Journal of Archaeological Science: Reports 16 (2017) 170–184

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

journal homepage: www.elsevier.com/locate/jasrep

Identification of historic landscape features and settlement mounds in the Western Nile Delta by means of remote sensing time series analysis and the evaluation of vegetation characteristics

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ARTICLE INFO

Keywords:
Nile Delta
NDVI
Vegetation
Remote sensing
Landsat
RapidEYE
Tell
Settlement mound

ABSTRACT

Remote sensing techniques gain increasing importance in landscape archaeological research. Traditional archaeological excavation techniques are slow and time in the Nile Delta is running out. The Nile Delta has been settled and used for agricultural cultivation since the Neolithic period and is shaped by the interplay of urbanization and agriculture. In particular, the study of ancient settlement mounds (tells) and landscape archaeological features such as former river channels requires urgent action. This study seeks to develop supervised classification techniques on the basis of multitemporal Landsat 8 images to easily monitor existing high tells in the Delta that have not been destroyed yet. In the 19th and early 20th centuries many tells were destroyed, because tell sediments (sebakh) were harvested on an industrial scale in order to be used as fertilizer. These activities continued on a smaller scale into the mid to later 20th century. Geochemical analysis of ancient settlement material (sebakh) has confirmed the high content of nutrients. In a second step which is based on these geochemical findings, we seek to identify the category of lost tells which had been transformed into agricultural areas. We suggest that the presence of ancient settlement material enhances the overall vegetation performance and indirectly allows identification of lost tells via describing the vegetation performance. In general, the vegetation performance is a new measure and invented within this study. It is calculated as the product of different measures describing the plant growth, namely the mean *NDVI* (Normalized Difference Vegetation Index), growth statistics and crop rotations derived from a large set of multitemporal *NDVI* images. Our results show that there exists a relationship between vegetation performance and the appearance of archaeological material in the topsoil and such information can be useful for planning of non-invasive archaeological surveys. Remarkably the vegetation performance corresponds with the location of former Nile branches that are currently investigated by the authors on the basis of TandemX elevation data and sedimentological investigations of the area. Several factors such as water availability and salinity also affect plant growth and mask this relationship. Additionally, our methods to describe the number of crop rotations or growth statistics from *NDVI* time series help to analyse the agricultural areas in the Nile Delta. Therefore, the methods used in this study may offer important insights on aspects of urban sprawl and agricultural areas in the Nile Delta and beyond.

1. Introduction

The Nile Delta has been settled and used for agricultural cultivation since the Neolithic period and is shaped by the interplay of urbanization and intensive agriculture. It makes up 2.8% of Egypt's territory and is home to 63% of Egypt's population, namely 50 million people (Hamza, 2009). Awareness is increasing that the intensification of land use by the rising population and urbanization leads to transformation of fertile agricultural land into urban areas. But Egypt's agricultural land does not only suffer transformation but also severe degradation of the soil, meaning that the potential capability of the soil to produce agricultural goods is lowered. Both processes drastically increase the pressure on the use of land and, therefore, increase the rate of land degradation (Abdel Kawy and Ali, 2012).In this context, Schiestl (2014) focused on the fate

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http://dx.doi.org/10.1016/j.jasrep.2017.09.034
Received 30 January 2017; Received in revised form 8 September 2017; Accepted 30 September 2017

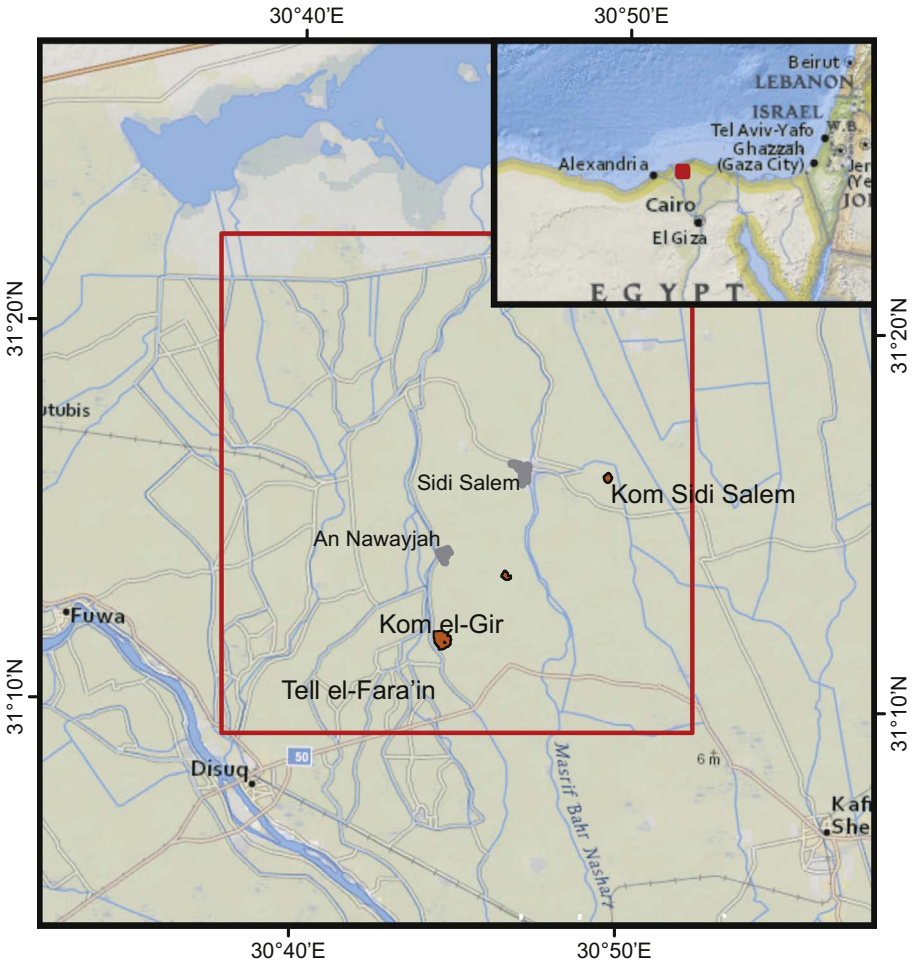

Fig. 1. The study area (red rectangle) is located in the northwestern Nile Delta. Important tells (ancient settlements) are shown in red as well as the location of the most important modern settlements. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

of archaeological sites which disappear due to the rising demand for new agricultural land or settlements and were harvested at industrial scale as 'sebakh' (ancient settlement debris) and spread as an important fertilizer. Awareness is increasing that the intensification of land use by the rising population and urbanization leads to the destruction of archaeological and landscape features. Remote sensing data are often the only available source of data for some sites and are gaining increasing importance. Their application allows archaeologists and geoarchaeologists to uncover unique data on a high spatial level compared to the punctual and site based design of archaeological excavations. With remote sensing techniques, archaeological or landscape features and sites can either be identified, characterized or analysed directly or indirectly. Directly via their specific shape, spectral signature and other remotely measurable characteristics or indirectly via their influence on entities such as vegetation or surface characteristics. Lastly, traditional archaeologic excavation techniques require a long time.

This study focusses on an area that covers approximately 560 km^2. It stretches from Lake Burullus in the north, the city of Desouk in the southwest and the city of Kafr el-Sheikh in the southeast (Fig. 1). In roughly the southern half of this area the German Archaeological Institute (DAI) is conducting the archaeologic excavation on Tell el-Fara'in, the former city of Buto, as well as the above mentioned survey conducted by Robert Schiestl to get a better understanding of the former landscape and the network of settlements that were connected with Buto.

The majority of archaeological sites in the Western Nile Delta are tells, a man-made mound, "[...] whose sediment matrices are for the most part culturally derived, the sediment itself may be treated as an artifact" (Rosen, 1986). Numerous studies have been undertaken to identify former settlements from space in order to get a better understanding of former settlement patterns. A study dealing with this topic and going beyond previous qualitative approaches (Trampier, 2009; Sherratt, 2004; Schiestl, 2014) is the work of Menze and Ur (2012). Menze and Ur (2012) name three distinctive characteristics of tells, dense surface artifacts, moundedness and anthropogenic sediments "anthrosols" for Near Eastern sites that might be remotely traceable. It is here argued these characteristics also hold true for sites in the Nile Delta. Additionally, Menze and Ur (2012) state that texture, hydrological and reflective properties of these anthrosols often differ significantly from the surrounding land in the region under study, the Upper Khabur Basin in northeastern Syria. To assess these differences, they proposed a mulitemporal classification strategy on the basis of multiple multispectral Aster scenes. This multitemporal approach is adopted for our study area in the Western Nile Delta, but conditions in the Nile Delta are quite different. Here we are dealing with an intensively used agricultural area that allows different characteristics of the surface to be classified, such as the surface variability or temporal vegetation patterns. Specifically, for this study area, we use remote sensing workflows and processing techniques to allow monitoring of existing high tells that are not completely occupied, that show tell material on the surface (see Fig. 2) and lack agricultural or other usage due to protection and conservation by the Egyptian ministry for Antiquities. This tell material on the surface is the target of the classification via the direct analysis of surface characteristics and their robust unchanging behaviour over time. In general, the fate of high tells is shaped by the interplay of archaeologic protection and conservation, population pressure and the need for new agricultural and industrial areas. Even though sites are protected, the latter processes can consume these