moments in time and the corresponding images (between brackets) are:

1. July 19th, 1963 (CORONA, KH-4)
2. September 18th, 1967 (CORONA, KH-4B)
3. April 5th, 1971 (CORONA, KH-4B)
4. August 7th, 1999 (Landsat)
5. May 24th, 2001 (ASTER)

A combination of these images allowed a multitemporal analysis to be made for the period 1963-2001.

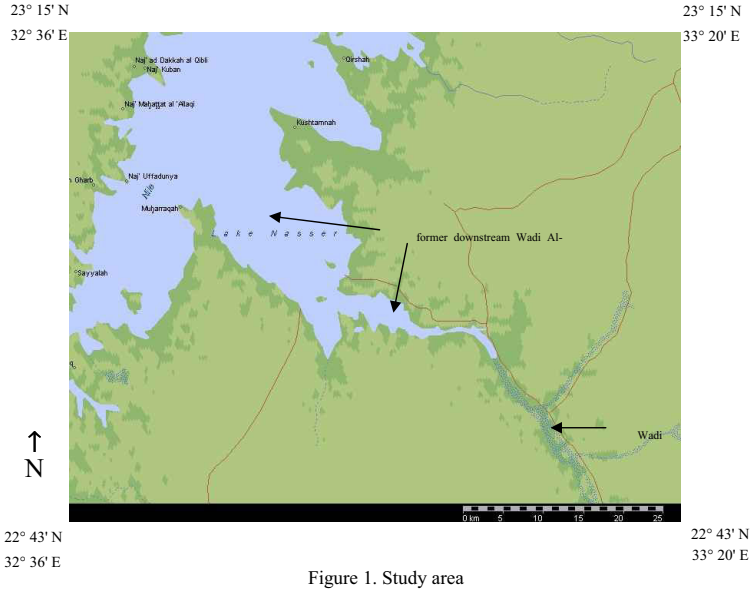

Figure 1. Study area

2 STUDY AREA

The study area is located in the southeast of Egypt. It comprises the part of Lake Nasser that stretches 100 to 150 km south of Aswan and that is centred on the former downstream part of Wadi (el) Allaqi (figure 1).

This wadi is the largest in Egypt's Southeastern Desert and drains currently an area of approx. 44.000 km² (Mekki, Dickinson, 1990; Springuel, 1995). A few decades ago it still led to the Nile, but since the formation of Lake Nasser the lower 80 km of its course have been inundated.

The study area has a hyper-arid climate, and if it were not for the waters of the Nile or Lake Nasser, human habitation would have been practically impossible in this region. The Egyptian Nile Valley has been occupied for several millennia, and this was also the case in the Nubian Nile Valley, although the population has always been less dense than more downstream because the Nubian Nile valley was much narrower (Baines, Malek, 1988). By the time the plans of the Egyptian government for the construction of the High Dam at Aswan were reaching realisation (end of the '50s), about 50.000 to 60.000 people were living along the Egyptian Nubian Nile (the stretch between Aswan and the border with Sudan) (Fahim, 1979; Caputo, 1985). Their subsistence and that of the many archaeological remnants in the area became severely threatened by the plans for the High Dam. But thanks to great efforts of the Egyptian government for the relocation of these people and the international campaign of the UNESCO to save the most important historical remnants, great losses were prevented.

3 METHODS

The first step in the processing was the development of the CORONA negative strips. These strips are very elongated and for a complete coverage of the study area 2 to 3 strips were needed for each considered moment in time. The development of the different strips was done on several A4 sheets that were consecutively scanned. The further processing of the images was executed with the ILWIS 2.2 for Windows software (ITC, Enschede, The Netherlands). For each moment in time (1963, 1967, 1971), the different A4 images were combined ("glued together") to form one synthesised image. These images were then further used as a basis to compose the desired maps.

The CORONA KH-4 image of 1963 formed the basis for the reconstruction of the former landscape (i.e. the landscape before the creation of Lake Nasser). This landscape was mapped by on screen interpretation and digitalisation. Hereby human as well as natural features were considered.

Three kinds of human elements were recorded: habitation, agricultural lands and ancient temples.

The very high resolution of the CORONA images (7.62 m when maximum enlarged (Day, Logsdon et

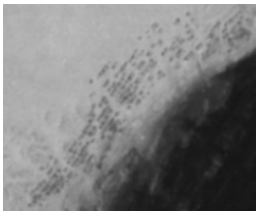

Figure 2. Houses on the CORONA image of 1963

al., 1998)) proved to be ideal to distinguish the individual houses (figure 2).

These were built in a typical manner: a high more or less square wall that enclosed several roofed one-story rooms which opened on an inner court (Gerster, 1963). Although the main agricultural lands were to be found on the alluvial plain, there was also agriculture outside the alluvial plain. On two places in the study area Late Pleistocene Nilotic deposits occurred, which, when irrigated, formed an ideal soil to grow crops. They can be seen on figure 3 and 4 and on the map in figure 7.

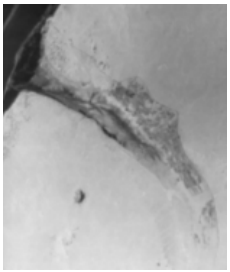

Figure 3. Agricultural lands outside the alluvial plain (area 1)

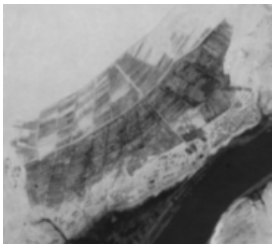

Figure 4. Agricultural lands outside the alluvial plain (area 2)

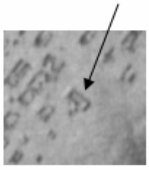

Figure 5. Dakka temple

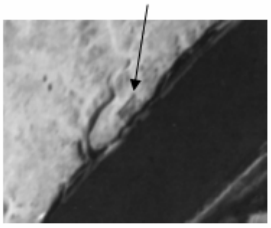

Figure 6. Qurta/Maharraqa temple

Notice also the irrigation canals running through these areas.

Finally the position of the temples (or what was left of them) was also recorded. In the study area two temples occurred: the Dakka temple and the Qurta or Maharraqa temple (figures 5 and 6, respectively).

The natural landscape features that were recorded are in the first place the river Nile and the several wadis that drain the surrounding desert. The second group of features comprises the different kinds of Nubian Sandstone: continuous Nubian Sandstone 1, continuous Nubian Sandstone 2, residual hills of Nubian Sandstone 2, residual hills of Nubian Sandstone 3 and Nubian Sandstone ridges. Hereby 1 stands for the oldest formation and 2 and 3 for consecutively younger formations. The rest of the study area can be considered as loose sand.

To be able to follow the filling of Lake Nasser, the lake borders on the CORONA images of 1967 and 1971 were on screen digitised. In addition, the lake borders in 1999 (Landsat image) were also digitised. Attention should be paid here that in order to overlay these images, they should have the same coordinate system. This is obtained by georeferencing them to a common basis. As there were no ground control points available, one of the images had to be designated as 'master'. Logically, the begin situation was chosen for this. After georeferencing the images, resampling was not needed as ILWIS provides an 'on the fly' transformation' of the different vector layers when overlaying.

In order to study the current cultural landscape on the shores of Lake Nasser, false colour composites of the Landsat and ASTER images were compiled. The main reason for this is the fact that on these colour composites the irrigated fields have a typical pink-red colour that distinguishes them from the rest of the land (figure 10).

4 MULTITEMPORAL ANALYSIS

4.1 *The lost landscape*

The result of the mapping of the landscape before the High Dam, based on the CORONA images of 1963, is depicted in figure 7. One year later, in July/

August 1964, the filling of the Lake Nasser reservoir started and this landscape slowly disappeared under the rising waters.

The houses are represented as circular points on the map. Each point corresponds with an individual house. It becomes clear that the population density was greater where the alluvial plain was broader. This is logical because people lived from what they cultivated on the plain. On places with a very narrow to no alluvial plain, no houses were to be found. The total number of houses in the study area was 2,192. It has been estimated that this number corresponded to approximately 12,000 inhabitants (Deprez, 2002).

The alluvial plain is surrounding the Nile; the two agricultural areas outside the alluvial plain can be seen in the northern part of the study area. The irrigation canals that supply them are also depicted. These soils on Late Pleistocene Nilotic deposits did not come under cultivation until the construction of the Old Aswan Dam (1902), which considerably shortened the growing period due to the creation of a seasonal lake. The bringing under cultivation of these higher lying lands was meant as compensation for the reduced yields on the alluvial plain (Butzer, Hansen, 1968).

The temples of Dakka and Qurta/Maharraqa are represented by little squares. They stand along the Nile. The most northern one is that of Dakka, situated between the houses, the one more to the south is that of Qurta/Maharraqa. It stands alone.

The Nile can be seen on the map as the dark feature flowing from the southwest to the northeast of the study area. The different wadis running to the Nile, e.g. the Wadi Allaqi, are represented in a lighter tone.

The different types of Nubian Sandstone Formations that occurred are divided according to their age (numbers 1, 2 and 3) and their degree of dissection (continuous or residual hills).

The loose sand (white) is wind blown. It forms sandsheets that cover the underlying rocks. The slope gradient in these areas is very low.

The black lines represent ridges in the Nubian Sandstone. They were caused by hogbacks on the edges of a basin structure developed in the Nubian Sandstone Formations in the study area (Dakka basin) (Butzer, Hansen, 1968).

4.2 *The evolution of Lake Nasser*

By overlaying the lake borders recorded from the CORONA and the Landsat images, the growth of the lake became clearly visible. Together with the original situation (the Nile in 1963) an evolution map of the landscape between 1963 and 1999 was obtained. The result can be seen in figure 8.

In addition to this general evolution map of the lake, we can also combine the vector layers of the lake borders on the different moments with the map of the original landscape. In figure 9 this is done with the lake borders in 1999. At this moment, the lake level was very high and corresponded almost with the maximum water extent possible (Deprez, 2002). The map clearly shows which parts of the former landscape were swallowed by Lake Nasser.

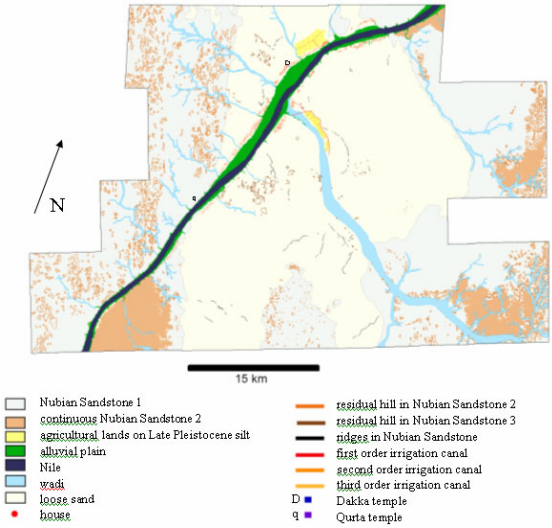

Figure 7. Map of the lost landscape

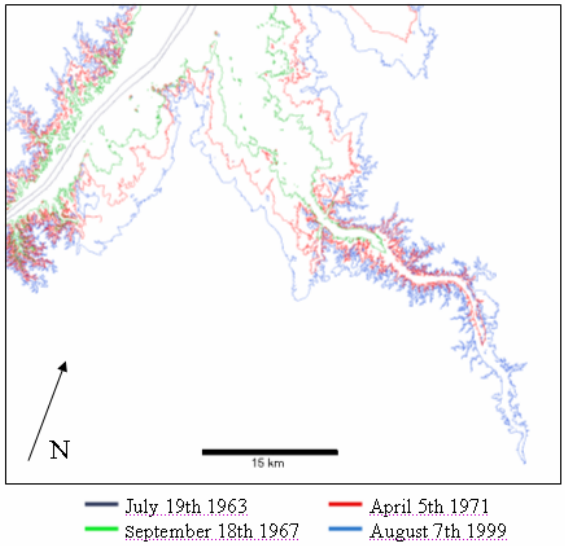

Figure 8. Evolution map of the landscape between 1963 and 1999

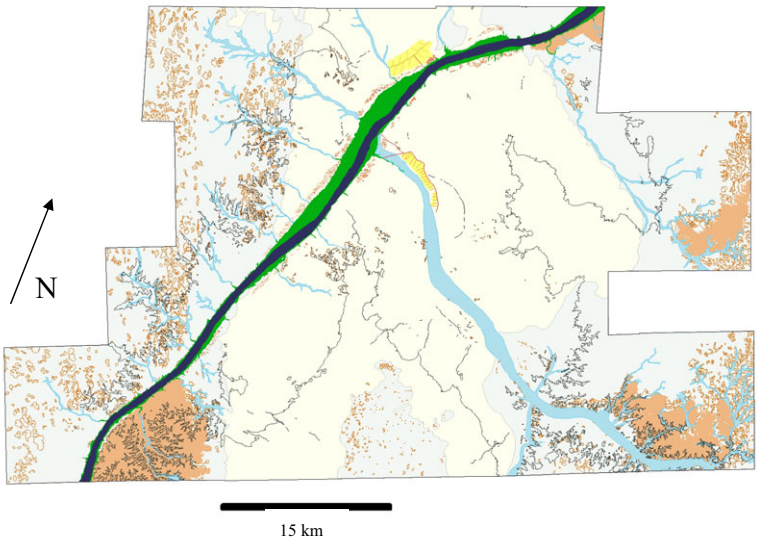

Figure 9. Map of the lost landscape with the lake borders in 1999

Figure 10. Irrigated cropland, irrigation canals and roads on the false colour composite of the Aster image (2001)

4.3 *The new cultural landscape on the shores of the lake*

The new cultural landscape that started to arise on the shores of Lake Nasser between 1975 and 1985 was studied with false colour composites of the Landsat image of 1999 and the ASTER image of 2001. Emphasis was laid on the irrigated croplands. It must however be mentioned that not every human feature could be recognised because of the lower resolution (30 m, respectively 15 m) compared to the CORONA images. The resulting restriction was thus that individual houses could not be registered. Despite of this limitation however, the irrigation canals that bring water from the lake to the agricultural lands could be detected clearly, especially on the ASTER image. Besides from the cropland and their irrigation canals, also roads could be recognised. An example of a part of the new cultural landscape is given on figure 10.

It is a cutout of the false colour composite of the ASTER image. The dark part of the image is the lake. On the lakeshores the agricultural areas that could be detected are encircled. In some places also the irrigation canals connecting them with the lake can be seen. The linear feature that is visible in the under left quarter of the image is a paved road.

5 CONCLUSIONS

In this study it is made clear that CORONA images are an invaluable source of information about the appearance of landscapes some 30 to 40 years ago. Because of this possibility to look in the past, they are indispensable for the study of landscapes that do not exist anymore, e.g. due to submersion by artificially created lakes. This study shows that, if CORONA images are available, every landscape that disappeared after the early sixties can still be studied, and this in great detail.

The map of the lost landscape that resulted from this study is very useful, for example to determine exactly where some archaeological features were located. Retrieving information about the position of archaeological remnants like temples and other similar sized remnants in long gone landscapes is, thanks to the time period and the very high resolution of the CORONA data, still possible at present.

The CORONA system stopped operating in 1972, which coincides with the year the first ERTS (Landsat)- satellite was launched. By consequence, a combination of CORONA with Landsat (and other systems) allows to follow the evolution of landscapes on a regular basis over the last 40 years. And recently, the Ikonos and Quickbird very high resolution imagery opened the doors again for very detailed investigations of landscapes, as was already possible with the CORONA images.

In this study the evolution of the study area was followed from 1963 until 2001, based on five moments in time. However, between 1971 and 1999 there is a gap. To be able to follow the evolution of Lake Nasser in greater detail, more images are needed. One or more images dating from the eighties would for example allow to assess the impact of the Great Sahelian Drought on Lake Nasser. It would be also interesting to use images from the same period but taken in different seasons. In this way seasonal

fluctuations in the lake level could be studied and related to the rainfall in the source areas of the Nile.

The combination of CORONA and Landsat was further essential to evaluate which parts of the former landscape are nowadays submerged.

To study the new cultural landscape on the shores of Lake Nasser, the Landsat and the ASTER image of 2001 were suitable. However, this was only to some extent, because when it came to the detection of houses, their resolution turned out to be restricting (30 m, respectively 15 m). The irrigated croplands could on the other hand be detected easily.

From this study we can conclude that the CORONA imagery on one side and the Landsat and ASTER imagery on the other side complement each other well when considered for a multitemporal analysis. A disadvantage of the latter is however the lower resolution, but on the other hand Landsat and ASTER are, in contrast with CORONA, multispectral systems, which offer the possibility of combining the different bands to form colour images (composites) that facilitate interpretation.

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