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Other links:

- https://mennaelmahy.wordpress.com/egypt/jami-al-sultan-al-zahir-baybars-al-bunduqdari/
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The result of this study is considered as a part of our project which included creating suitable solutions for the environmental risks around the archaeological areas in Egypt. The authors would like to express them appreciation to (NARSS), University of Kafrelsheikh, University of Basilicata, and (CNR) for supporting and funding the publication. Thanks are also given to the Egyptian Cultural Affairs sector and the missions (Ministry of Higher Education) for supporting the study.

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- Depending on the suggested points, Drainage system has been proposed to withdrawal the groundwater through digging up some of the trenches at spaced distances around the mosque. The suggested model is used to withdraw the wastewater slowly. The wastewater will be transferred for these trenches with tubes to water recycle station. Finally, this water can be used as pure in the Nile (Elfadaly et al. 2017) (Fig. 20).

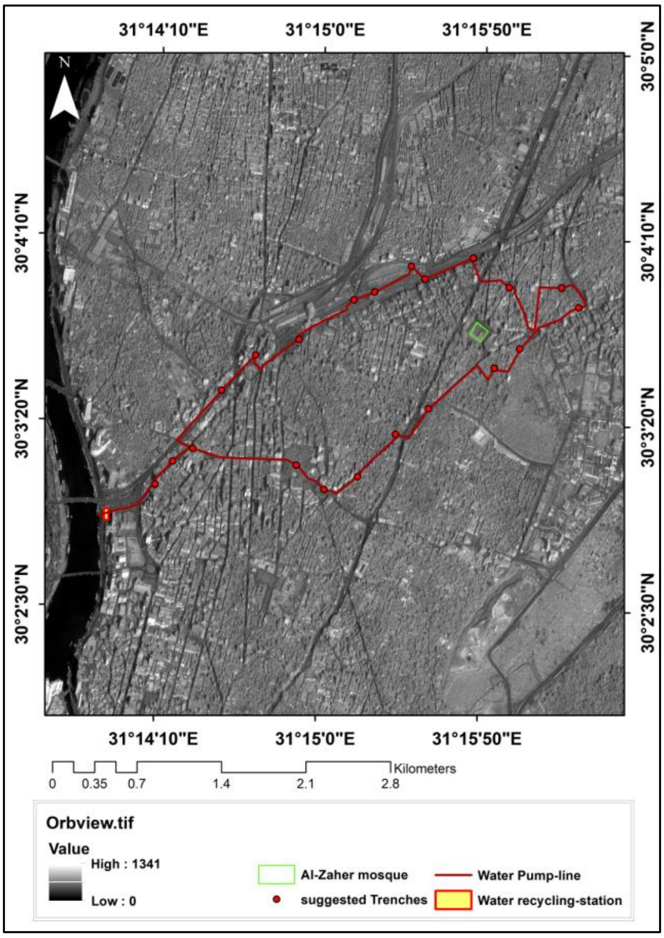


Fig.20 Proposed GIS-modeling around the mosque using Sentinel 2-A satellite image 2017 (RGB 4.3.2).

5. Conclusion

Large areas in Cairo have been experiencing groundwater and water table rise during the last decade. This has resulted in serious problems to the foundations of old houses, antiquities, and monuments. The main causes behind this rising water table and groundwater is the increased recharge from surface activities in a city experiencing increased population. As a whole, outputs from our investigations cleared highlight the environmental monitoring, and detected the changes by the classification and the indices techniques of the study area to observe and quantify the land use/cover changes from a global view down to a local scale. According to UNESCO and accepted published recommendations, some of the innovations solutions have been created to protect the archaeological mosque.

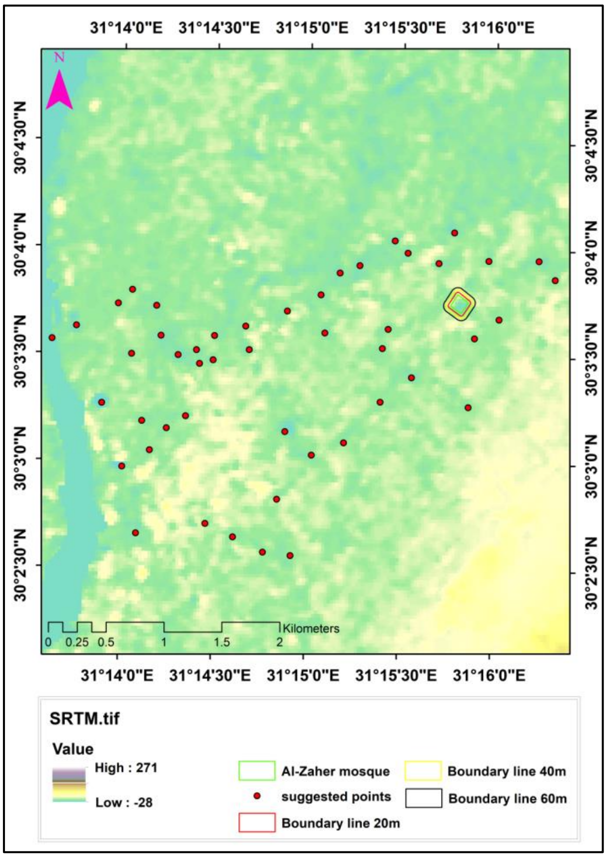


Fig.18 Suggested points for the proposed trenches around the study area.

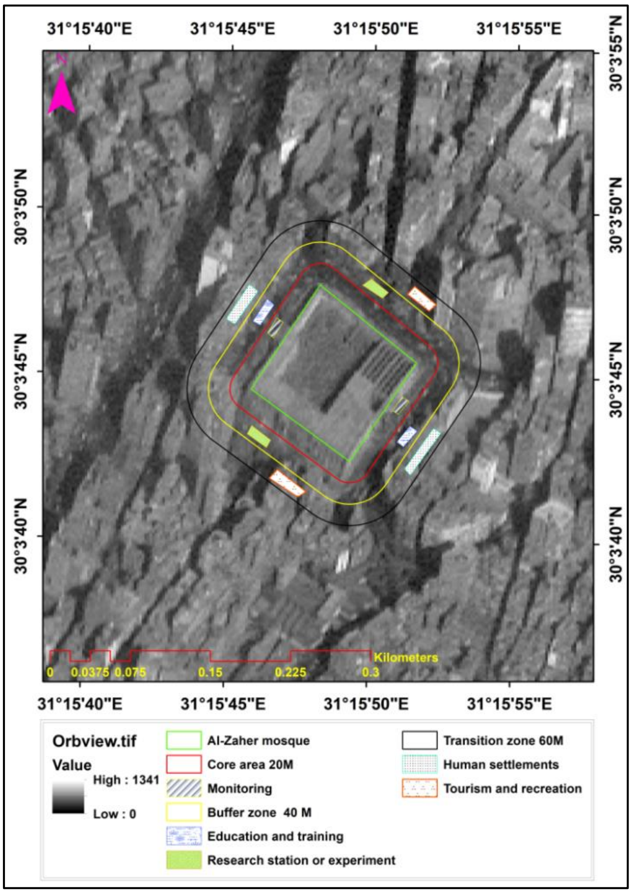
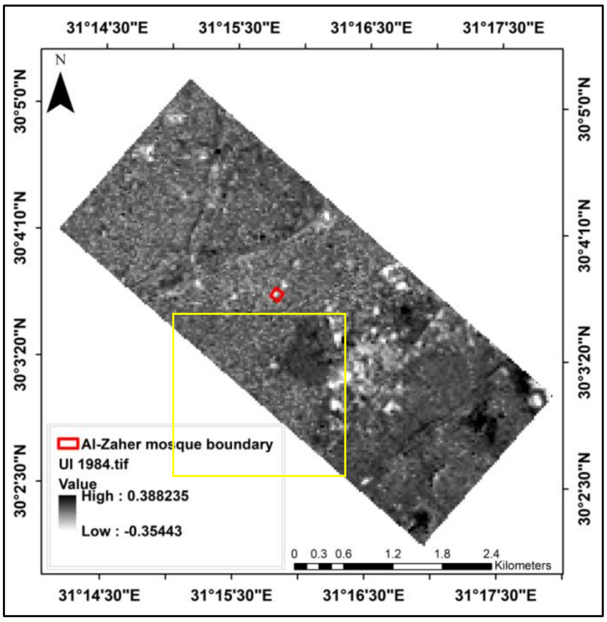
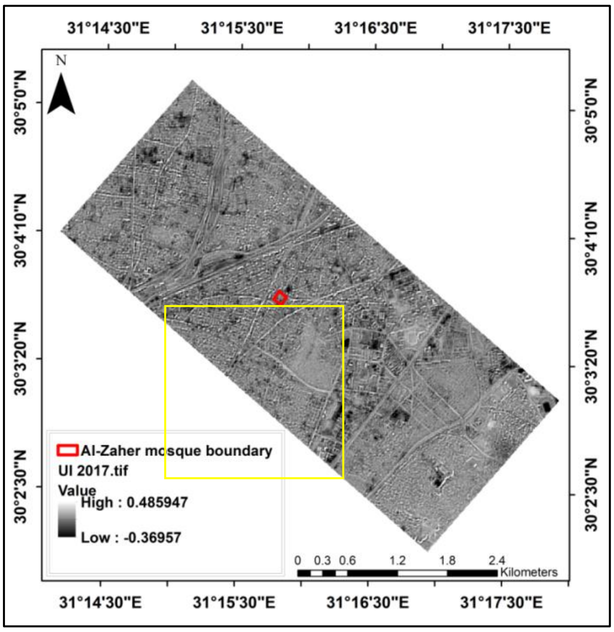


Fig.19 Suggested Zonation areas around the mosque by 3D Orbview satellite image.



(a)

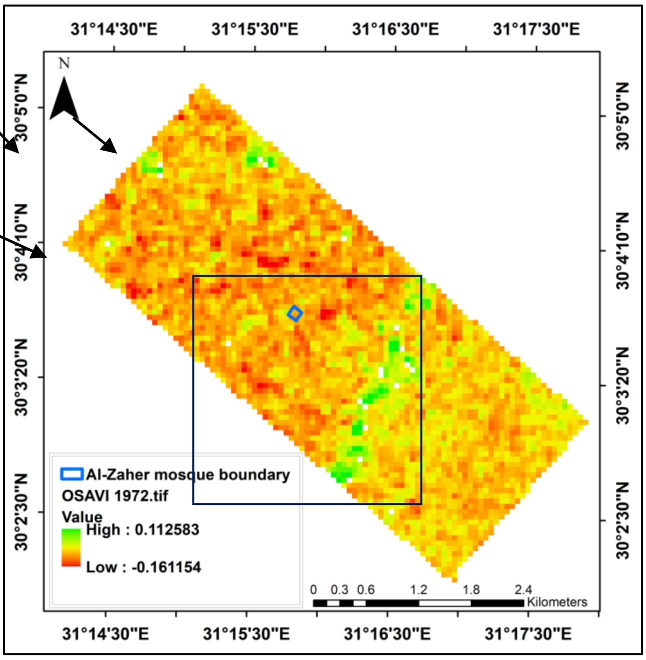


(b)

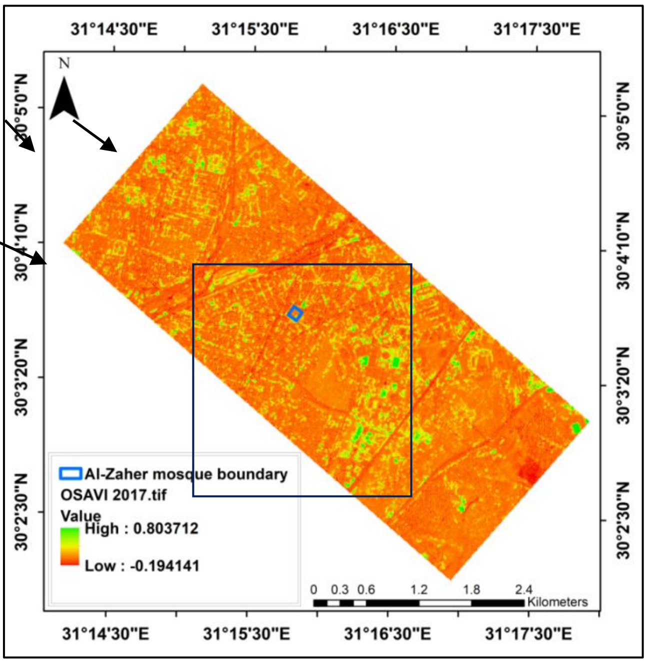
Fig.17 The UI classification for the study area between 1967 (a), and 2017 (b).

4. Recommendation

- Remote sensing and GIS techniques can be met by a Zonation System in Cairo that applies different management policies to different boundary zones. The distances have been chosen as a result of the environmental situation in the study area. The archaeological area must be surrounded by three areas. A suggested points for the proposed trenches around the study area have been carried out using the SRTM Dem (Fig. 18). The first boundary is between the mosque and the core area (monitoring 20 M). The second boundary is between the core and the buffer zone (education, training-human settlements and research station or experiment 20 M). The last is between the buffer zone and transition zone (tourism and recreation 20 M) (Lasaponara et al., 2017) (Fig. 19).



(a)



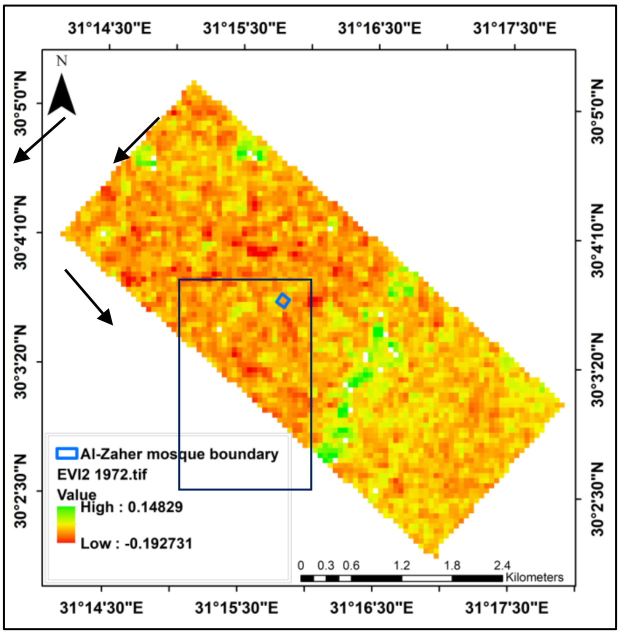
(b)

Fig.16 The OSAVI classification for the study area between 1972 (a), and 2017 (b).

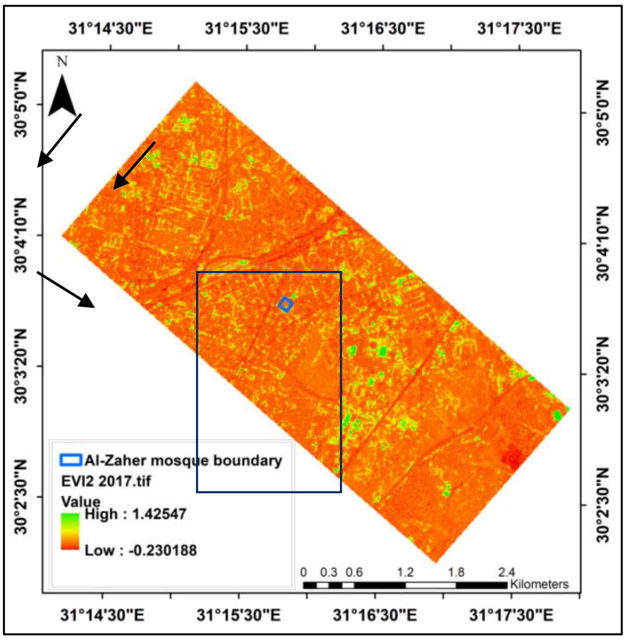
On the other hand, the Urban Index (UI) using Landsat TM 1984 and Sentinel 2-A 2017, The expression of the EVI2 equation is presented as follow (Li et al., 2017);

$$\mathbf{UI = SWIR2 - NIR / SWIR2 + NIR} \qquad \textbf{(3)}$$

The results in the UI index, indicated that there is a development in urban area. UI value Clearfield that the change in the built-up value from 1984 to 2017 was enormous. These effects are very clear in the built-up around the archaeological area from 1984 and 2017 (Fig. 17a, and b).



(a)



(b)

Fig.15 The EVI2 classification for the study area between 1972 (a), and 2017 (b).

OSAVI (optimized soil adjusted vegetation index) is a simplified version of SAVI to minimize the influence of soil brightness (Bagheri et al., 2013). The expression of the OSAVI equation is presented as follow;

$$\mathbf{OSAVI = 1.6\ [(NIR - Red)/(NIR + Red + 0.16)]} \qquad \mathbf{(2)}$$

Results indicated that there is a decrease in the changes between the two studied dates. These effects are very clear in the vegetation area around and interior of the archaeological area between 1972 and 2017 (Fig. 16a, and b).

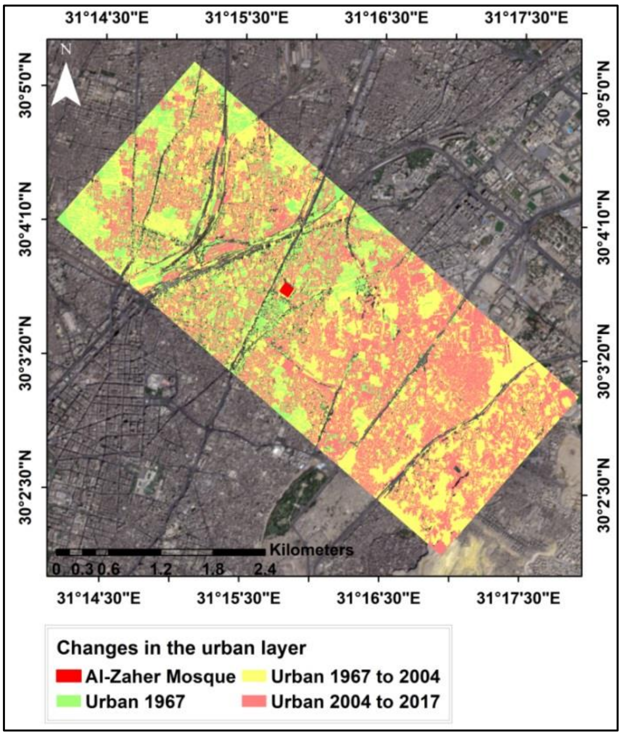


Fig.14 The total changes in the urban layer between 1967 and 2017.

Band combination analysis were carried out in the study area in order to measure the effects of urban sprawling and vegetated areas. The EVI (enhance vegetation index) is designed to enhance the vegetation signal with improved. The expression of the EVI2 equation is presented as follow;

$$\mathbf{EVI2 = 2.5 \times \rho NIR - \rho red / \rho NIR + 2.4 \rho red + 1 \qquad (1)}$$

Where ρNIR and ρred are the NIR and red reflectance (Miura et al., 2003). In details, the EVI2 value highlighted and identified that the decrease in the vegetation change value from 1972 to 2017 was enormous. These effects are very clear in the agricultural land around the urban area from 1972 to 2017 (Fig. 15a, and b).

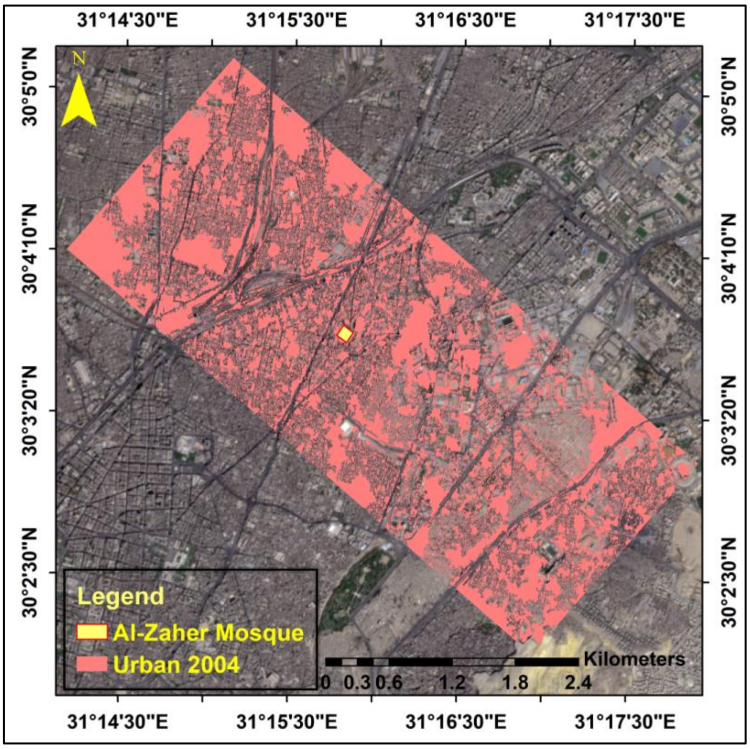


Fig.12 The supervised classification for the urban area in 2004.

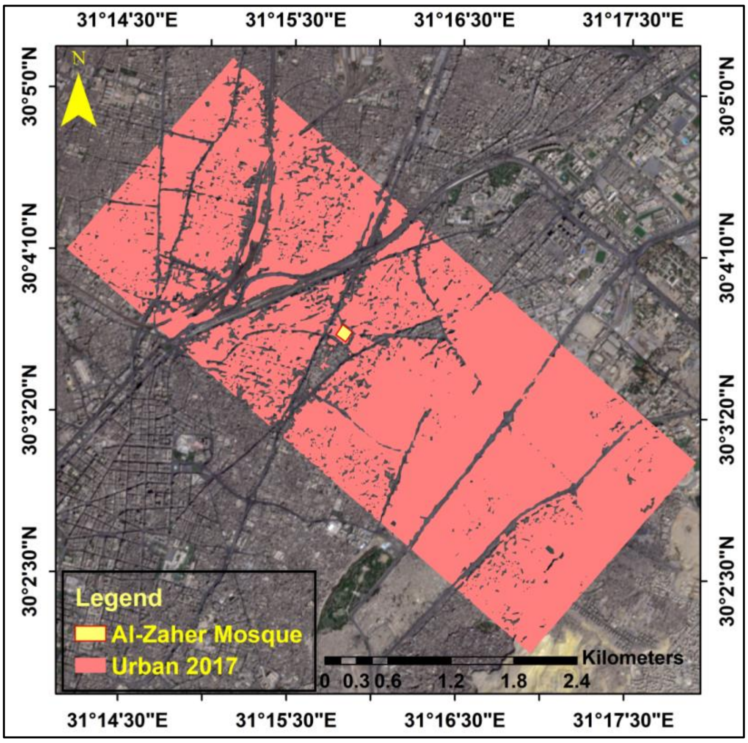


Fig.13 The supervised classification for the urban area in 2017.

The changes have been extracted by the differences revealed from unsupervised, supervised classification, and post classification applied to the scenes acquired at different times for the study area. The results obtained from the classification images of the three dates are used to calculate the area of change related to different land covers. In particular, the analysis of Corona 1967, Orbview 2004, and Sentinel 2-A 2017 imagery in Cairo revealed that the urban area increased about 3.93 km2 from 1967 and 2004. In the other hand, increased 4.06 km2 from 2004 and 2017. (Table 1). As a whole, over time between 1967 and 2017, the urban area clearly increased (Fig. 11-14).

Table. 1 The urban layer changes in the study area by ±Km^2 between 1967 and 2017.

Year / Layer	1967	2004	2017
Urban Km^2	3.46	7.39	11.45
Changes Km^2	3.93		4.06
Total Changes %	49.19%		50.81%

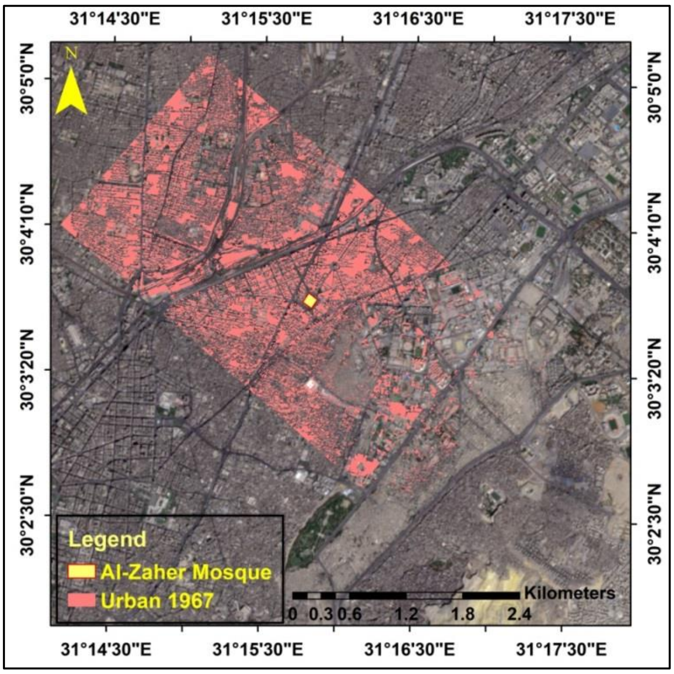
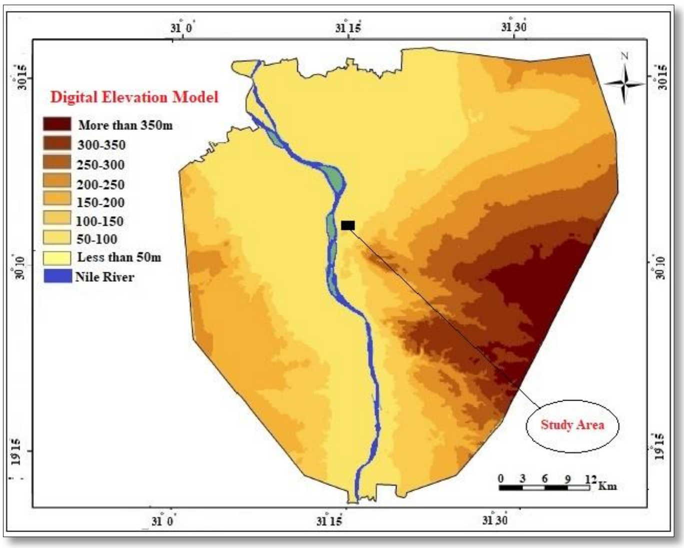


Fig.11 The supervised classification for the urban area in 1967.



(b)

Fig. 9 Topographic contour line (a), and Digital Elevation Model of the studied area (b).

3. Results and discussion

The 2D Elevation model and the watershed has been carried out by SWAT model. The elevations statistics are reported in meters. According to the SRTM Dem and SWAT tool, the mosque is situated between 14m and 23m elevation. It's observed that the direction of the inclination from the southeastern to the northwestern side. Also, the mosque is situated inside a basin, and this situation gave the indicate that one of the reasons of rising the groundwater level in the site of the mosque (Fig. 10).

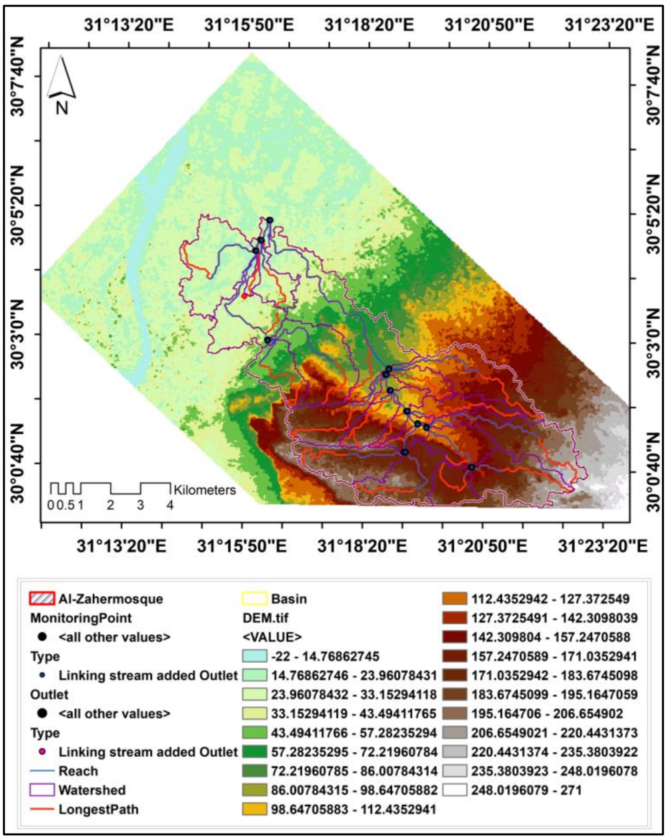


Fig. 10 Watershed delineation by SWAT model and 2D for the study area.

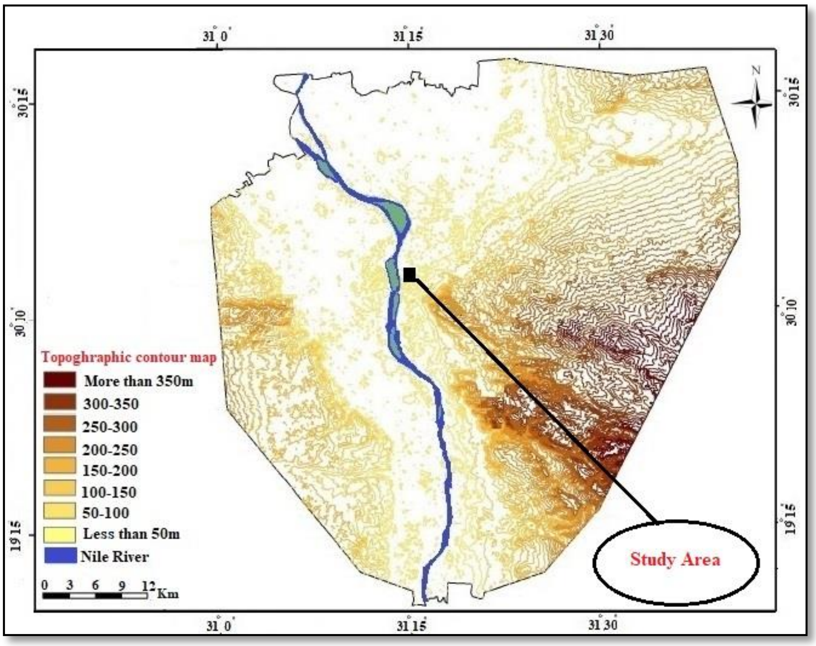
2. Material and methods

2.1 Material

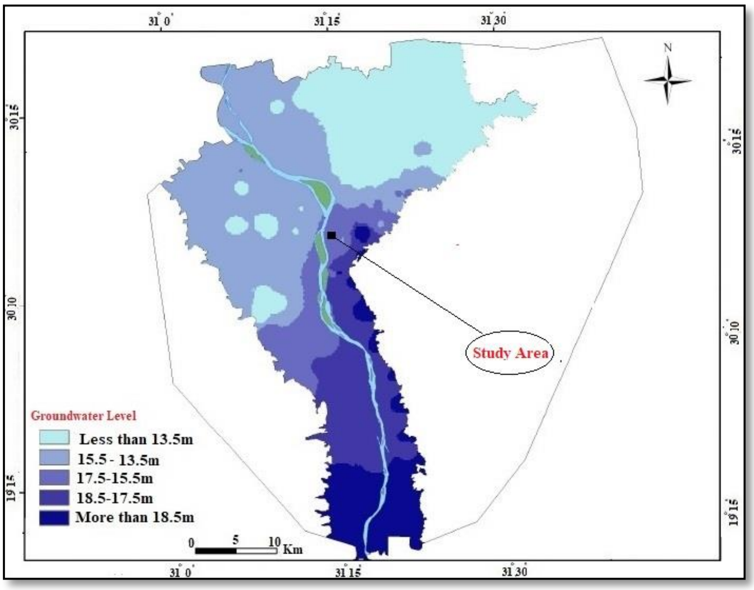
Different sets of data have been integrated to study the effect of rising of the groundwater levels on the archaeological site (Mosque of Sultan Al-Zahir Baybars) at Cairo. Geological and structure map (Scale 1: 100,000, geological survey of Egypt, Cairo, 1983), have been used to study the geology setting of the area and the effecting factors on the groundwater level. The hydro-geological map (Scale 1:100:000 RIGWA, 1990) is used to determine the groundwater flow directions and groundwater characteristics. The material of the satellite images are depended on the one and multispectral bands. SRTM, Corona 1967, Landsat MSS 1972, Orbview 2004, and Sentinel 2-A satellite images.

2.2 Methods

In this study, various remote sensing data have been used to detect the changes in the urban layer. Another technique has been carried out using the band indices to detect the changes between 1973 and 2017 in the vegetation and new built-up areas. Classification, Urban index (UI), Vegetation indices techniques have been used. Digital Elevation Model of the studied area was generated from the elevation points and the vector contour line (using topographic map scale 1:50,000) using Arc Map V.9.3 software (Fig. 9a). Topographic situation of the study area as an impact of this structural setting (Fig. 9b). Geological and structure map (Scale 1: 100,000, geological survey of Egypt, Cairo, 1983) used to study the geology of the area and the factors effecting on groundwater level. The hydrogeological map (Scale 1:100:000 RIGWA, 1990) was used to determine the groundwater flow directions and groundwater characteristics. The processing of the satellite images is done in ArcGIS 10.1 and ENVI 5.1 software. The layer stacking, dark subtract, geometric correction, unsupervised classification, supervised classification, and post supervised classifications techniques are carried out using Envi and ArcGIS software.



(a)



(b)

Fig. 7 Depth to water table of groundwater in the study area (a, and b).

(a)

(b)

Fig. 8 Vegetation area is spreading interior of the mosque (a), and the deterioration in the Mosque as a result of the rising in the groundwater level through the studied area (b) https://en.wikipedia.org/wiki/Mosque_of_al-Zahir_Baybars .

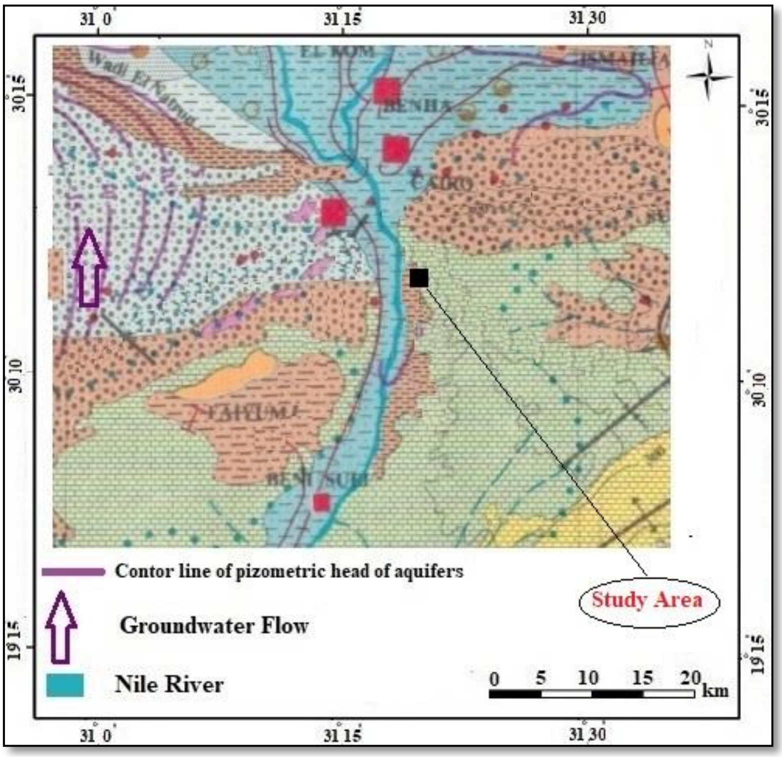
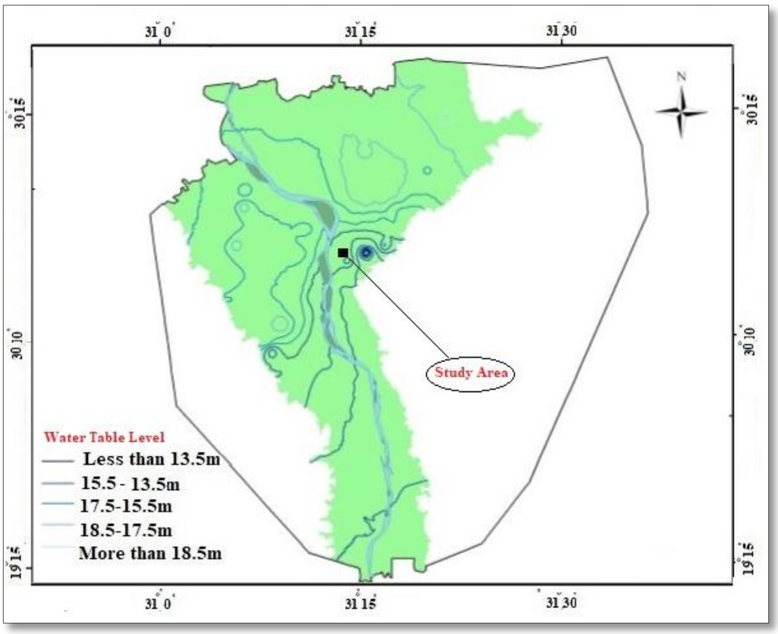


Fig. 6 Hydrogeological map (scale 1:100:000 RIGWA, 1990) showing the groundwater levels and Flow paths map.



(a)

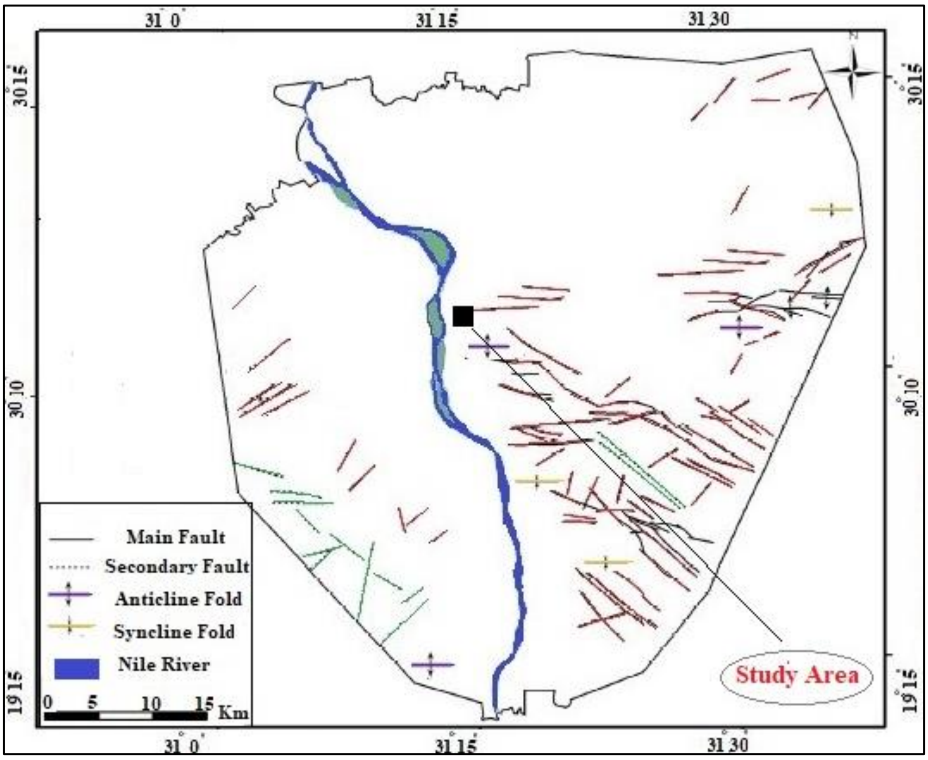
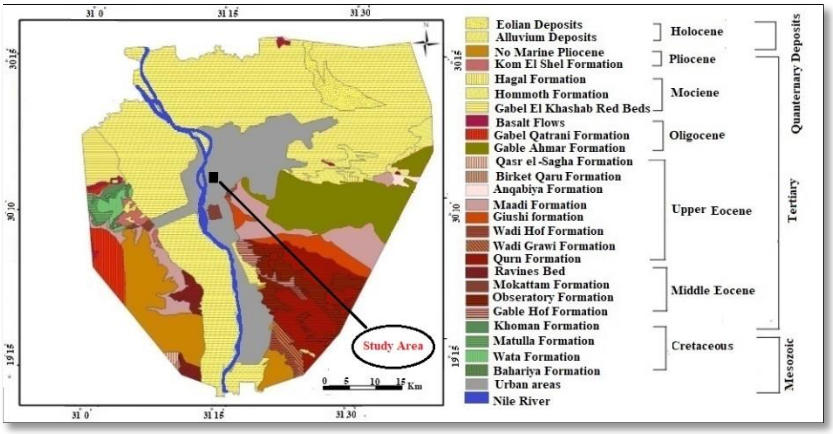


Fig. 5 Structure map of the study area, after geological survey of Egypt, Cairo, 1983.

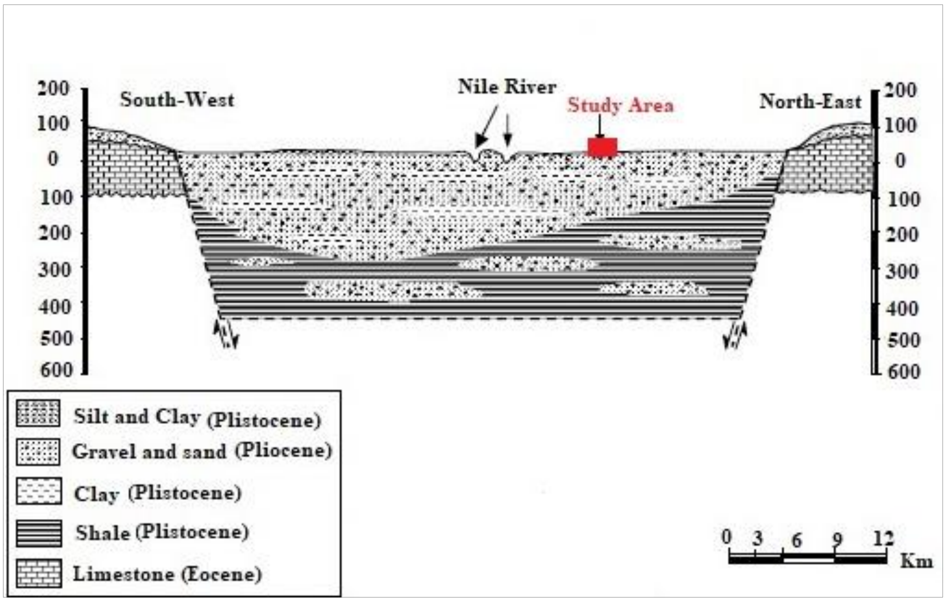
1.3.2 Hydrogeological Setting

Many researchers worked by various methods to protect the archaeological sites in Egypt against the groundwater threats (Elfadaly et al., 2017, 2017, Lasaponara at al., 2015, 2016, Antoniou 1985, Moselhy 1989), threw light on historical back ground of AL-Fustat city (Hefny 1989, Attalla 1997), which investigated the groundwater problems in Old Cairo (Fig. 6). Besides the problems of the urban sprawling, the eastern part of the study area affected by the rising in the levels of the groundwater, this indicates that the recharge rate is high than the discharge of the Nile River. The highest levels of groundwater are in the Eastern part of great Cairo, as in Abbasia district, the levels of groundwater and that of the River Nile are affected by each other, especially after the building of the high dam (Zaghloul and Elbeih 2014) (Fig. 7a, and b). Urban encroachments, the geological, and hydrological setting have a great role in the archaeological damage (Fig 8a, and b).

although they agreed with pervious worker (Swedan 1991) (Fig. 4a, and b). The horizontal and vertical movement of water is greatly affected by structures (Faults and folds), as, it is considered to be one of main factors responsible for changing the groundwater in the area (Sadek 1926, Sanford and Arkell 1939) (Fig. 5).

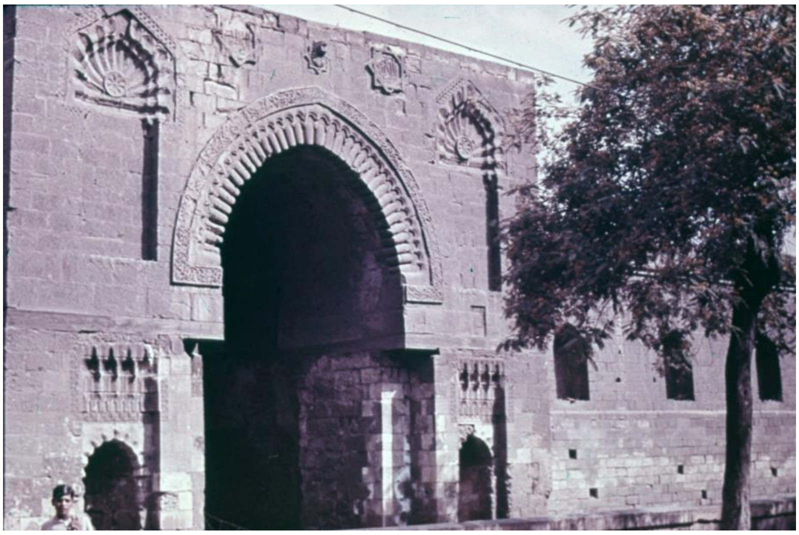


(a)

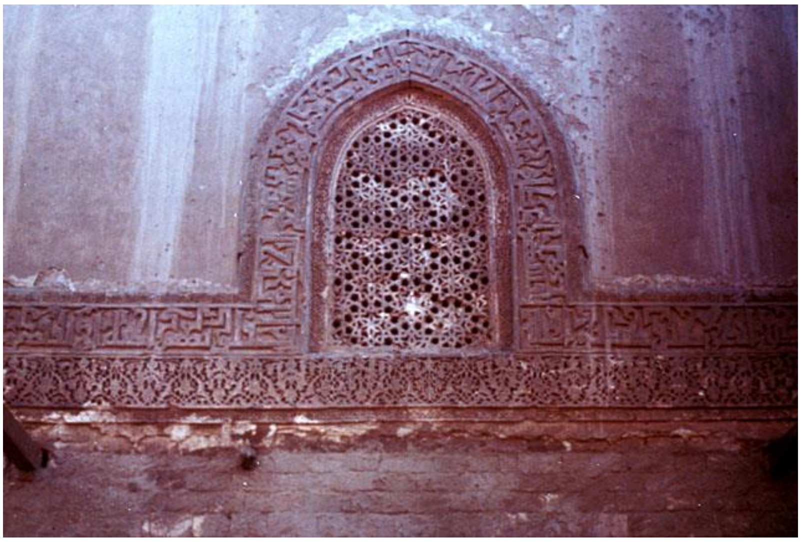


(b)

Fig. 4 Geological map and b lihological cross section of the study area, after geological survey of Egypt, Cairo, 1983.



(c)



(d)

Fig.3 Some of the architectural elements of Al-Zahir Baybars mosque (a, b, c, and d).
https://archnet.org/sites/1552/media_contents/6512

1.3 Problem definition.

1.3.1 Geological and structure setting

For more than a century, studying the geological status of Cairo have been received a great attention of many geologists (Schweinfurth 1883, Blanckenhorn 1901, Barron 1907). For Identifying the formation that covered this district as Oligocene sands and gravels (Sandford and Arkell 1939). There are no doubt that, the geological characteristics played an important role for highlighting the role of geological formations and structures as one of the factors affecting water characteristics in the study area, whether it surface water or groundwater (Abu ELSoud 2006), investigated the environmental relation between the geologic structures and the geo-morphological characteristic of New Cairo area and its vicinity (Shukri and Ayouty 1956), emphasized the structural importance of folding associated with the Syrian arch system

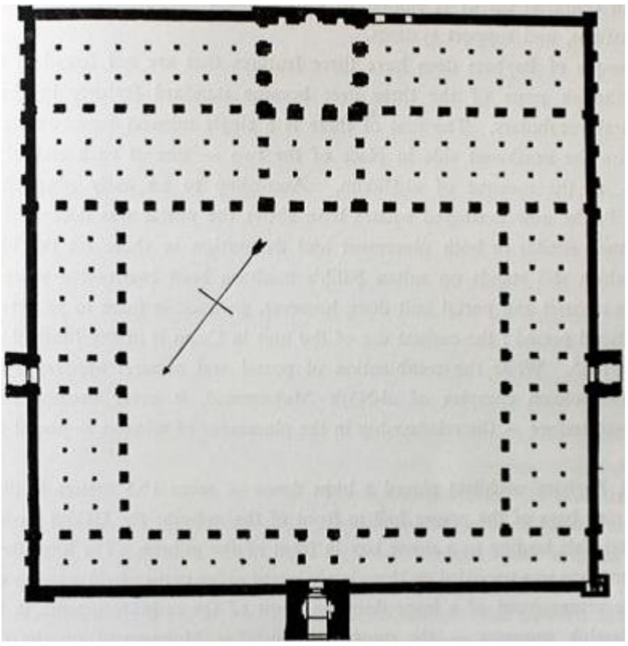
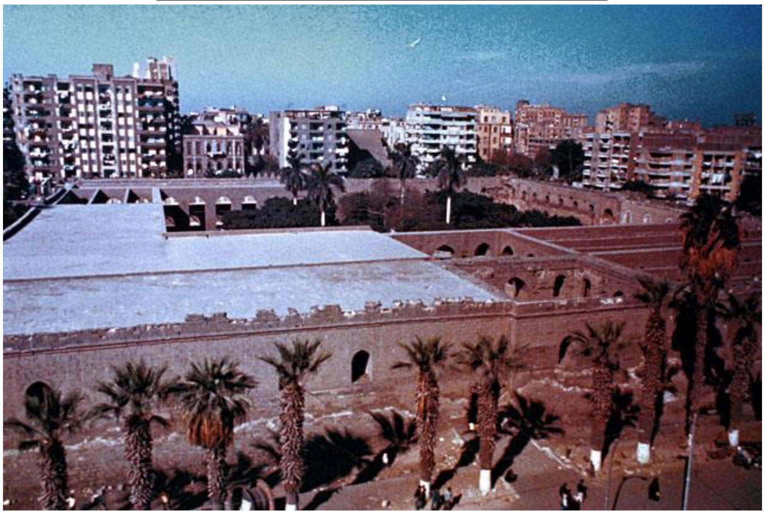


Fig.2 Mosque of Baybars al-Bunduqdari planned. https://mennaelmahy .wordpress.com/egypt/jami-al-sultan-al-zahir-baybars-al-bunduqdari/



(a)

(b)

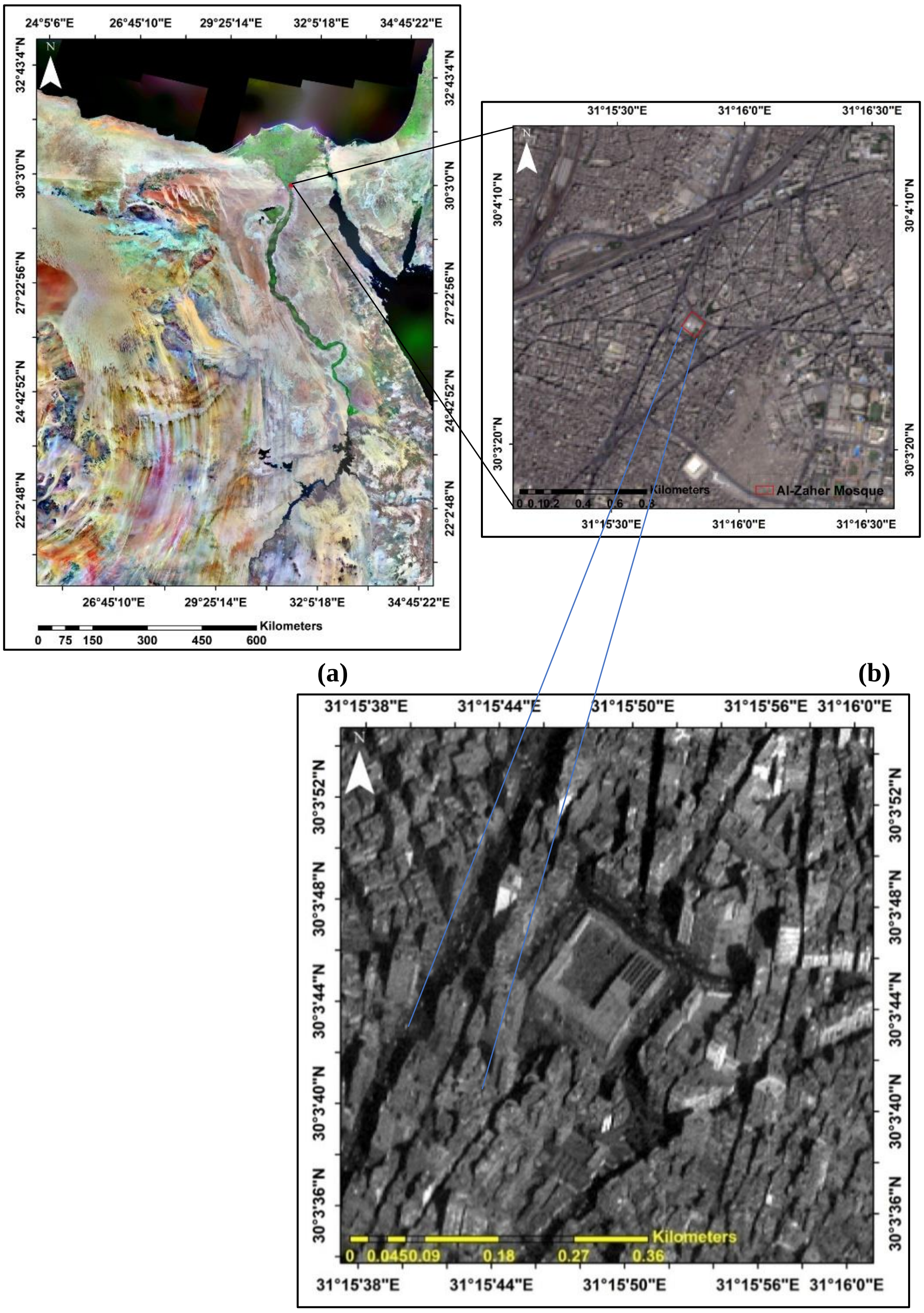
western tower which is stuffed with a drawer reaching up to roof of the mosque. The architect has used several shoulders for buttressing the west-southern and east-northern walls extending from the Qibla's portico. These shoulders are based on the beads of an arch that constitute such portico. The higher distance higher above the walls are ornamented with seventy-two windows at around eighteen windows for each front; these windows take the form of arches that are framed with Kofi-styled Koranic verses; as regards the windows themselves, they are shielded with geometric decorations (Fernandes 1987). At the center of the mosque there lies an open court yard and square in area; it is surrounded by four portico, the most important of which is the Qibla's portico; it consists of nine arcades with arches based on column and pier. At the center of the Qibla's portico in front of prayer nich, there lie a square Maqsurah, it is surrounds by eight piers with their corners engaged columns, This Maqsurah was covered with a large dome (currently not available, and described by Al-Maqrizi to be as big as that of Imam Shafiae, and it must have been made of wood). At the front of the southern side of the Maqsurah's niche a semi-circular cavity that is portable by a pair of columns; such a niche is void of ornamentation, and it must have been covered in a layer of colored marble as there lies above the niche a white marble slab upon which there exist a foundational text of four lines; within the text the establishment year is mentioned as 666 A.H/1268 A.D. Notably, the Qibla's portico is composed of four arcades with arches carried over marble columns whereas the arches overlooking the court yard are carried over pier built with red brick attired with stucco; and also there exists a transept composed of three Aisle and their arcades start with a perpendicular from the court yard to the niche’s walls (Parker et al., 1985). The two side porticoes comprise three arcades whose arches are perpendicular at the niche’s walls. These porticoes are a transept at the two side entries as parallel to the walls of the niche. As for the west-northern portico, it is composed of two arcades with arches that are posed in parallel with the niche’s walls whereas these two arcades are a transept at their center right in front of the entrance where a columnar post appears. It is noticed that all the internal piers have disappeared except for the piers of Maqsurah; and it can be observed from the arches’ shapes that the buttresses were supported with wooden joints. There is no more trace of any ceilings of this mosque although its overall planning foretells of wooden ceilings which were golden and colorful (Vermeulen and D'hulster 2010) (Fig. 3a, b, c, and d).

1.2 Architectural background of the mosque

The mosque follows the style of traditional mosques with an open courtyard surrounded by four porticoes, the largest of which is contains the Qibla (mubark 1901). The mosque has three main entrances, with the main entrance in the west-north destination and the two other entrances are to the side areas. Despite its negligence and abuse, the mosque is still admirably attracting attention in terms of the beauties of its architecture and luxury of its buildings, which appear at first sight through its Axial entrances and stucco inscriptions (Maher 1971) (Fig. 2). The mosque is more than a hundred meters, with unequal sides where its east-northern side is 106 m, west-southern 105 m, west-northern 103 m, and east-southern 102 m. As such, the mosque has no square shape in reality. The mosque's walls were built out of huge stone reaching up to 11 m high with crenellations that are 1.30 m in height. It has three Axial entrances. The mosque is currently surrounded by a steep ditch below ground level, although it was on the same level of the ground at the time of its construction. It can be observed that the mosque's main entrance lies at the heart of the west-northern, whereas the position of the two side entrances lies at the last third of the two west-southern and east-northern fronts (Yeomans 2006). The main entrance consists of a huge mass that is 11.33 m in width, and it protrudes off the mosque's walls at 8.86 m. At the center of the entrance there lies a door opening that is 3.95 m in breadth, and it is crowned with a arch of stalactites on which there pivoted a pair of engaged columns – missing by now. The entrance is enveloped with two cavities that end with fronts that have stalactites, and below these two cavities are two small cavities which are akin to niches; each cavity is crowned with a arch that takes the posture of semi-circle, and the spandrel of the main arch is enameled with two other cavities ending with two keel-arch that divide off from the center. The front of the higher façade is inscribed with geometrical shapes which are like two squares cutting across at the writing of the divinity expression (Allah). As regards the sides protruding off the entrance, they are enameled with three cavities ending with keel-arch which are capped with geometrical ornaments like circles and polygons filled with star- polygons that are carved in stone. The entrance leads to a vestibule whose sides have two cavities that are crowned with semi-circular arch which were carried over the Engaged columns. The vestibule is roofed with a shallow dome carried over spherical triangles pendentive where a pointed arch appears at the center, and there above lie rows of stucco arch. Above the previous entrance there lie the remains of an ancient building which lasted till the era of Napoleon. It was most certainly a base for the minaret; such a base is decorated along each of the three fronts, where there exist three arch cavities (Creswell 1959). Such an entrance is smaller than the main one; it reaches up to 8.13 m in width, and protrudes off the walls' thickness around 4 m. At the center of the entrance there exists a door above which there lies arch of 3.73 m in breadth. The arch's front is decorated with two stripes of glass ornaments filled with plant-like arabesque. Further, there lie two rectangular cavities that end with fronts that have stalactites, and below these two cavities with oyster arch, this entrance leading to a rectangular vestibule covered with across vault; the vestibule is surrounded by two cavities crowned with horseshoe arch (Meinecke, Michael 1992). Such an entrance is similar in its formation to the east-northern entrance, though it may be a little bigger. The outer angles of the mosque are supported with four towers, two of which are square-shaped occupying the east-southern angle; the other two towers, northern and western, are rectangle-shaped. All towers are hollowed except for the

1.1 Study area

The mosque of Sultan Al-Ẕahir Baybars Al-Bunduqdary at Al-Ẕahir Square is related to its provenance as an ancient site for the game of al-Sauaalijah (Al-Maqrizi 1967, Thoreau 1987). The mosque is considered one of the earliest surviving royal mosque of the Mamluks in Cairo. Situated outside and northwest of the gate of the Fatimid city (DMS Long: 31° 15' 30", 31° 16' 00" E, Lat: 30° 04' 10", 30° 03' 20" N), in what was then the northern suburb of Cairo, it was built on the site of a polo ground, surrounded by greenery and overlooking the Khalij (the quarter now called colloquially "al-Dahit" takes its name from this mosque which, thought in very dilapidated condition, still suggested the grand appearance it must originally have had (Bloom 1999) (Fig. 1a, b, and c).



(a) (b)

(c)

Fig. 1 Egypt by Landsat7 satellite image (a), study area by Sentinel 2-A 2017 (b), and the mosque by 3D of Orbview satellite image 2004 (c).

الملخص

تم بناء مجموعه من المباني الدينيه علي يد السلطان الظاهر بيبرس (حكم 17 عاما، 1260-1277). مسجده في القاهرة مثال على عظمة العمارة المملوكية. يتبع هذا المسجد في تخطيطه النمط التقليدي، بما في ذلك الفناء المفتوح المحاط بأربعة أروقه، أكبرهم رواق القبلة. وتسببت المواد الفيزيائية والكيميائية في إحداث أضرار جسيمة للحجاره التاريخية القيمه للمسجد . تعاني معظم آثار القاهرة الاسلاميه من الأضرار والتدهور وفقا لسبب رئيسي وهو ارتفاع منسوب المياه كنتيجه لسوء شبكات الصرف الصحي والزحف العمراني الغير مخطط. في الوقت الحاضر؛ أصبحت التكنولوجيا الجديدة مثل تقنيات الاستشعار عن بعد تلعب دورا هاما في إدارة التراث الثقافي. بعد أن أصبح الزحف الحضري مشكلة عالمية في البلدان النامية مثل مصر. تتناول هذه الدراسة التوصيف المكاني على مرور الوقت و كشف التغيرات البيئية باستخدام مؤشرات صور الأقمار الصناعية من خلال الصور الجويه Sentinel2-A TM وستستخرج المناطق الحضرية السابقة والحالية باستخدام تقنيات الاستشعار عن بعد ونظم المعلومات الجغرافية. وبشكل عام، فإن الناتج عن هذه الدراسه سوف يسلط الضوء بوضوح على رصد التغيرات البيئيه والكشف عن التغيرات بين المؤشرات الحضريه لمنطقة الدراسة لمراقبة كمية التغيرات في استخدامات المناطق الحضرية والأراضي من وجهة النظر طويلة المدي ووصولا الى النطاق المحلي لحماية المناطق الأثرية. الدراسه الهيدرولوجيه للموقع مع تفسير البيانات الساتلية جنبا إلى جنب مع الدراسات الأثرية التاريخية والدراسات الاستقصائية هي تطبيقات هامة في دراسة إدارة التراث الثقافي. وأخيرا، فإن التكامل بين تقنيات الاستشعار عن بعد ونظم المعلومات الجغرافية سيساعدنا على خلق بعض الحلول الجديده لحماية الموقع الأثري.

1. Introduction

The historical Islamic buildings in Cairo area suffer serious deterioration aspects as with physico-chemical and biological factors (Abd El-Tawab et al., 2012). Like groundwater relate disuses to problems caused by lack of maintenance and inappropriate previous repair attempts. Several parts of deterioration exist such as structures with collapsed elements, cracks and decomposing stone or other materials (Orphy and Hamid 2004). UNESCO World Heritage List encompasses over 1000 cultural, many of these sites are faced with hydrological and geological threats which could have serious effects on the value, integrity and accessibility of their heritage assets (Cigna et al., 2017). Aerial and satellite imagery is considered a critical step toward preserving and restoring a historic sites (Chu et al., 2017). The scientific field of remote sensing has exhibited great potential over the last years for archaeological investigations, even in challenging environments. Optical and radar satellite datasets have been used to reconstruct the archaeo-environment, to map recent land use and land cover changes in areas with archaeological interest, to detect traces linked with archaeological remains or even to investigate spatial patterns between archaeological sites (Agapiou et al., 2017). These non-contact techniques can be used to obtain surface and sub-surface information about damage in the archaeological buildings (Themistocleous et al., 2014, Abdel-Hameed et al., 2015). Indeed, since the beginning of the twentieth century, archive aerial images have been systematically used in the archaeological context (Agapiou et al., 2016). Recently, the spread of new satellite and LiDAR data is leading to the development of effective methodologies to support the monitoring and management of monument disaster risks and assessing the level of damages (Saganeiti et al., 2017). Technically, the multi-temporal remotely sensed variables (e.g., reflectance, spectral indices) have been typically applied at different geographical scales. Within these variables, spectral indices, computed using the spectral signatures of two or more bands of remotely sensed imagery, are one of the most convenient means for extracting land properties (e.g., vegetation, built-up, barren, and impervious surfaces) (Denga et al., 2015).

Deriving the Environmental Problems and Solutions Using Satellite Images Analysis around the Archaeological Mosque of Sultan Al-Zahir Baybars At Cairo, Egypt

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Abstract

Series of great Islamic buildings has been built by Sultan Baybars (1260-1277). His mosque in Cairo is an example of the magnificent Mamluks architecture. This mosque follows the design of traditional mosques, with an open courtyard surrounded by four porticos, the Qibla portico is the largest one. Recently, many of the monuments of Cairo suffer from damages and deterioration according to groundwater. Due to many physical and chemical effects, a valuable historic mosque stone faced serious damage. The rising groundwater due to the overloading of the subterranean hydraulic and sewage systems. Also, the urban crawling has become a universal problem in the developing countries like Egypt. Nowadays; the new technology e.g., remote sensing techniques play an important role in cultural heritage management. The hydrological analysis and satellite data interpretation alongside the historical and survey archaeological studies are important applications in studying the cultural heritage management. This study deals with the band indices, changed detection, and spatial characterization over times. The environmental changes will detect using satellite Images indices in Multispectral Scanner System (MSS), Thematic Mapper (TM) imagery, and Sentinel 2-A. The past and current urban will extract using consolidated remote sensing and GIS techniques. Finally, the integration between the remote sensing and GIS techniques will help us to create some of the models to protect the archaeological site.

Keywords; Environmental problems, Satellite Images, Sultan Al-Zahir Mosque