Construction of GIS Database of Alexandria Based on the Old Maps

古地図に基づくアレクサンドリアのGISデータベースの構築

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要旨

本研究の目的は、エジプト・アレクサンドリアの過去5世紀にわたる景観変遷を明らかにするために、複数の古地図や衛星画像のGISデータベースを構築することにある。アレクサンドリアの古地図は、歴史的に様々目的のもと、外国の探検家、軍人、スパイらによって調査され、作成されてきた。ここでは、1921年にSultan Fouad I（1918-1936）の支援の下で公開された、Eng. M. Gaston Jondetが収集した歴史地図 "*Atlas Historique de la ville des ports d'Alexandrie*" をベースマップとしてGISデータベースを構築し、デジタル・ヒューマニティーズの時代に対応するために、ArcGIS Onlineを通して一般公開した。

abstract

Alexandria was surveyed by foreign explorers, officers, and spies for several purposes. Some produced historic maps were inaccurate, as a result of technical error or rushing implementation. Chosen historic maps extracted from; "Atlas Historique de la ville des ports d' Alexandrie" collected by Eng. M. Gaston Jondet and published under the patronage of Sultan Fouad I (1918-1936) in 1921, plus more recent sources. Recent satellite images are provided from different sources.

In the age of digital humanities, the construction of historic maps of Alexandria via ArcGIS generates a database for understanding the historical attributes of Alexandria and analyzing its LULC change that was carried out over the last five centuries and providing the data for public use.

Introduction

Diversity of the human activity distinguishes Alexandria over twenty-four centuries (4th BCE - 20th CE). Although this civilized multiplicity, the irregular sequence has produced due to several motivations; military, political, social, economic, even religious that impacted the topographic feature and urbanism of Alexandria.

The chronicle and excavation tell the urban transformation from the founding of Alexandria in 332 BCE to the present. On the other hand, the natural hazard was not away from causing an urban transformation in Alexandria over time. Destructive earthquakes and tsunami shocked the city causing the subsided of its shoreline that generated submerged antiquities, subsequently. Digitization and analysis of the historical maps of Alexandria via remote sensing and GIS applications represent a gate to investigate and realize the topographic and urban transformations that distinguished medieval Alexandria.

Sharing data and knowledge is one of the major objectives of this contribution throughout providing it for public, scientific, and development use, in particular.

Historical Urban Evolution and Land Use Change:

The database of the old maps accurately reflects these historical urban changes, which can scientifically support the relevant research studies, especially the urban development of the city over the past five centuries, and adds to leading archaeologists to more positioned discoveries. On the other hand, this database supports the decision-makers and stakeholders to adopt realistic scenarios for proposed development plans of the city from the point of the historical land use and soil stratigraphy.

A narrow strip of land between the Mediterranean Sea to the north and Lake Mareotis to the south was an excellent strategic site for a city. Alexander the Great appointed one of the best architects of the time to build his new city in 332 BC: a Greek named Deinocrates of Rhodes. (Escoffey 2012).

Deinocrates planned Alexandria in Hipodamic (crisscross) pattern and divided it into five quarters attributed to the first five letters of the Greek alphabet. The first two Ptolemaic kings erected many splendid buildings in Alexandria. The Island of Pharos was joined to the mainland by the overpass; a thick wall built in the sea called the Heptastadium encompassed the Great Harbor to the east and the Eunostos Harbor or "Harbor of Safe Return" to the west. A 17 km long canal was dug from the nearest branch of the River Nile to Alexandria conducts fresh water to a complicated underground water network (Escoffey 2012).

Alexandria had access to the Mediterranean countries through its two harbors as well as access to the rest of Egypt via the internal port on Lake Mareotis. All the trade and goods transported by ships across the sea and by boats on the lake and the River Nile made Alexandria a very wealthy city.

Actium battle in 31 BCE converted Alexandria to be the capital of a Roman province instead of an independent Ptolemaic empire. Despite the new modest political position, Alexandria did not lose its value. However, the urbanism of the city has begun to collapse as a result of the civil ideological Christian war against the Roman paganism during C. 3rd and 4th CE (Mahmoud 1961).

Alexandria has exposed to a deep urban tide after the Islamic conquest in 641 CE by 'Amr ibn al-'As, due to establishing al-Fustat south of Cairo as the first capital of Islamic Egypt (Abouseif 1989). The Byzantine Empire attempts never stopped to retake the city, so once 'Amr restored Alexandria after a succeeded attack of a huge Byzantine fleet in 645 CE, he demolished its fortifications to prevent potential Byzantine. As a result of that, most of the Roman and Jews communities migrated to other Mediterranean cities to practice their commercial activities, which are not matching with "Sharia", Islamic Law (Salem 1982).

Alexandria had risen once again, occasionally throughout the successive Islamic eras since C. 9th until early C. 16th. The city was refortified and became the main harbor not only for Egypt but also for the world transit trading, which secured huge income that reflected on its urban expansion. Unfortunately, the Ottoman invasion of Egypt and the new geographic discoveries in C. 15th and 16th that deprived the city of trading income converted Alexandria to a village of fishermen. Over the upcoming three centuries (C. 16th-18th), Alexandria lost most of its urbanism and economical value. People deserted the fortified medieval city, while few of them inhabited the peninsula, which generated around the Heptastadium that attributed as Ville Moderne (New City) on the Napoleonic map 1801 CE, while the medieval city known as Ville Enceints de Árabes (the Ancient Arab City).

The most medieval urban area of Alexandria has been developed during C. 19th, due to the European modernization that spread in the city in response to the Mohamed Ali dynasty and the European community that settled in the city.

Natural Hazard and Human Activities Impact on Alexandria:

The natural hazard and human activities impacted Alexandria and caused a deep topographic and urban transformation. The old maps database presents maintained historical landmarks, and leads to figure out the historical context of the land use and urban evolution of the city (Fig. 1).

Seismic hazard, destructive earthquakes, and tectonic movements, in particular, were shocking Alexandria, frequently. Between 320 and 1303 CE, twenty-two destructive earthquakes were recorded. The massive one of 396 CE split the shoreline and submerged the northern strip of the city that contains the Ptolemaic Royal district and naval platforms (Samir *et al.* 2005). During the Islamic period, another destructive earthquake shocked the city, causing the collapse of the splendid ancient buildings. Among them was Pharos (lighthouse), one of the seven wonders of the ancient world (Table 1).

Table 1. Samples of destructive earthquakes on Alexandria (Samir *et al*.2005).

AD	AH	Lat. N	Long. E	I	M	Location
396		31.3	29.55	VI	5.1	Alexandria
672	108	30	29.21	VII	6	Alexandria
1303	702	22.9	32.8	VII-VIII	5.8	Mediterranean

The natural hazard was not the only superior impact on Alexandria, but also the human hazard that had this feature represented in colonial expansion, due to various aspects, especially ethnic and religious conflicts, added to the economic and political conditions that characterized the medieval ages.

Within the framework of the database, the satellite images overlaid on old maps provide a comprehensive visualization of the impact of the natural disaster on Alexandria. The change of the shoreline, which is the main urban axis of developing the city, is the most prominent feature represented in the submerged antiquities that condense on the shoreline of the eastern harbor. The successive development projects that had been

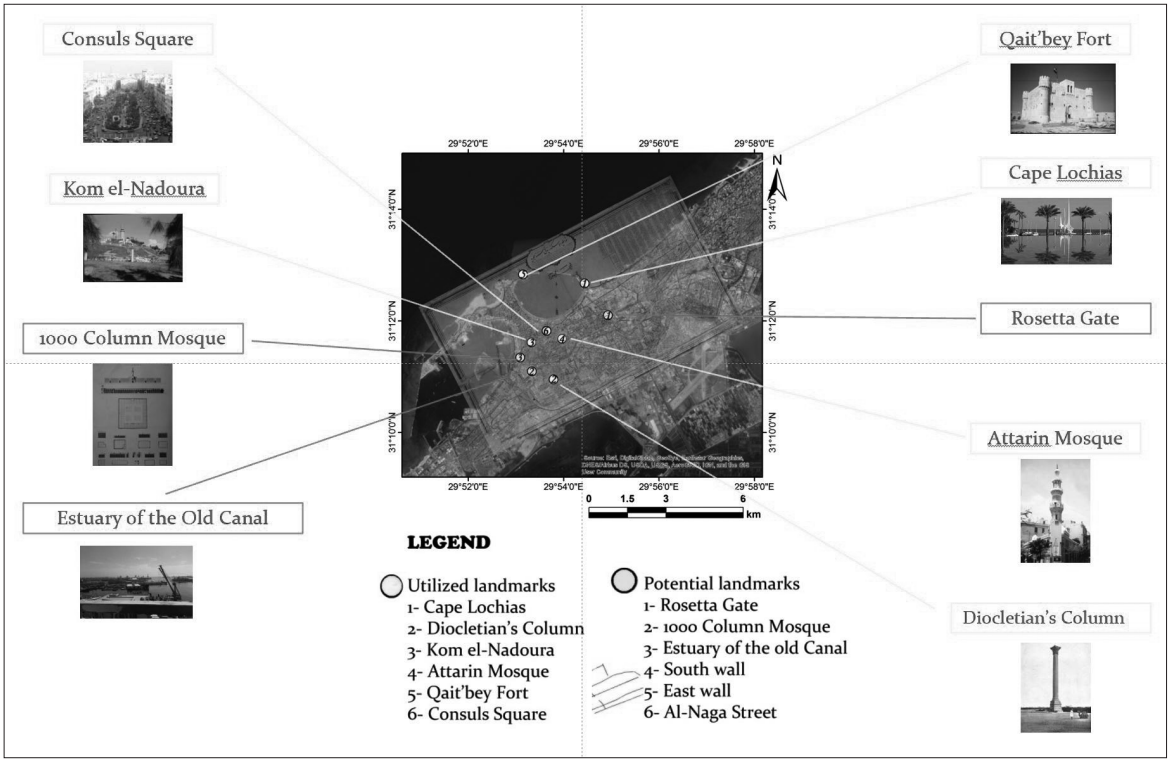

Figure 1. maintained and potential historical landmarks of Alexandria on al-Falaki map, 1866 CE.

carried out in the city since the late C. 19th, contributed to changes in the shoreline aiming to the construction of sea road that demanded filling the shoreline itself to add more expansion to the sea road, which connected the vital activities of the city, so far.

In the same context, the database shows historical development projects that changed Alexandria's land cover, especially the water bodies. Lake Hadara was filled by the early C. 20th to plan Smouha, which is one of the most preferred neighborhoods of the elite. Additionally, Lake Mareotis is shrinking, frequently for commercial and industrial use.

Methodology and Data Acquisition:

Currently, the database contains twelve cards of historical maps that record Alexandria over five centuries, derived from several sources. Despite the abundance of historical maps on Alexandria, it has been taken into consideration to follow the criteria of chronology and accuracy. The utilized maps have been nominated for GIS digitization and provided for public use, researchers, and relevant disciplinaries (Fig. 2).

On the occasion of the anniversary of *"La Société Sultanieh De Géographie"* of Egypt. M. Gaston Jondet, the engineer and chief of the maritime utilities of Egypt, edited a special issue of an Atlas of historical maps of Alexandria entitled: *"Atlas Historique de la ville des ports d'Alexandrie"* that published by *"L'Institute Français D'Archéologique Orientale"* in Cairo, (MD CCCC XXI) 1921 CE. Jondet's atlas preserves old maps of Alexandria date back to the late medieval and modern ages from 1472 CE until 1920 CE. (Jondet 1921). The atlas contains fifty-five historic maps that conclude attempts for mapping Alexandria by foreign explorers, officers, and spies for civil or military purposes, some of which were not accurate enough, due to technical reasons or speed implementation.

The database contains an Egyptian contribution of Mahmoud Pasha al-Falaki (the Astronomer) in 1866 CE, who was appointed by Khedive Ismail (1863-1897 CE) to survey Alexandria to identify the ancient city. Al-Falaki's map is one of the most accurate historical maps recording the LULC of Alexandria in the middle C. 19th (Fig. 3).

The Egyptian Authority of Survey had carried out systematic mapping of Alexandria in 1935. The indexed "Atlas of Alexandria" includes (1:10000) sixteen maps that had been published in Arabic edition for the first time in 1935 (E. A. S. 1935). The database includes the sheets that cover old Alexandria.

The old maps of the database were digitized based on maintained historical landmarks which represent the eras of Alexandria, ancient, medieval, and modern. The selected landmarks were chosen according to their location in terms of covering the centre and outskirts of the city, ensuring high accuracy for the old map itself. Fortunately, Alexandria has a diversity of these landmarks, whether in era or typology. Pompey's Pillar dates back to the Roman period (C. 3rd CE), which is the remained archaeological feature of Serapis Temple in the south eastern suburb, Qai't bay Fort of the Mamluk period (1479 CE) located on the north cape of Pharos peninsula, and the estuary of al-Mahmoudiya Canal that was developed by Mohamed Ali (1820 CE) that empties into the western harbour (Fig. 1).

The old maps in TIFF format were processed via ArcGIS (ArcMap/10.5.1) and Arc Pro. that were used to produce this phase according to datum WGS84/EPSG 3857, which was adopted for Egypt (Figs. 4 and 5).

Classification of the used old maps takes into consideration chronology, cartographer, scale, etc. to provide specific reference data (Table 2).

Since the last terrestrial survey of Alexandria in the 1940s, there are no maps that could reflect the

situation in almost one century. As a result, for realizing the contemporary status of Alexandria, the database includes recent satellite imagery used to investigate the changing average of the existing LULC of Alexandria.

Pléiades-B satellite provides orthorectified images of two different years (May 2012/Nov. 2019), which record the variation in the urban change of Alexandria after the 2011 revolution. Additionally, ALOS-2 digital surface model (DSM) and LANDSAT/USGS are used for the same objectives (Table 3).

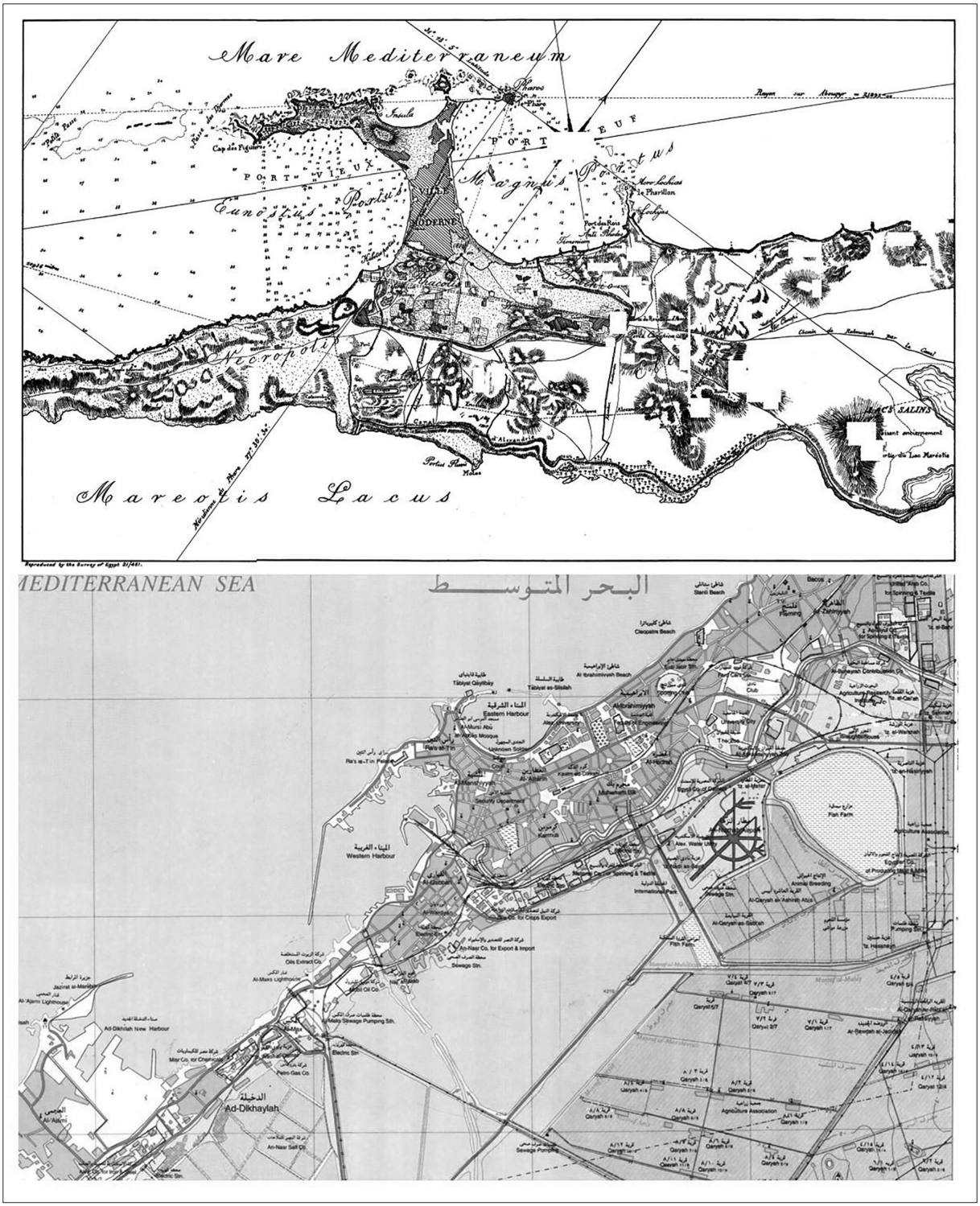

Figure 2. LULC change of Alexandria - the Napoleonic map, 1798 CE (Up) and aerial survey E.M.A.S. 1996 (Down)

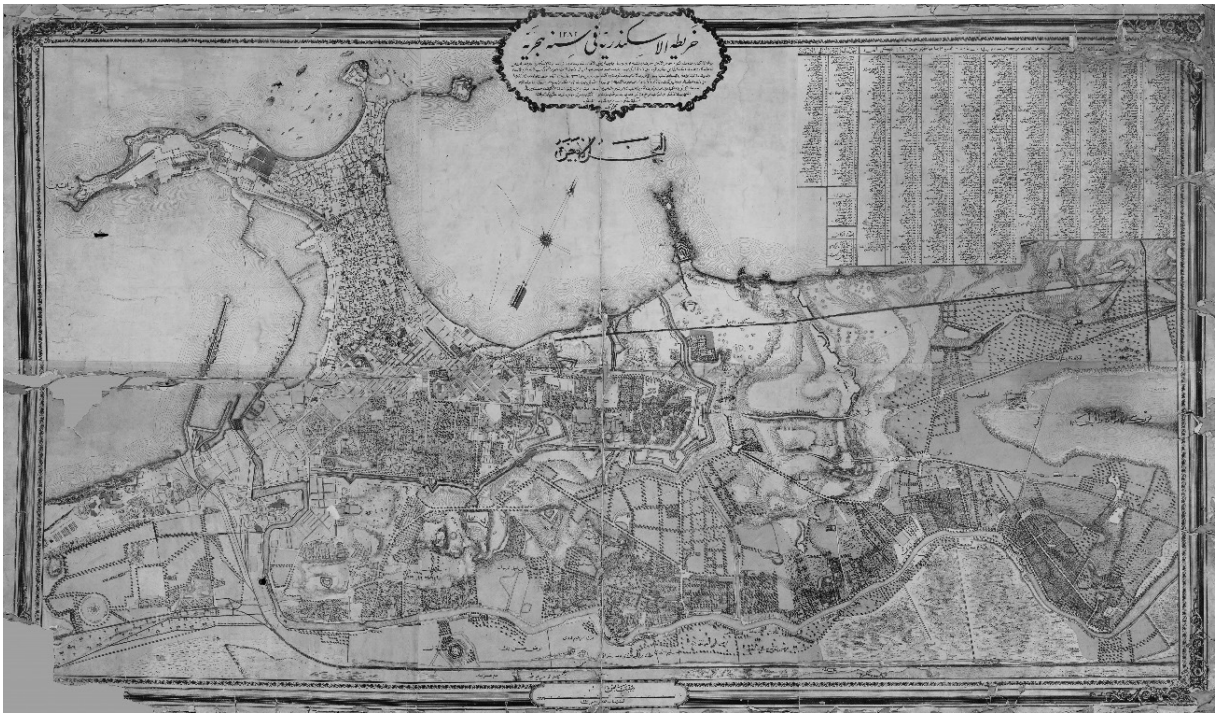

Figure 3. Al-Falaki original map of Alexandria, 1866 CE.

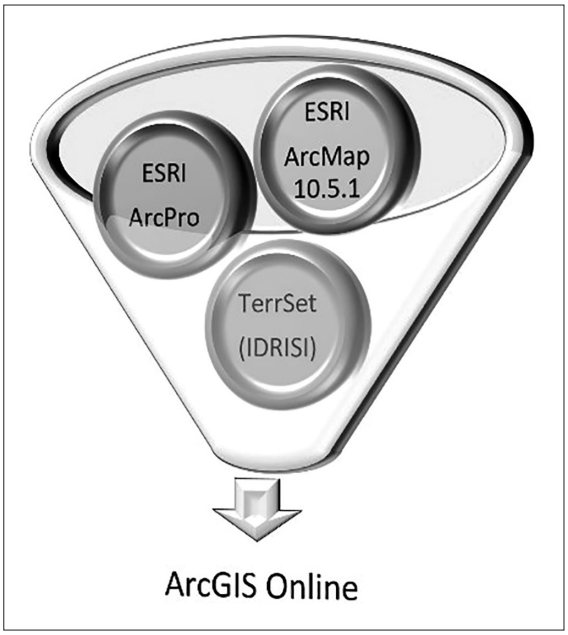

Figure 4. Utilized processing software.

On the other hand, the collected satellite images of Alexandria were analyzed via TerrSet, which was an integrated geospatial software system for monitoring and modelling the earth system for sustainable development.

TerrSet System incorporates the IDRISI GIS Analysis and IDRISI Image Processing tools along with a constellation of vertical applications (Fig. 6).

In the same context, ArcGIS (Arc Map/10.5.1) 3D analysis had carried out for Alos-2 satellite images to classify Alexandria digital surface model DSM 30m (Fig. 7).

Eventually, all data is publicized via ArcGIS Online, which opens new gates for the public use. Access to this database requires creating an ArcGIS Online account in the same way for similar software. All maps in the database have an ascending order according to the year of the survey, where each of them has a legend that includes the cartographer name, map attribute, and the year of the survey, which facilitates to recognize its references.

The ArcGIS Online database, based on ArcGIS Experience Builder, includes an upper matrix of historical maps and satellite images icons, which are displayed in the lower section of the screen by clicking on each, while the navigation panel appears directly on it (Fig. 8).

However, this is the first stage of the uploaded historical maps of Alexandria to this database that will be followed with successive contributions. Now, the contributed database is available via these links:

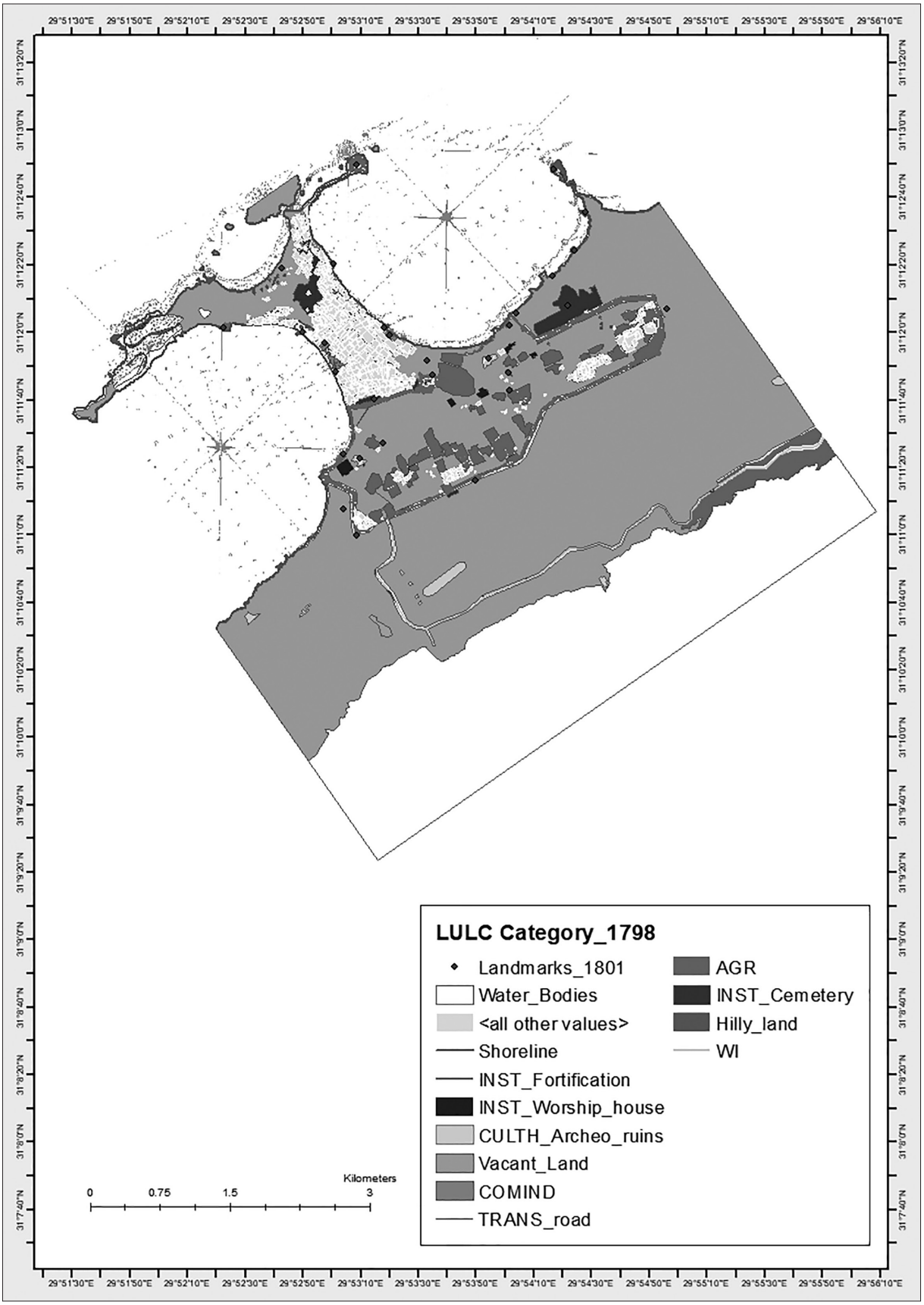

Figure 5. Classifications of the digitized Napoleonic map 1798 CE via ArcMap.

Table 2. Index of database of historical maps.

No. on ArcGIS Online		Cartographer	Attribute	Scale	Date	Source	Cart No.		Remarks
1		A Lyon, chez Horace et Georges Remeus Boissat	Vue d'Alexandrie	Unknown	1665	Jondet, 1921. (CE-Alex. http://www.cealex.org/	Planche VI		Journal de Voyages de Monsieur de Montcony
2		François Cassas	Alexandrie	Unknown	1785	CE-Alex. http://www.cealex.org/			
3	1	MM. Les ingénieures de l'armée d'orient	La Ville Moderne et de Ville des Arabes	Unknown	1798	Jondet, 1921. (CE-Alex. http://www.cealex.org/	Planche XVII		Description de l'Egypte (3 cards)
	2		Carte Générale des côtes, rades, ports, ville, et environs d'Alexandrie	Unknown			Planche XVIII		
	3		Chenaux d'accès au port d'Alexandrie	Unknown			Planche XIX		
4		Charles Muller	Comprenant toutes ses fortifications, rue et édifices principaux	Unknown	1855	Jondet, 1921. (CE-Alex. http://www.cealex.org/	Planche XXXV		
5	1	Mahmoud Pasha al-Falaki	L'Antique d'Alexandrie et de ses faubourgs	1 :5000	1866	"L'Antique d'Alexandrie" Ses faubourgs et environ découverts, par les fouilles, sondages, nivellement et autres recherches			26 Cards
	2		خريطة الإسكندرية في هجرية سنة 1282						
6		Direction Générale du Tanzim	La Ville d'Alexandrie	1:10000	1887	Jondet, 1921. (CE-Alex. http://www.cealex.org/	Planche XLVII		NOT HD
7		Chas et Goad, Civil Engineers, London	Insurance plan of Alexandria	1in:120ft	1898-1905	The Harvard Geospatial Library (HGL) https://iiif.lib.harvard.edu/manifests/view/drs:15525296$1i			
8		Egyptian Survey			1917	CE-Alex. http://www.cealex.org/			
9		Egyptian Authority of Survey	Atlas of Alexandria	1:10000	1935	Atlas of Alexandria (1935)	11	12	Split to 7 sheets
							15	16	
		Total					12 Maps		

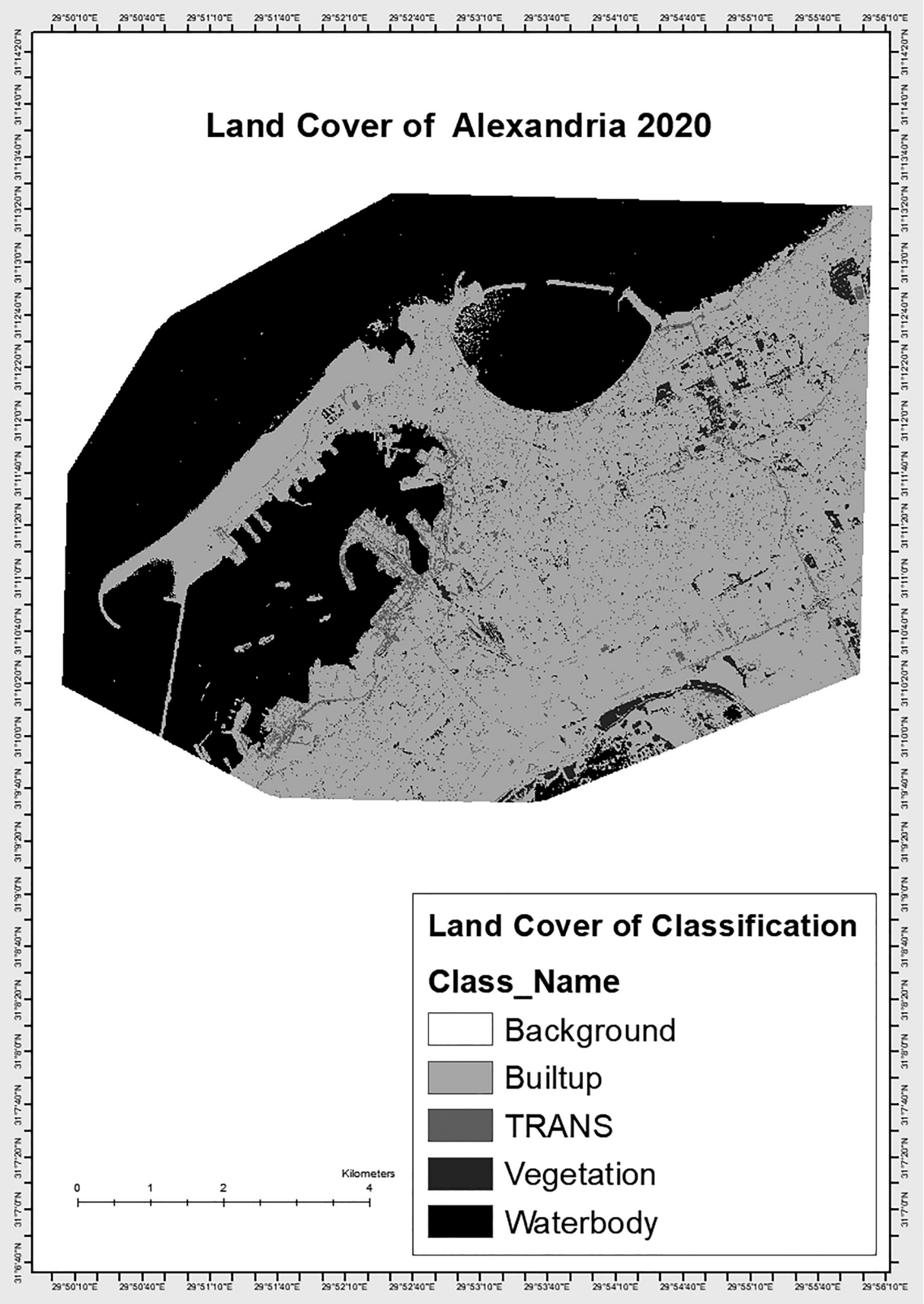

Figure 6. Land cover analysis of Pléiades-B Satellite image 2019 via Terrset.

Table 3. Indexed satellite images.

No. on ArcGIS Online	Item	Source	Description	Resolution
1	2	Pléiades-B	Stereo_DS_PHR1A_201205280854224_FR1_PX_E029N31_1205_00822	Stereo/ 60cm
2	1	Pléiades-B	DS_PHR1B_201911190848364_FR1_PX_E029N31_1106_02862	Ortho/ 60cm
3	3	ALOS-2	ALPSMLC30_N031E029_DSM	DSM/ 30m
4	1	LANDSAT/ USGS	L1C_T35RQQ_A014533_20191218T084754	DEM/ 30m
Total	7			

https://arcg.is/1GPSqT0

https://experience.arcgis.com/experience/bf2197256893419d888874f85fd3af88

Conclusion and Results

A public database of old maps and contemporary satellite images of Alexandria is deploying for public use, in particular scholars and stakeholders to achieve sustainable development goals NSDS 2030.

The current ArcGIS Online database includes twelve old maps of Alexandria integrating with seven satellite images derived from ALOS-2 and LANDSAT/USGS to identify the historical LULC change, so far, in terms of topography and urbanization, which reflect economic, social, and political historical transformation. Pléiades-B raw satellite images of Alexandria are not published on the database regarding commercial considerations.

Providing the collected and analysed data to the public helps scholars of the cultural heritage and other relevant disciplines. On the other hand, the database supports decision makers for developing Alexandria by providing accurate data and historic assessment, particularly for infrastructure, transportation, and housing in the old city.

From the perspective of disaster management, the identification of demolished archaeological sites in Alexandria leads to further discoveries. Additionally, the interpretation of unknown features and phenomena became visualized, such as the resulting subsidence of heterogeneous soil containing multi-layered human activities.

However, the current uploaded data is the beginning of creating an ArcGIS Online database, based on ArcGIS Experience Builder, where future successive contributions will be uploaded and made available publicly.

Now, the database is available to the public via these links:

https://arcg.is/1GPSqT0

https://experience.arcgis.com/experience/bf2197256893419d888874f85fd3af88

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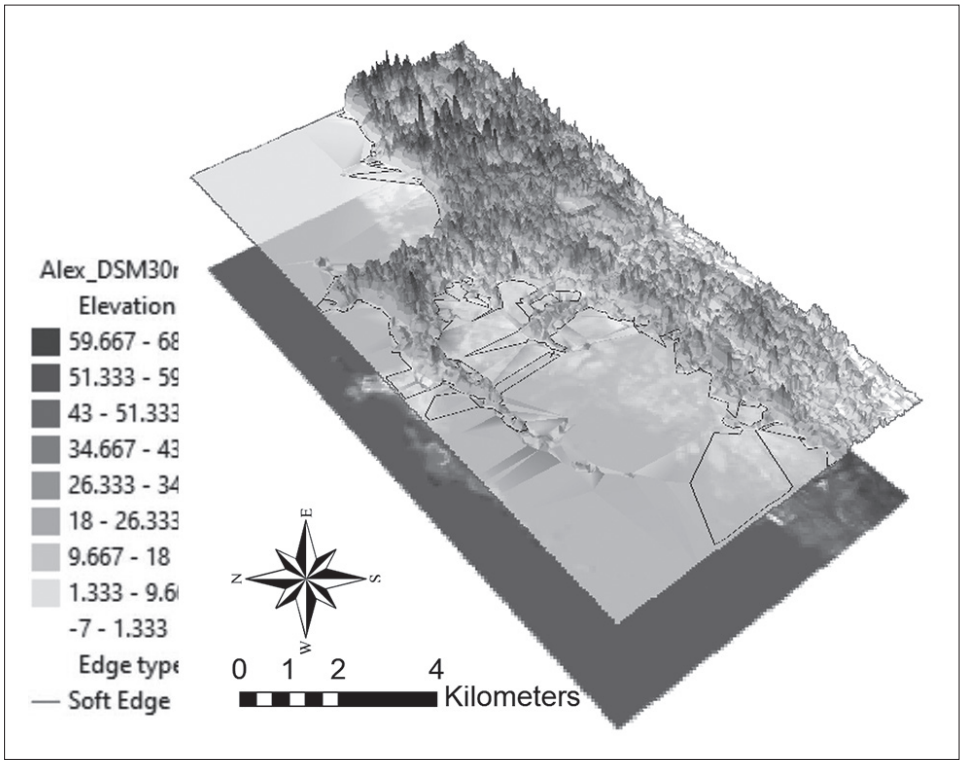

Figure 7. ALOS-2 DSM 30m via Arc Scene.

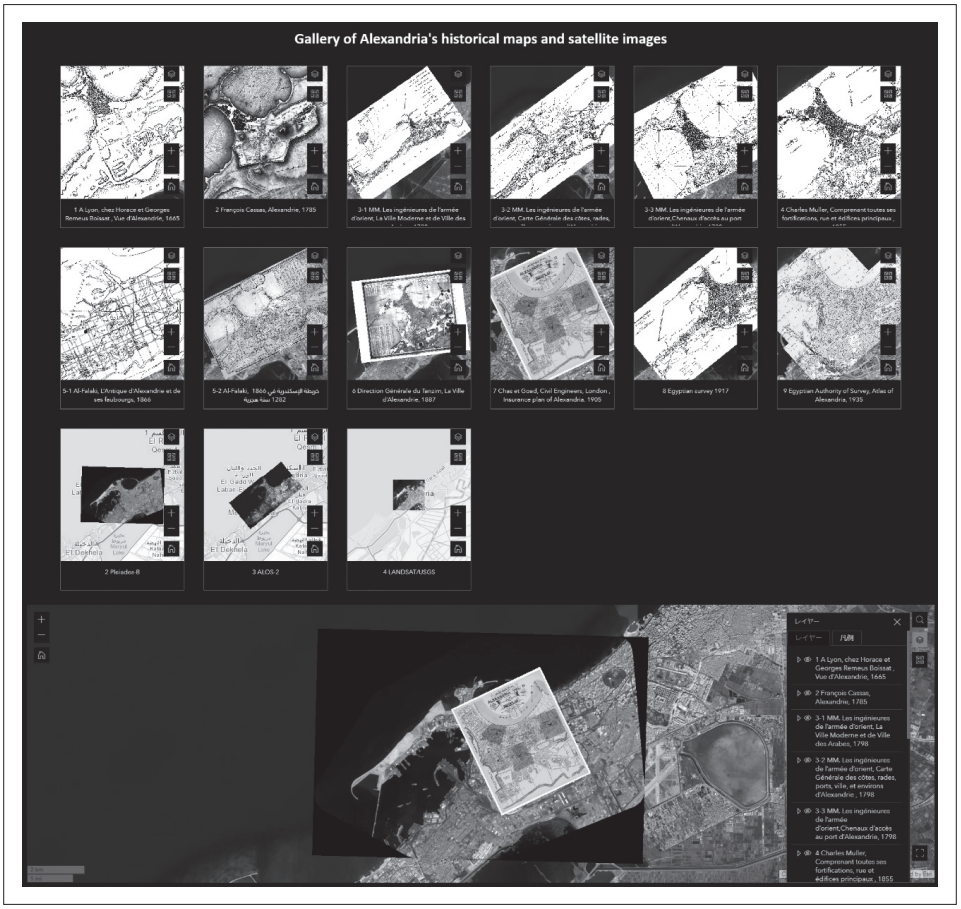

Figure 8. The gallery of the ArcGIS Online database.

Note: Satellite images are not available for public, due to license consideration

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