Documentation – Observation – Evaluation. Ancient Yemen Digital Atlas (AYDA). A WebGIS Based Monument Information System

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Almost unnoticed by the world public, the war in Yemen is destroying a unique cultural heritage. Due to a lack of accessibility and information, it is difficult for the Yemeni "General Organization of Antiquities and Museums" (GOAM) to document these damages on site, so that hardly any countermeasures can be taken to protect the cultural heritage. Since 2017 the Sanaa Branch and the IT Department of the "German Archaeological Institute" (DAI) developed a WebGIS-based monument information system of Yemeni sites. Financed by cultural conservation funds from the Federal Foreign Office, the system is to be linked with various databases that contents historically, archaeologically and for conversion measures relevant data. System tasks will be research, monitoring and management of Yemeni sites, not only operated by the DAI, but in particular by the Yemeni Antiquity Authority GOAM, which can enter its own data into the system. Up to now, about 4200 archaeological sites have been mapped and important site plans digitized. Besides the digitalization of published sites and storage of factual data, site management is an important aspect in the creation of the digital atlas. By monitoring satellite images, changes in the state of conservation of archaeological sites and their surroundings can be quickly and clearly detected and structural changes caused by destruction or looting can be documented. A WebGIS developed especially for the "Ancient Yemen Digital Atlas" (AYDA), whose user interface will be available in English and Arabic enables GOAM to enter new information about sites or even new sites, to use the data scientifically and to plan measures for the preservation of their own cultural heritage.

Key words:
Yemen, German Archaeological Institut, Cultural Heritage, GIS, Digital Atlas, Remote Sensing, Google Earth, Monitoring and Site Management, Archaeological Risk Assessment

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INTRODUCTION

The country historically known as "Arabia Felix", meaning "Happy Arabia", is facing now the threat of destruction of its history and heritage. Since 2015 Yemen has been caught up in a complex civil war, mainly between the internationally recognized Yemeni government, led by Abdrabbuh Mansur Hadi, and the Houthi armed movement (Ansar Allah), along with their supporters and allies [e. g. Khalidi 2017]. Besides the humanitarian catastrophe, the war threatens the unique cultural heritage of Yemen: mosques, Islamic shrines, medieval villages, and also UNESCO world cultural heritage sites such as Shibam[1], Zabid[2] and the old town of Sanaa[3] with its traditional clay and stone

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[1] The old town of Shibam in Hadramawt, with its five to eleven story mud brick skyscrapers known as the "Manhattan of the Desert", was damaged in November 2016 as collateral damage by IS. The main target was a military checkpoint of Yemeni troops. https://www.globalresearch.ca/yemen-one-of-the-oldest-civilizations-crimes-against-humanity-saudi-bombings-of-yemens-heritage-sites/5512617 Accessed 25.01.2019.

[2] During an attack on the historical city Zabid, former capital of Yemen between the 13th and 15th century, some historical houses were destroyed by coalition bombs [e.g. Khalidi 2017].

[3] Coalition bombs hit Sanaa's old city in 2015, targeting two neighborhoods. Beside houses and mosques, numerous antique alabaster windows of the old buildings were destroyed as collateral damage [e.g. Khalidi 2017].

architecture as well as 3000 year old temples, palaces, settlements, dams and cemeteries, right up to entire museum buildings[4] with thousands of objects that altogether fall victim to the conflict (Fig. 1). A total of about 80 partially damaged or completely destroyed sites have been listed by the Yemeni "General Organization of Antiquities and Museums" (GOAM)[5] so far. The number of unreported cases is significantly higher. The full range of the plundering and destruction of archaeological sites and cultural treasures can only be estimated to a certain extent due to the limited accessibility of the various regions of the country affected by the armed conflict. The documentation of these damages is therefore only possible to a small degree, so that countermeasures to protect the cultural heritage can only be taken in rare cases.

Fig. 1. Examples of destruction of Yemeni cultural heritage. a) Museum of Dhamar before[6] and b) Museum of Dhamar after[7]. c) Nakrah Temple of the ancient city of Baraqish before (© Alessandro de Maigret) and d) Nakrah Temple completely destroyed (© GOAM Mohanad al-Sayani)

Since the late 1960s the "German Archaeological Institute's" (DAI) research field has expanded to the southwest Arab region and is continuously and systematically dedicated to the study of South Arabian cultures, culminating in the founding of a branch in Sanaa in 1978, which was assigned to the Orient Department in 1996. The success of this research activity is based on the close cooperation with various cooperation partners and local institutions, in

[4] In May 2015 the Dhamar Archaeological Museum, which housed more than 12500 objects and numerous unregistered archaeological remains, was completly destroyed by Saudi Arabian coalition bombs. http://aiys.org/blog/?p=1884 Accessed 28.01.2019. In February 2016, the National Museum in Ta'izz came under artillery fire. The museum, which includes rare manuscripts and pre-Islamic and traditional artifacts, was almost completely burned. https://www.globalresearch.ca/yemen-one-of-the-oldest-civilizations-crimes-against-humanity-saudi-bombings-of-yemens-heritage-sites/5512617 Accessed 28.01.2019.

[5] The list is provided by Mohanad al-Sayani, president of the Yemeni General Organization of Antiquities and Museums (GOAM), and being updated continuously.

[6] Licenced by https://creativecommons.org/licenses/by-nc-nd/4.0/

[7] Photo Link: https://americaforyemen.wordpress.com/2017/03/01/dhamar-regional-museum-yemen-before-after/ Accessed 10.02.2019. Licenced by: https://creativecommons.org/licenses/by-nc-nd/4.0/

particular the GOAM. Since 2013 it has not been possible for foreign missions to travel into Yemen. Also staff of the local Antiquities Authority has not been able to visit all cultural heritage sites safely. It is therefore not possible to monitor and observe the condition of the sites on ground. For this reason, possibilities were considered to carry out these tasks off-site.

ANCIENT YEMEN DIGITAL ATLAS

AYDA, the Ancient Yemen Digital Atlas is a system planned to work spatially in the sense of a “Geographical Information System” (GIS) and enables the mapping as well as the collection and retrieval of geographical data. When creating the system under the direction of Iris Gerlach, particular importance is attached to the use of existing open source solutions. In addition, the software must be completely installable and operable in Yemen. This also includes a user and rights management system that can be used independently by the Yemeni side. Since the end of 2017, a WebGIS-based monument information system for Yemeni sites has been set up with funding from the Cultural Preservation Programme of the Federal Foreign Office of the Federal Republic of Germany. The system is to be created and maintained together with our Yemeni colleagues from GOAM and at the end will link each site with as much historical, archaeological and conservation data as possible. This includes the interconnection to various research projects, image and object databases. The software programming has not yet been completed. In this respect, the entire system is not available with all its application features now.

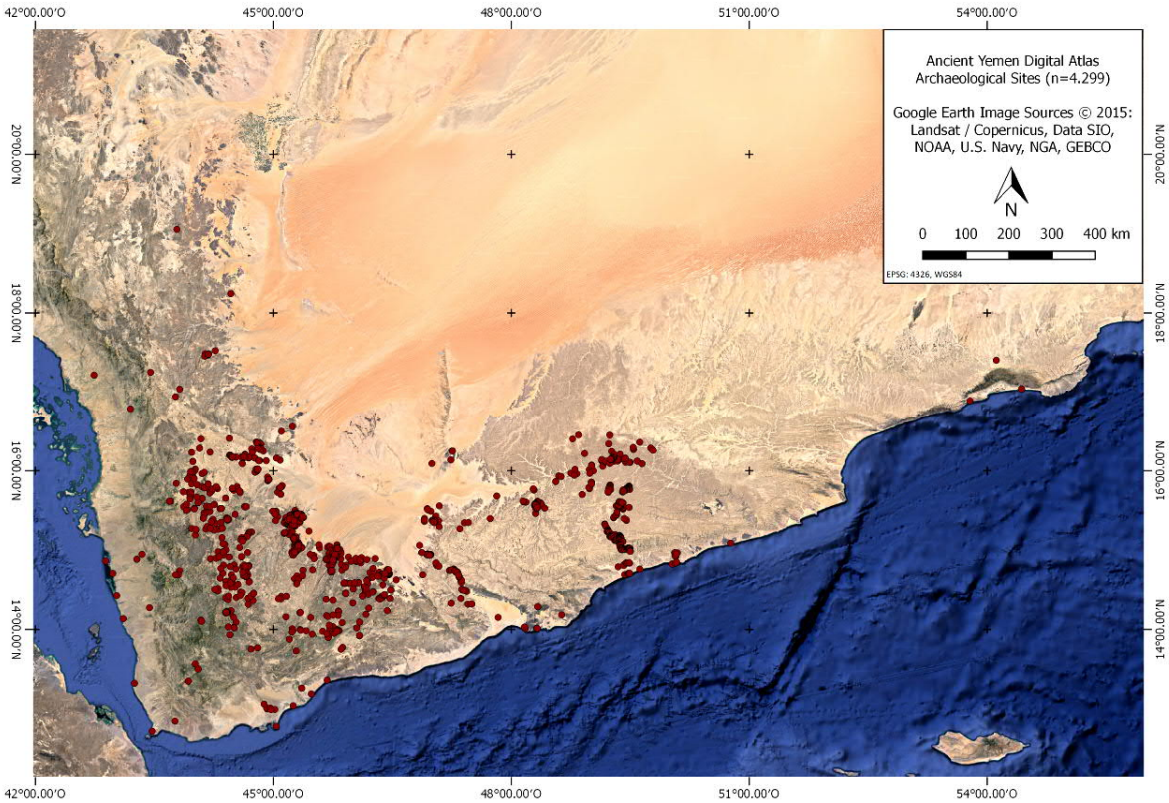


Fig. 2. South Arabian Archaeological Sites mapped in QGIS as ground database for AYDA (© Josephine Schoeneberg / DAI)

- GIS System[8]: The geodatabase serves as primary storage for the AYDA basic data. The Digital Atlas is mainly based on the extensive archaeological data collected by the Sanaa branch of the DAI during more than 40 years of research. To date, a large part of this data is only available in analogue form, which is why, in addition to programming the entire system, the digitalization of research data was implemented in a first step. Old data on already published sites, such as maps, siteplans and aerial photos, play an important role in the compilation of the state monument register: These are systematically digitized, georeferenced, checked on current satellite images and entered into the digital atlas with relevant factual data such as ancient and/or modern name, type, dating, short description, source, threat or condition. In this way, about 4200 archaeological sites have been mapped and up to 40 important site plans have been digitized (Fig. 2).

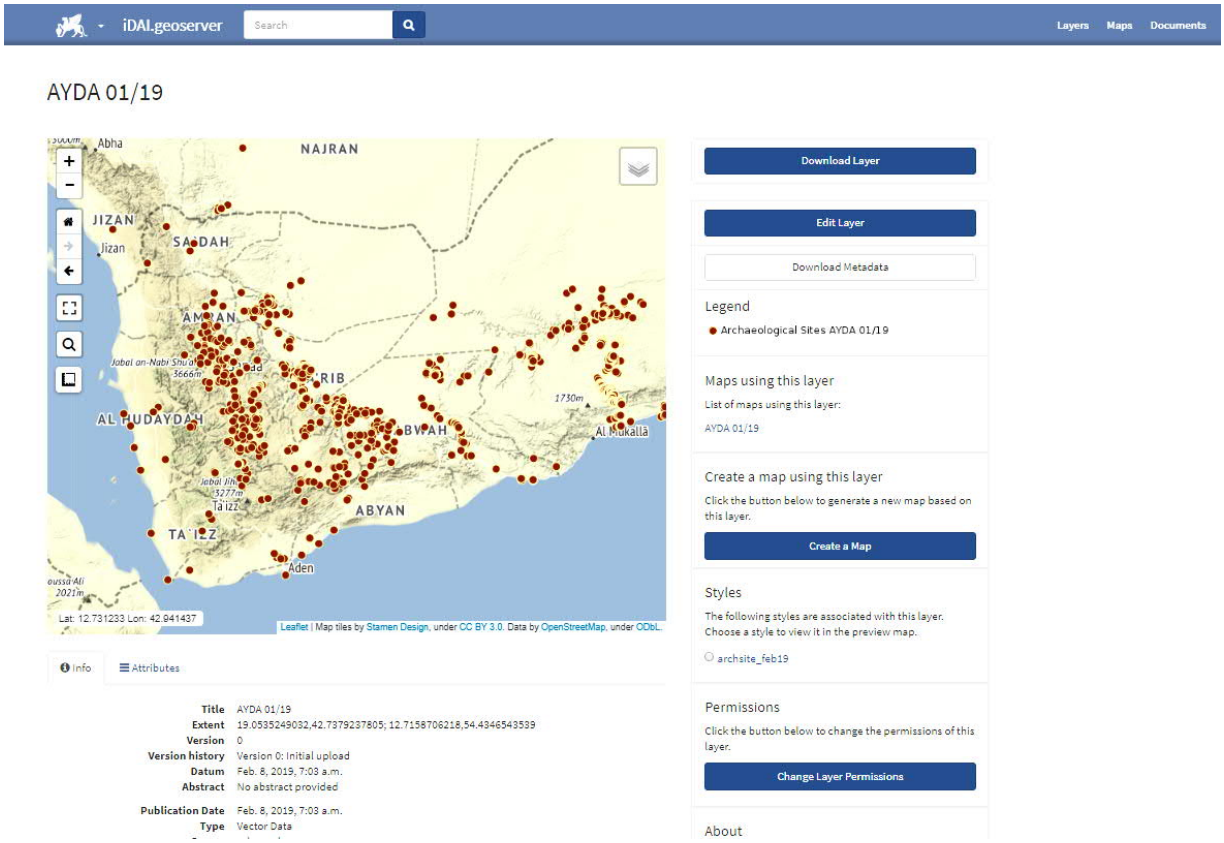


Fig. 3. Yemen Geoserver as tool for sharing geospatial data and maps. The layout is based on the geoserver of the DAI, but has been specially adapted for the Arabian region (© Josephine Schoeneberg / DAI)

- WebGIS[9]: The processing of geodata plays an increasingly important role in archaeological research. Since research projects usually consist of several, sometimes distributed employees, the infrastructure is designed as an online resource. This enables employees to access the common geodata at the same time, which solves the problem of different versions by reason of several editors. For this project, a central geoserver was designed and implemented, which enables the collection, analysis, visualization and archiving of geodata (Fig. 3). In general, the infrastructure consists of open source components in order to be independent of commercial solutions. This online component enables the mapping and retrieval of geodata. At the same time, it represents an easy-to-

[8] QGIS is a free and open-source desktop geographic information system application that supports viewing, editing, and analysis of geospatial data. https://qgis.org/de/site/.

[9] Geoserver serves as an open platform for sharing geospatial data and maps. It hosts GIS datasets, complete maps and various documents related to archaeology and cultural heritage. Registered users can upload and share data and maps with others. http://geoserver.org/.

manage repository in which geodata can be stored, searched and provided with metadata in a structured manner. By granting access rights, sensitive data will only be available to certain user groups. Thematic mapping with layers selected by the user can be directly created and used scientifically. Depending on requirements, the data can be downloaded in various data formats. In addition, the DAI guarantees long-term data storage. This WebGIS, whose user interface is available in English and Arabic, will allow GOAM not only to use archaeological data scientifically, but also to plan measures for the preservation of its own cultural heritage. – *Work in Progress*

- Excavation Database iDAI.field[10]: This component is an easy-to-use application for the management of digital excavation documentation. Part of this module is the migration of the previously used FileMaker databases of the DAI into the new excavation database. This enables users to enter, view and search excavation data online and offline and synchronize it using an own server component. – *Work in Progress*
- Photo Database: This additional online feature is intended to provide photos with a uniform metadata scheme, archive image collections and serve as an image browser. – *Work in Progress*
- Object Database: – The object database of the Sanaa branch office is a pure finds database in filemaker format, which is to be linked to the project. Museum and collection objects are also systematically included and their placement in their spatial find context is possible. – *Work in Progress*

In contrast to other systems [Bewley et al. 2015], which have already been able to map much more ancient sites for Yemen[11], the relatively few sites of the AYDA system have always a name, have been checked and verified for their positional accuracy using satellite images, aerieal photography and well-documented sources. AYDA deliberately uses several sources for the identification of individual sites. The data obtained from remote surveys using free available satellite imagery are only used and integrated into the system if they have been confirmed by other sources (e.g. fieldwork, publications or personal observation). Only a few types of sites such as settlements and the characteristic turret tombs are taken directly from the satellite image analysis. This is specifically noted in the system's factual data. As the EAMENA team could prove in a comparative study of remote survey results and field survey results [Banks et al. 2017], both methods have to be combined in order to arrive at reliable conclusions. In addition, a spot check of sites identified only by satellite image evaluation can already show that many of these points are merely geological or similar formations. In order to exclude misinterpretations, only sites identified by several methods are included in AYDA, which explains their relatively low number.

MONITORING AND SITE MANAGEMENT

In addition to the scientific processing possibilities, like spatial analysis (e. g. viewshed, watershed or least-cost-path-analysis), the Digital Atlas is primarily responsible for monitoring and managing of Yemeni sites in order to protect the national cultural heritage. Aerial photography and satellite imagery have been used for years to explore and monitor archaeological sites around the world [Wilkinson et al. 2006, Parceck 2009, Fowler 2010, Lasaponara and Masini 2011]. By monitoring satellite images, changes in the conservation status of archaeological sites affected by conflicts or natural disasters or looting can be detected quickly and documented remotely. The sites mapped in AYDA are checked for structural changes on old and current satellite images that are mainly available on Google Earth. Google Earth is an easy-to-use tool for identifying archaeological sites [Beck 2006, Ur 2006, Thomas et al. 2008, Kennedy and Bishop 2011, Thakuria et al. 2013] and quantifying looting areas [Contreras and Brodie 2010, Parcak et al. 2016] in arid regions. It is an inexpensive solution to get a first impression of the sites. Imagery resolution ranges from 15 meters to 15 centimeters. Since 2015, the Pro-Version has been available free of charge and enables the storage and print of high-resolution images. Additions to the Google Earth repertoire, such as the “history” feature, allows users to view a decade of images from a single location, provides data that can be used to understand ongoing site-formation processes. In addition to remote monitoring, the constant contact with Yemeni colleagues and their observations on location offers an initial overview of changes and potential dangers at the ancient sites. This is an important step in the initial damage assessment and enables the planning of countermeasures. Unfortunately, the satellite images are exposed to different update intervalls und qualitative

[10] https://www.dainst.org/ergebnis/-/asset_publisher/NZrOgZ37QcYu/content/idai-field Accessed: 14.02.2019.

[11] EAMENA - The Endangered Archaeology in the Middle East and North Africa: The approach for the project is the rapid examination of satellite imagery, historical aerial photographs, and other sources to provide the location and brief description of each site and an assessment of threat. http://eamena.arch.ox.ac.uk/.

differences in the image resolution, so that the same detailed prospection and monitoring cannot take place everywhere by using free sources. For example, images from economically interesting regions such as Marib are updated regularly. In contrast, the latest satellite image from the isolated region around the ancient settlement of Shabwa (Upper Hadramawt) dates to 2010.

Most of the sites mapped in AYDA seem to be in good condition under the given circumstances, but also a variety of destruction caused by human activities through the Yemeni civil war, mainly caused by airstrikes of the Saudi Arabian coalition, looting, urban and agricultural development, could be observed:

- Destruction caused by war: Among the most prominent examples of destruction in the course of the ongoing conflict are the Northern Outlet of the Great Dam of Marib[12], parts of the city wall and the Nakrah Temple of Baraqish[13] or the al-Qahira fortress in Ta'izz[14], which have already been reported on several occasions [Bewley et al. 2015; UNESCO 2016; Khalidi 2017]. Sites still not recognized by UNESCO include the archaeological site of Sirwah, also bombarded by the coalition in April and May 2015. Due to its proximity to local administrative facilities, Sirwah [Gerlach 2003/2004; Gerlach et al. 2011], one of the most important religious and political centres of the Sabaean polity at the beginning of the 1st millennium BCE, suffered severe damage[15]. To avoid further destruction, the DAI in cooperation with other international institutions have provided UNESCO with a "no strike" list of important archaeological sites and museums in Yemen, which has been forwarded to the Saudi government. But, it seems that the Arabian coalition is only partially adhering to this protective list. Information collected from local sources and newspaper articles about these damages as well as significant changes in the satellite image are noted in AYDA.
- Destruction through modern settlement activity: A recent example comes from the Sabaean capital Marib [Eichmann and Hitgen 2003]. New satellite revealed structural changes in the ancient settlement area images in December 2017. Within a month, development areas were marked, old houses were demolished and a modern road system was laid out (Fig. 5). The visible patterns of construction were digitized in GIS and immediately passed on to UNESCO and GOAM by the DAI hoping to prevent the imminent destruction of this most important site of ancient South Arabia (Fig. 4). In other cases, the destruction of previously recorded sites by modern settlement expansion could be documented. This concerns especially ancient animal traps (kites) which were found in dozens in the region around Marib. These kites were digitized in GIS for AYDA. Kite No. 146, for example [Brunner et al. unpublished] was completely destroyed in the course of a new landfill, others were levelled or damaged during road construction (Fig. 6). The extent of destruction, as far as can be seen, was documented for each kite. Later, these informations can be verified on site and if necessary extended with further details.

[12] The Great Dam of Marib [Vogt 2007], mentioned in the Qur'an, was built in the middle of the 1st millennium BCE and is considered the largest irrigation system of antiquity. During air raids in 2015, the recently restored [Vogt 2005] northern irrigation outlet was severely damaged.

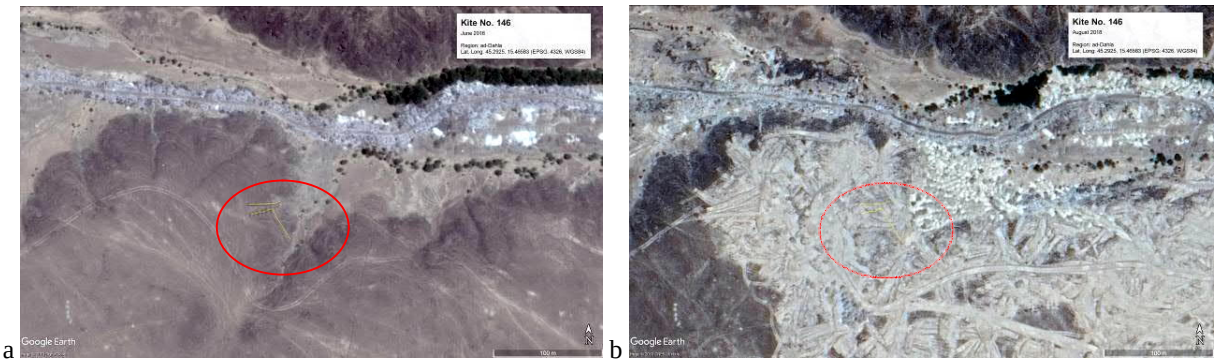
[13] The Nakrah temple of Baraqish was excavated by an Italian team in the 1980s and 1990s and then extensively restored over several years [de Maigret and Robin 1993]. In 2015 a single air raid strike destroyed the temple and parts of the city wall as well as excavation shelters and depots completely.

[14] The al-Qahira fortress of Ta'izz, a site settled since pre-Islamic times was taken over by Houthi rebels in March 2015 and its fortress subsequently bombed by the Arabian coalition in May 2015.

[15] Yemeni sources reported the DAI several damages at the monumental buildings of the Sabaean city of Sirwah, located about 30 kilometers west of Marib. The ancient site was not the direct target of the attacks, but it was severely damaged in ground battles for nearby administrative structures of the Marib Governement.

Fig. 4. Various layers from AYDA document the construction measures in the ancient settlement area of Marib in December 2017 (© Josephine Schoeneberg / DAI)

Fig. 5. Detailed view north of the settlement. The rectangular construction patterns are clearly visible (Google Earth Image © 2019 Digital Globe)



a b

Fig. 6. Complete destruction of Kite No. 146 (about 7 km NW of ancient Marib) by a landfill between a) 2016 and b) 2018 (Google Earth Images © 2019 Digital Globe / CNES / Airbus)

- Illegal Excavations and Looting: Extensive looting and illegal excavations were to be recognized repeatedly during the work on AYDA. This has been a major problem even before the war, especially in the north of the country and on the desert outskirts, where the old South Arabian polities had their centres. Inside and outside the fortified settlement of al-Bayda (ancient Nashq), one of the largest archaeological sites in southern Arabia, illegal excavation holes can be seen side by side (Fig. 7).

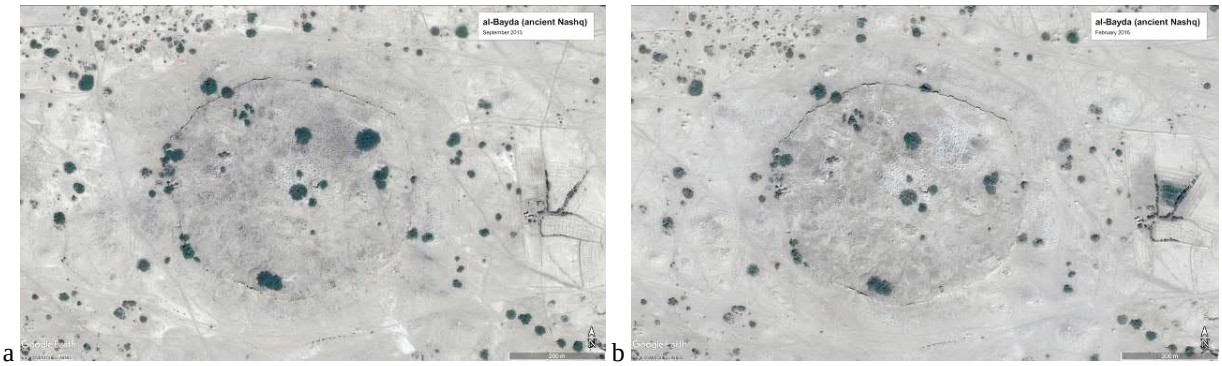


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Fig. 7. a) Illegal excavations in al-Bayda even before 2013. b) After 2013 especially outside the settlement, excavations have been carried out (Google Earth Images © 2019 CNES / Airbus)

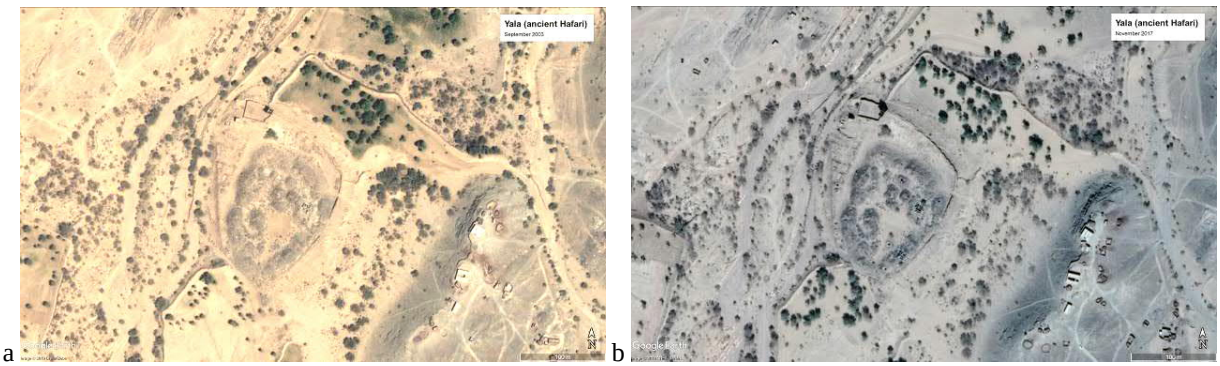

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Fig. 8. a) In Yala only "House A" was excavated until 2003. b) Since 2003 several structures were illegaly unearthed (Google Earth Images © 2019 Digital Globe / CNES / Airbus)

Also in the Sabaean city complex of Yala (ancient Hafari) numerous looting holes can be observed. In the 1980s an archaeological excavation [de Maigret 1988] took place at the site. Only one building, the so-called “House A”, was excavated. This is clearly visible in the satellite image from 2003. After this time several uncontrolled and illegal digs were conducted and multiple structures unearthed (Fig. 8).

However, the monitoring of satellite images also reveals archaeological findings that have not yet been discovered or researched. This is especially true for Bronze Age tombs, which are easy to recognize in the satellite image due to their remarkable shape, but also for kites or entirely unexplored settlement sites, for example in al-Jawf region. These are recorded in AYDA with a short description, date of the satellite image and capture by remote sensing (Fig. 9). These sites have to be checked on site later and described in more detail.

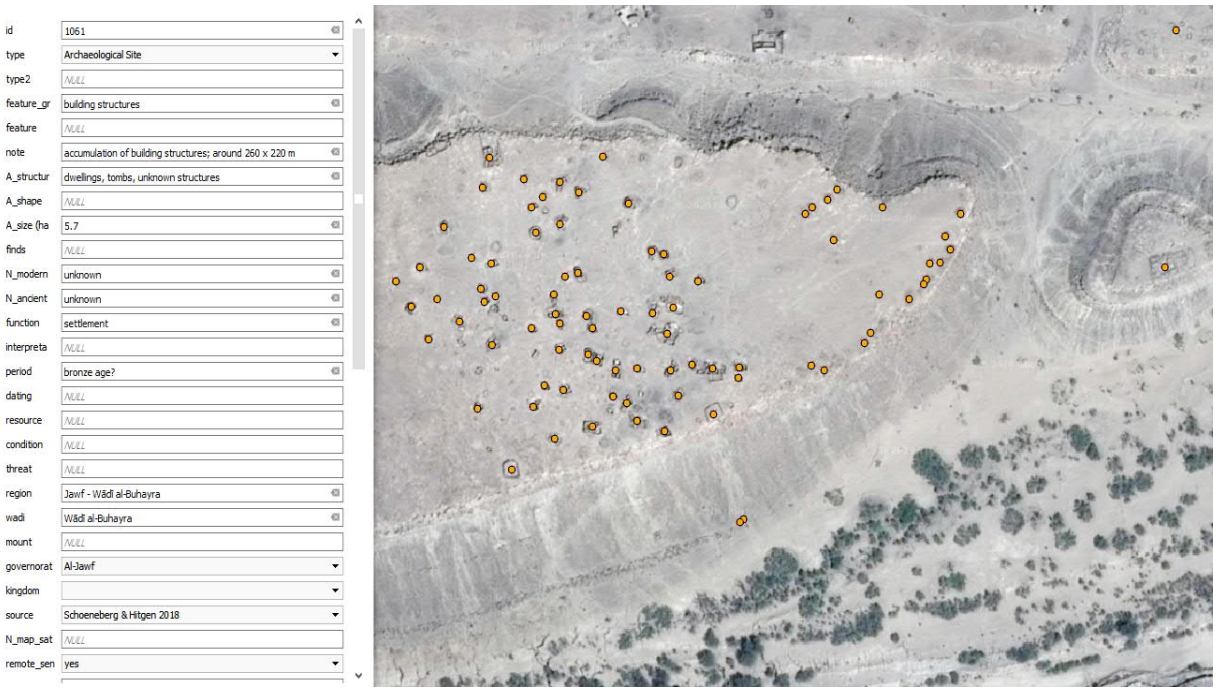

Fig. 9. Unknown settlement in Wadi al-Buhayra (al-Jawf region). Each structure gets an own ID in AYDA with a short description, coordinate assignment and source reference (Attribute Table © Josephine Schoeneberg / DAI, Satellite Image GIS Map data © 2015 Google)

CONCLUSION

AYDA is still *Work in Progress*. While digitization work is progressing well, the linking of the WebGIS with other databases is still to be done. In the end, the system should link every point in AYDA with a wide variety of information sources such as objects, excavation, photo and literature databases. AYDA will be available for selected scientists and cultural institutions. Together with the DAI, the Yemeni colleagues of the Antiquities Authority will keep the program up to date by entering new data and sites. The last-mentioned is necessary in order to enable an exact monitoring of the sites, to guarantee the basis for their preservation as well as a later possible development for the public. A complete release of the system to the public, however, can only take place to a limited extent, since the spreading of sensitive data, including exact coordinates if necessary, can lead to sites being targeted by potential robbers.

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