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Morphology Detection in Archaeological Ancient Sites by Using UAVs/Drones Data and GIS techniques

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Abstract

Today, Unmanned Aerial Vehicles (UAVs) or Drones are a valuable source of data on inspection, surveillance, mapping and 3D modelling matters. Drones can be considered as the new alternative of classic manned aerial photography due to their low cost and high spatial resolution. In this study, drones were used to study archaeological sites. The archaeological Nineveh site, which is a very famous site located in heart of the city of Mosul, in northern Iraq, was chosen. This site was the largest capital of the Assyrian Empire 3000 years ago. The site contains an external wall that includes many gates, most of which were destroyed when Daesh occupied the city in 2014. The local population of the city of Mosul has also largely overtaken the central part of this archaeological site, while the northern and southern parts are still uninhabited. The awareness of the existence of unchanged surface and ground forms in the northern or southern parts led us to prepare an urgent study to interpret the outer surface of those parts and to analyze any discovery in the surface morphology. So, drone data and GIS technologies were used in this study to find any discovery that could aid in understanding the original surface of this ancient site. Visual and digital interpretations of satellite images, drone images, and Digital Surface Models (DSMs) were used to analyze and study the data. As a final result, certain morphological features were identified in the southern parts of the ancient site which could be a new archaeological and compositional discovery with reference to the earlier activities of the ancient society during the Assyrian empires, represented by the ditches and building lands used by the ancient inhabitants. Small modern tunnels penetrated the ancient wall were also discovered in addition, to a drainage canal and a motorway newly constructed during the occupation of the city that had penetrated the archaeological land.

Keywords: Remote Sensing, Photogrammetry, Aerial survey, Unmanned Aerial Vehicles, Aerial photography.

كشف التغيرات في المواقع الأثرية القديمة بإستعمال صور الطائرات بدون طيار ونظم المعلومات الجغرافية

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الخلاصة

تعد الطائرات بدون طيار (UAVs) او ما يسمى الطائرات المسيرة اليوم، مصدرًا قيمًا للبيانات المتعلقة

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بمسائل التفتيش والمراقبة ورسم الخرائط والنمذجة ثلاثية الأبعاد. حيث يمكن اعتبار الطائرات المسيرة البديل الجديد للمسح التصويري الجوي المأهول التقليدي بسبب تكلفتها المنخفضة ودقتها المكانية العالية. في هذه الدراسة استعملت الطائرات المسيرة لدراسة المواقع الاثرية. واختير موقع نينوى الاثري وهو موقع مشهور جدا يقع في قلب مدينة الموصل شمال العراق. كان هذا الموقع أكبر عاصمة للإمبراطورية الآشورية قبل 3000 عام. يحتوي الموقع على سور خارجي يضم العديد من البوابات التي تم تدمير اغلبها عند احتلال داعش للمدينة في عام 2014. كما قام السكان المحليين في مدينة الموصل بالتجاوز على هذا الموقع الاثري بشكل كبير في الجزء الأوسط منه، بينما الأجزاء الشمالية والجنوبية لا تزال غير مأهولة. إن الوعي بوجود أشكال سطحية وأرضية غير متغيرة في الأجزاء الشمالية أو الجنوبية يقودنا إلى إعداد دراسة عاجلة لتفسير السطح الخارجي من تلك الأجزاء وتحليل أي اكتشاف في شكل السطح. لذا ولأول مرة في محافظة نينوى، استعملت بيانات الطائرات بدون طيار وتقنيات نظم المعلومات الجغرافية في هذه الدراسة لاستكمال أي اكتشاف يمكن أن يساعد في فهم السطح الأصلي لهذا الموقع القديم. تم استعمال التفسيرات المرئية والرقمية لصور الأقمار الاصطناعية وصور الطائرات بدون طيار ونماذج السطح الرقمية (DSM) لتحليل ودراسة البيانات. وكنتيجة نهائية، حُددت بعض السمات السطحية في الأجزاء الجنوبية من الموقع القديم والتي يمكن أن تكون اكتشافًا أثريًا وتركيبيًا جديدًا مع الاخذ بنظر الاعتبار الأنشطة السابقة للمجتمع القديم خلال الإمبراطوريات الآشورية، والممثلة بالخنادق وأراضي البناء التي استعملها السكان القدماء. كما تم اكتشاف أنفاق صغيرة حديثة اخترقت الجدار الاثري بالإضافة الى وجود قناة تصريف وطريق سريع للسيارات قد اخترقوا الارض الاثرية شيدوا حديثا واثناء احتلال المدينة.

1. Introduction

Remote sensing and Geographic Information Systems (GIS) are being increasingly used in planning and strategic management of earth resources. Remote sensing is one of the several powerful present techniques for monitoring morphological changes and archaeological features, along with determining their dimensions and gradations through the work of geomorphological maps employing geographic information systems [1]. In recent years, new archaeology technologies have been emerged to provide reliable data easily with a lower cost. UAVs or Drones have become advanced technological devices that archaeologists use and aim to add to their survey and exploring kits [2]. Drones were used for 3D documentation and analysis of landmarks, historical structures, aerial mapping, and forest archaeological analysis. Drones are used now instead of the conventional field walking approach known as the "Pedestrian Survey," which was historically used by archaeologists and archaeology students [2].

According to the international definition, an UAV is a generic aircraft design to operate with no human pilot on board. The simple term UAV is used commonly in the Geomatics community, but also other terms like Unmanned Vehicle System (UVS) or Drone are often used. UAV photogrammetry indeed opens various new applications in the close-range aerial domain, introducing a low-cost alternative to the classical manned aerial photogrammetry and being a valid complementary solution to terrestrial acquisitions (Figure 1) [3,4,5].

While traditional airborne remote sensing still has some benefits, UAV platforms are an important alternative tool for researching and discovering our world. They can provide spectacular illustrative photos of sites, and they can also be used to establish metrically accurate records for surveys and conservation work, particularly in historical sites or for quick response applications. Sensors such as cameras, multi (hyperspectral) imaging systems, and even laser scanning may be carried by UAVs.

The use of UAVs to survey archaeological sites is becoming increasingly widespread, due to the ease of use and the accuracy of the measurements being processed. In order to conduct an archaeological survey, the UAV should be capable of safe flying and composed of high-quality materials. They may be pre-programmed or radio-controlled to correct themselves.

UAVs perform surveys as a mean of tracking and supplying information to archaeologists as needed. The UAV flights also provided researchers with updated details on the excavation phase in this field in addition to, the 3D model of the archaeological site. Several cultural heritage explorers have used unmanned aerial vehicles (UAVs) to survey archaeological sites in the Mediterranean [6,7,8]. Germany, Cambodia and Hungary [9,10,11]. Scientists also used UAV-derived aerial imagery for the 3D restoration of heritage sites [12,13].

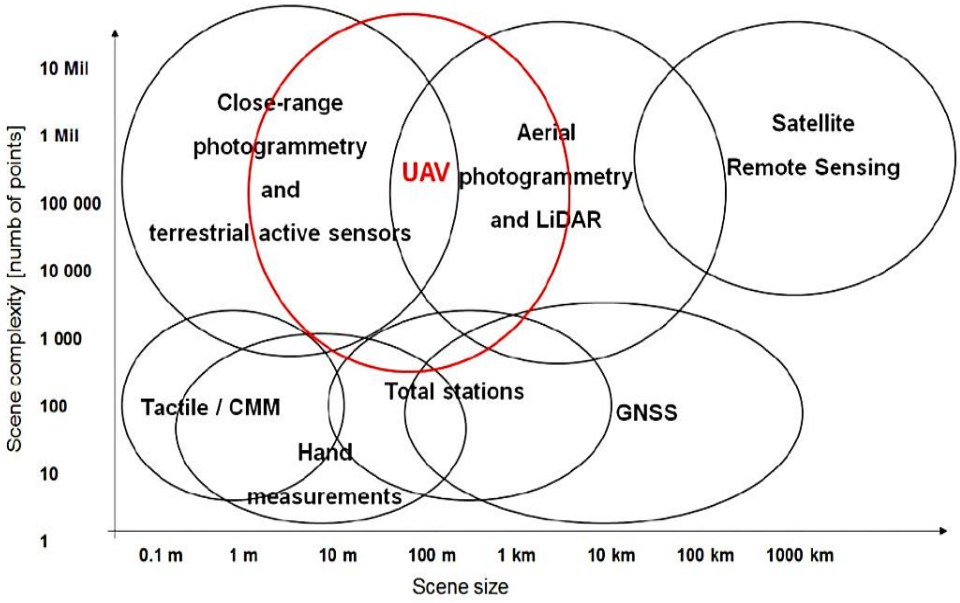


Figure 1-Available Geomatics techniques, sensors, and platforms for 3D recording purposes, according to the scene's dimensions and complexity [13].

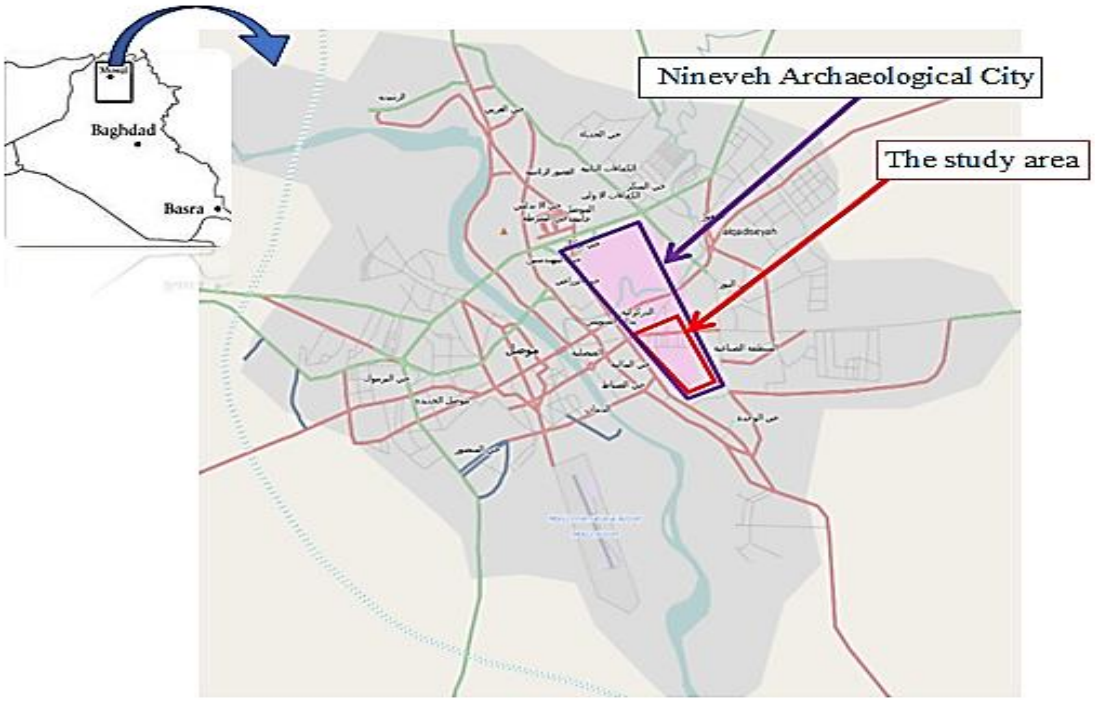
Iraq contains many places with a variety of archaeological sites and various geological formations. Yet, still buried archaeological features are disturbed by the effects of agriculture which complicates the interpretation of the subsurface [14]. Nineveh archaeological area was one of the oldest and greatest cities in antiquity. It was considered the capital of the ancient Assyrian Empire before 3000 years. The exploration of the ancient Nineveh archaeological area began in 1820 by foreign missions and continued intermittently, both from foreign missions and national efforts until years ago. A mission for University of Mosul - College of Archaeology began exploration and excavation in the northern site of the region, specifically on 10/24/2011. The excavations continued for three seasons until 2013 which resulted in a new archaeological discovery [15]. All of these missions had used traditional methods, no modern technologies, such as drones to conduct archaeological surveys and were limited to study gates and walls surrounding the city or some of the palaces and buildings whose remains are still visible on the surface of the earth [16,17].

The main aim of this research is to investigate and outline the locations of buried archaeological features in an ancient area as well as the changes or abuses, using Drone images. This paper reviews morphological features that were determined in the southern parts of the Nineveh ancient city, referring to former activities by the ancient community during Assyrian empires, these features represented by ditches and construction land use by the ancient residents. The data was taken about the Nineveh archaeological area inside the city of Mosul using an aerial surveillance system, which consists of modern DJI Phantom 4Pro drones and advanced PIX4Dmapper software. Compared to conventional airborne platforms, drones have reduced operating costs and the risk of accessing harsh environments, while maintaining high-precision capabilities.

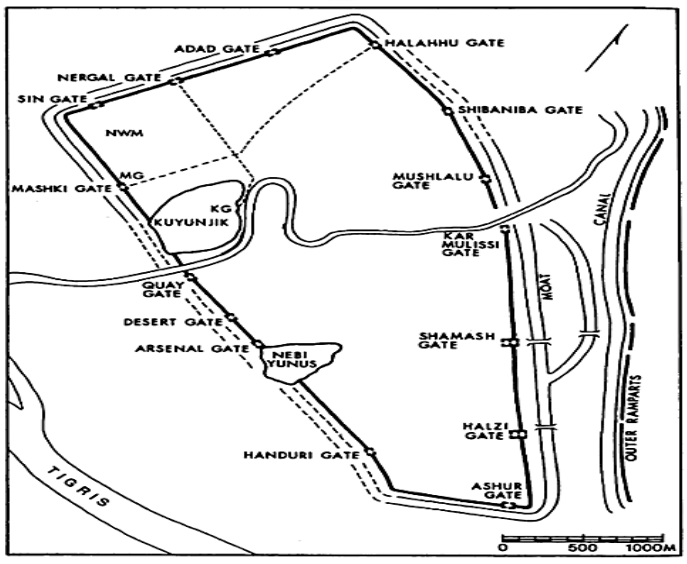
2. Materials and Methods

2.1 The Study Area and Devices used

The southern part of archaeological site of ancient Nineveh was chosen as a case study, located in Mosul city at (36° 20' 10" – 36° 20' 40") North and (43° 10' 00" – 43° 10' 43") East, also located in the eastern side of the Tigris River as seen in Figure 2. This area was chosen for its historical importance and was considered the capital of the ancient Assyrian Empire before 3000 years [17]. It had been established during King Sennacherib's period who made it a defensive line to protect the empire from foreign military attacks. It also included archaeological evidence of weapons in several camps and stores [18]. Halzi Gate is the southern gate in the eastern wall, which is five kilometers long. Researchers reported that this gate located in the far south was one of the most important gates among fifteen other gates that were subjected to many attacks [19]. Despite the historical and archaeological importance of the region, it has been noted in recent years that more and more abuses had taken place, such as the construction of residential areas, stone warehouses and many agriculture fields.



(a)



(b)

(c)

Figure 2-(a) Nineveh archaeological city. (b) Nineveh city wall and gates. (c) Satellite imagery dated 2010 for the study area.

The aerial survey was performed throughout the region, where the Drone type DJI Phantom 4Pro was used. A drone flight trip was done on March 2020 after obtaining official approvals and in collaboration with the Nineveh Directorate of Archaeology and Heritage which own this Drone (Figure 3). This modern drone contains autopilot capabilities and GPS ground points that will be used in the mosaic mapping process [20]. Images were selected for further use in digital processing, and photogrammetry.

Utilizing the new specialized program PIX4Dmapper, Drone images of the study area were uploaded and analyzed. PIX4Dmapper includes the possibilities of using geographical coordinates and specific overlapping mosaic function of the region being surveyed. The software also includes the possibility of using mathematical equations to obtain more technical measures from images [20]. The geographic information system (ArcGIS) software was also used to process the satellite images of the study area.

Figure 3- DJI Phantom 4 Pro, the Drone used in this study.

2.2 Drones data acquisition and processing

When using Drone platforms to explore an area with archaeological potential or a location that is already identified and partially explored, a sequence of operations must be carefully planned [21]. The traditional image-based aerial survey using Drones requires, first of all, flight arrangements and, in some cases, ground control (GCP) for geo-referencing. After image acquisitions, the images can be used to make mosaics or can be introduced into the imaging process. In this case, camera calibration and image triangulation are done initially, in order to generate a Digital Surface Model (DSM) or Digital Terrain Model (DTM), respectively. These products can eventually be used to produce 3D modelling images, applications, or to extract more measurement information using photogrammetry science [3]. All these processes (after image acquisitions) can be offered by the PIX4Dmapper software. Figure 4, shows the general workflows.

The missions were planned in lab and a choice the dedicated software was made. Started study of the region of interest, by selecting the required ground sample distance, ending to put the flight parameter and camera calibration steps. Drone images were used, for the study area which represents the southern part of the Nineveh archaeological region. Many Drone flight trips were done in March 2020 after obtaining official approvals and in collaboration with Nineveh Directorate of Archaeology and Heritage. Security forces co-operation and accompaniment were necessary to cover the field experiment.

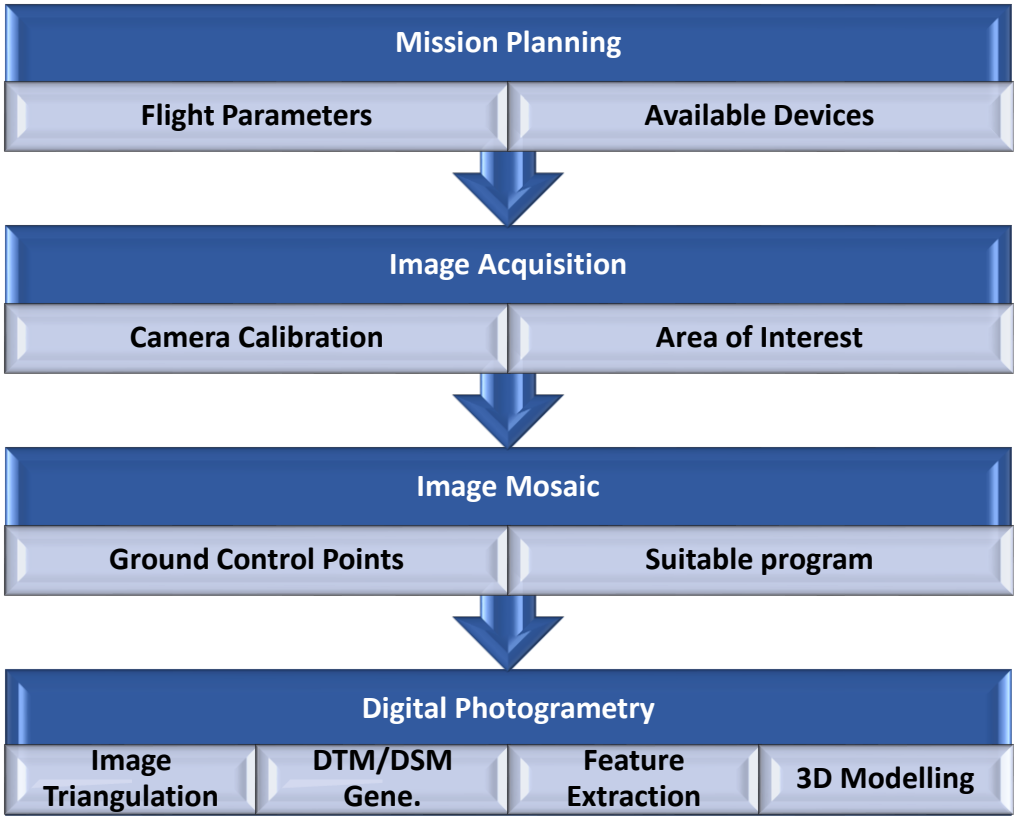


Figure 4-Typical acquisition and processing pipeline for Drone images.

At the mission planning stage, the flight parameter was adjusted and set at 70 meters altitude for the control of the Drone to achieve a resolution of approximately less than 5 cm per pixel. The pictures were taken in a serial manner and were stored in the memory accompanying the Drone according to their digital sequence with an interruption allowing the mosaic phase to be performed. In information storage area for every image, the geographical location information and coordinates were also stored. Figure 5 shows the serial photos taken with the Drone

portable camera at the location. After the scanning process was completed, the captured images were provided to computer for preparation and processing of the entire location show.
Figure 6 shows the use of the proficient PIX4Dmapper software to access sample photos taken for the photography's location, where the system performs spatial return process according to information stored in the pictures. The figure also demonstrates the direction of route and number of lines covered by the survey. That covered nearly 125,000 square meters in the field. The high spatial resolution of Drone images provided an understanding of boundaries and measurements of the areas, moreover their small size.
After the program completed the process of all images, the whole ancient area image will be showed in Figure 7. After completing the mosaic work, the program will match and return the geographical coordinates of the area over the available satellite images stored in the program and display them over a background in form of a map or a satellite image. The PIX4Dmapper program is used to extract information from the surveying process and makes comparisons, analyses and other operations. The software has the ability to show a 3D of the region as well as can do all the wanted photogrammetry.

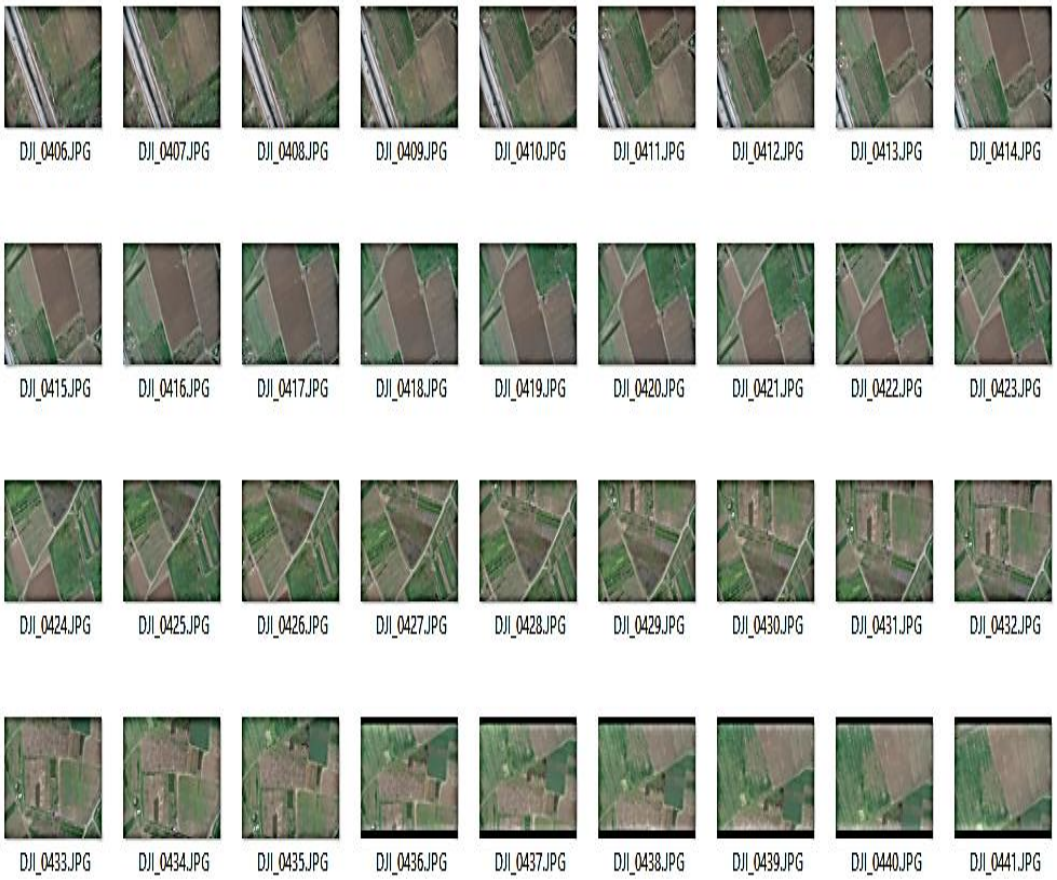


Figure 5-Sample of a serial picture captured using a Drone.

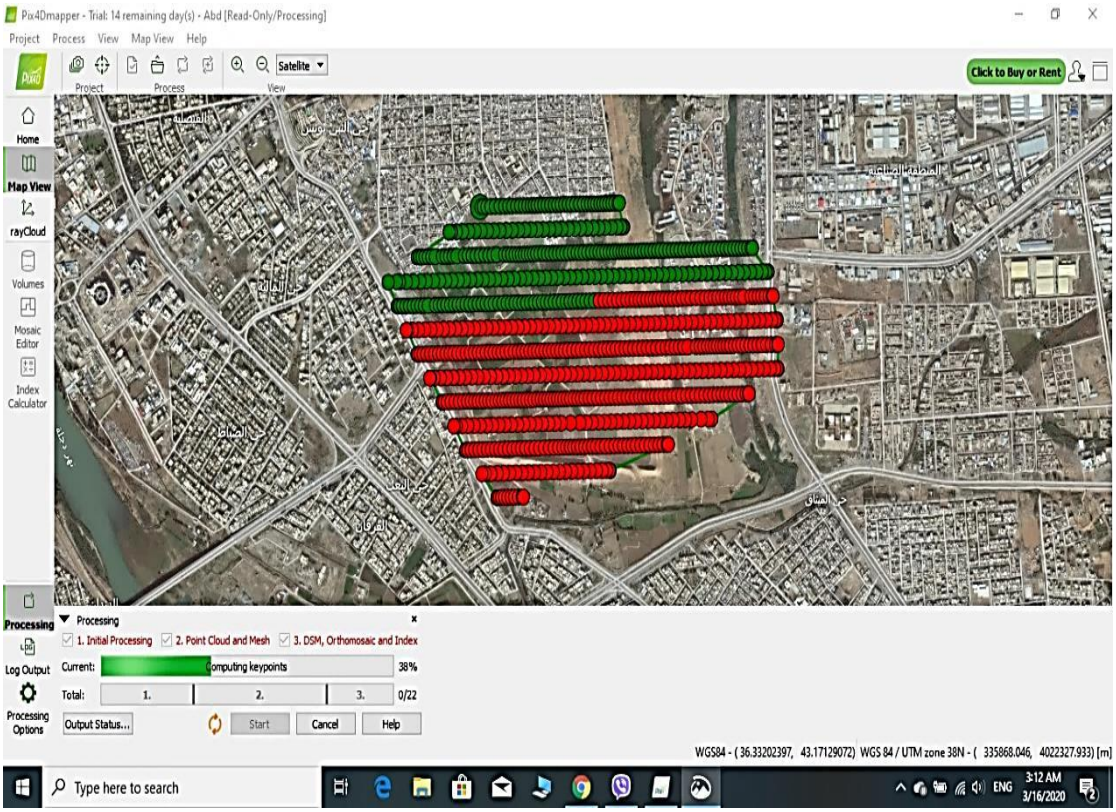


Figure 6-Processing of the collection images using a mosaic mechanism, projected onto its true geographical coordinates. Green color indicates completed processing.

Figure 7-Shows the aerial survey locations after the mosaic's operation using the Pix4D Program.

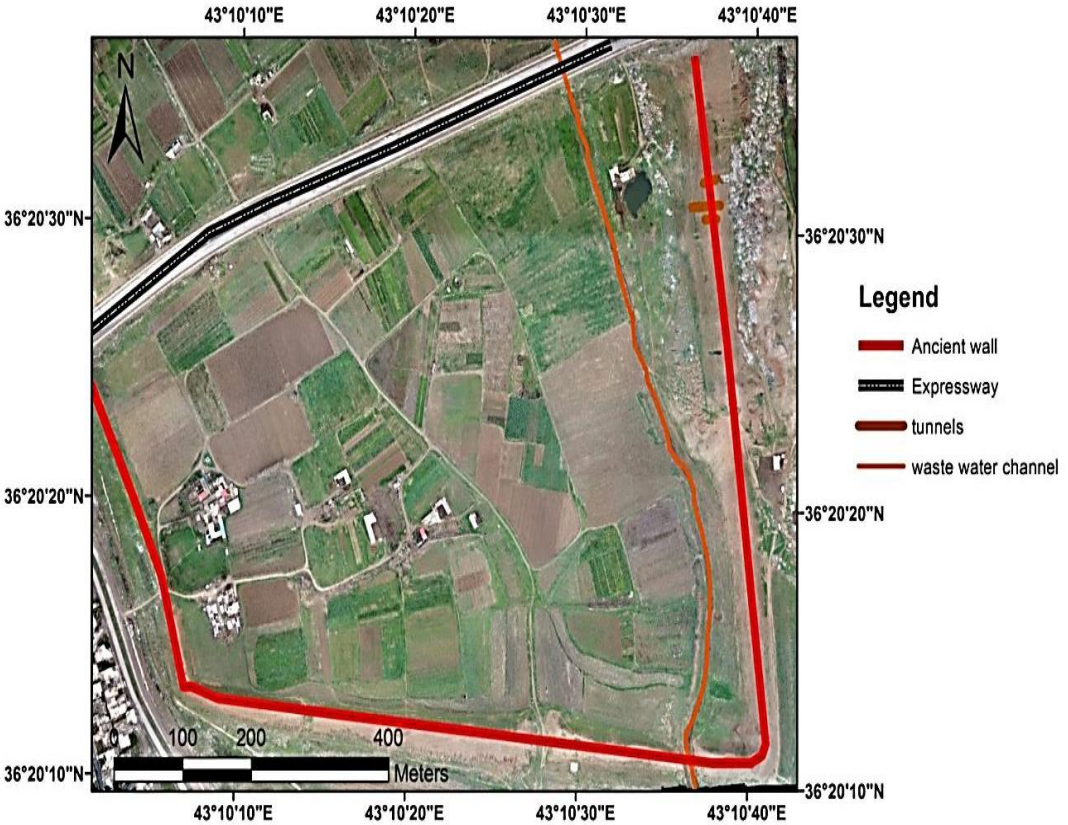
3. Results and Discussion

The area was studied with help of high-resolution Drone images. Those images enabled drawing external borders of the archaeological area. The area contains a high earth wall surrounding an important strategic area of the Assyrian Reserve. After a careful survey and

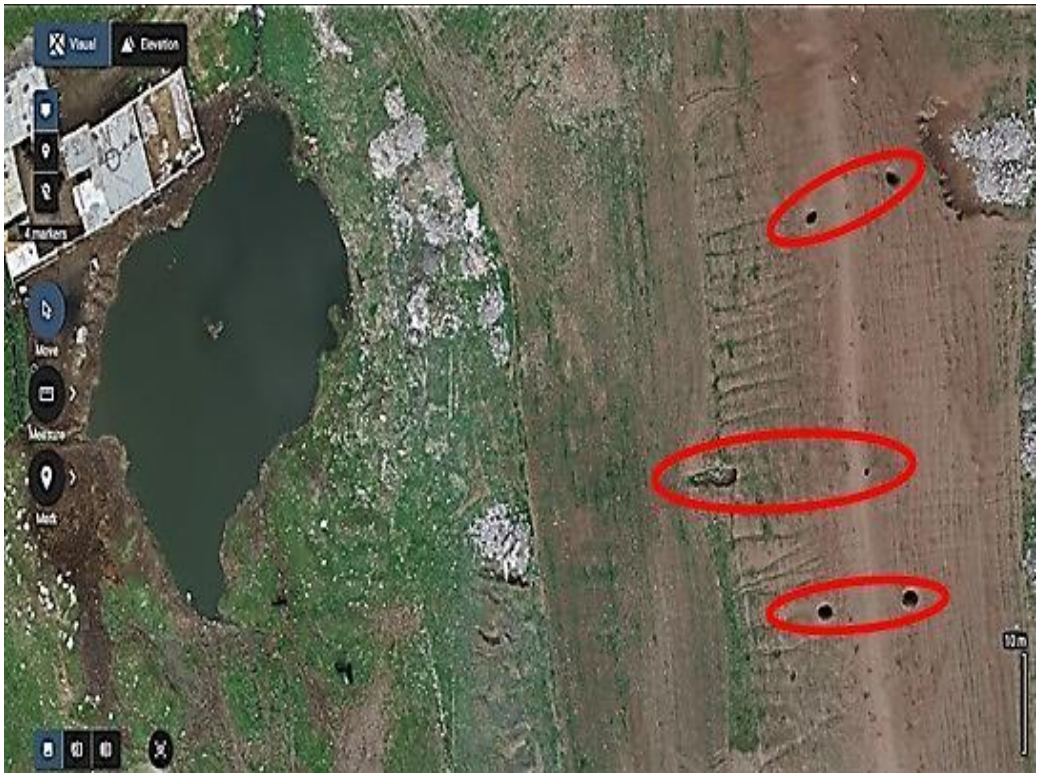
with the 3D capability of PIX4Dmapper software, it was found that there were three tunnels penetrating this wall from the eastern side, which are illustrated in Figure 8. These modern tunnels were dug at the time of Daesh's occupation of the city between 2014 and 2017, and could be weapons caches or links to other underground tunnels leading to palaces and important historical rooms. A modern wastewater channel was also observed in addition to, the high way street, which was recorded in the 3D image manufactured by PIX4Dmapper software as in Figure 9.

The changes on the surface of this site were not marked by the satellite imagery in 2010, that refers to those changes in morphology of the site happened after 2014 during Daesh control. The waste-water channel is lightly small and weak that it mixes with topography of the region. Therefore, the drone resolution and capabilities of the three-dimensional model of used program clarified the new creation more accurately. Regarding the tunnels, the new motorway, and waste-water channel are clarified on the 2010 satellite imagery in Figure 10.

From the DSM data of the ancient site, it is obvious to determine a structure in the south-eastern part of the ancient site which could be a new discovery in the presence of a ground formation. That suggests the existence of an important strategic building that was perhaps the center of the security forces that were protecting the city. It is noticed that there are several roads leading to this center or archaeological building, which have not been discovered by archaeologists so far [15, 16, 19]. This confirms the existence of a formation in that place also the wrapping of the water channel around it. This new exploration can be seen by the red circle in Figure 11.



(a)



(b)

Figure 8-(a) The ancient wall, the modern wastewater channel, motorway, and tunnels. (b) Close-up of modern tunnels using the high-resolution (less than 5 cm) drone image.

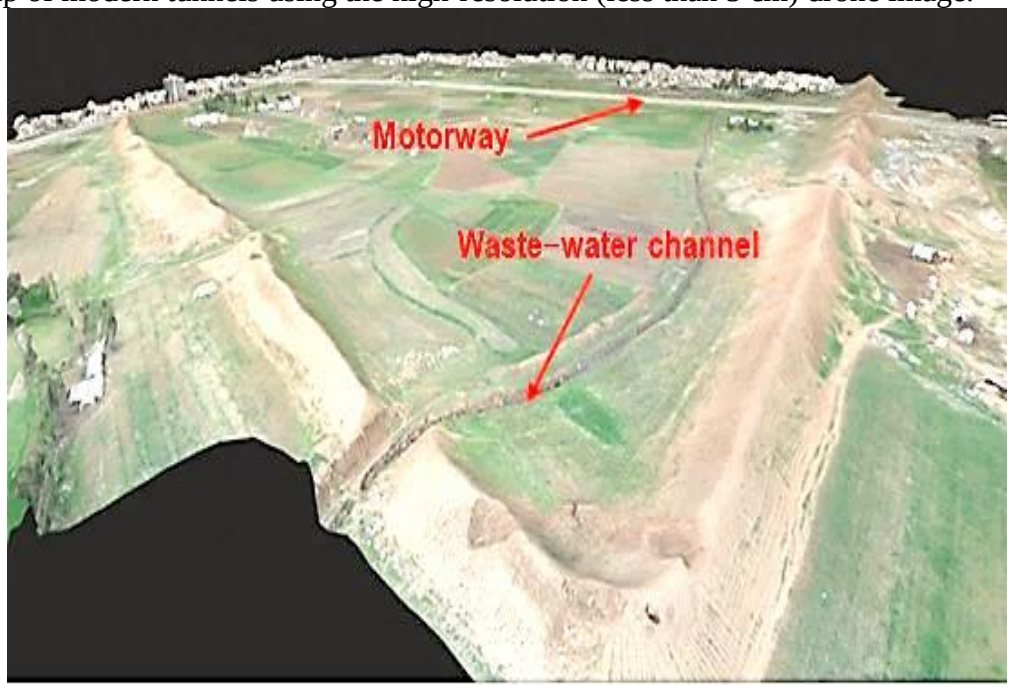


Figure 9-3D view clarifies the modern wastewater channel and Motorway within the archaeological sites.

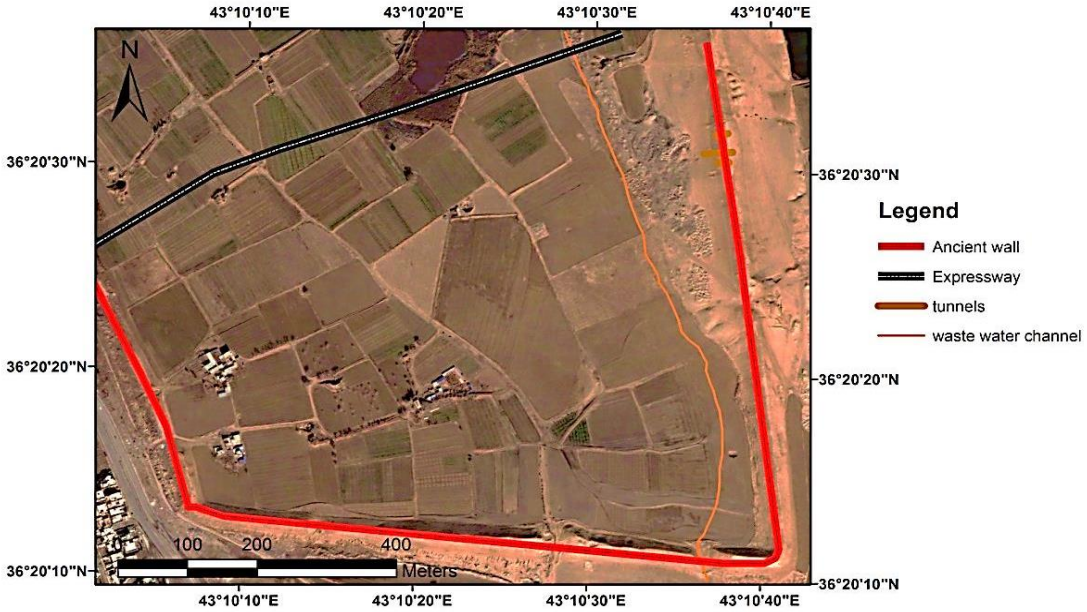


Figure 10-Satellite imagery dated 2010 (the new motorway and wastewater channel are clarified).

The southern part of the ancient site has not been affected by direct human impacts or urban activities as same as for middle part, except the individual service agriculture activities, which would help to make extensive and concentrating studies of the area by using modern techniques (satellite imagery or Drones data).The new exploration can be recognized from old satellite imagery or aerial photographs such as Corona-Satellite imagery as in Figure 12. In this imagery which is dated 1964, the structure in the south-eastern part of the ancient site could be seen clearly, and it had a spear-head shape. Regarding the shape of this structure and location of the southern gates of the ancient site in between Halzi and Ashur gates (which faced many strong attacks as mentioned and found in previous studies [15,16,19]), this structure could be an arsenal site or a strategical defensive space.

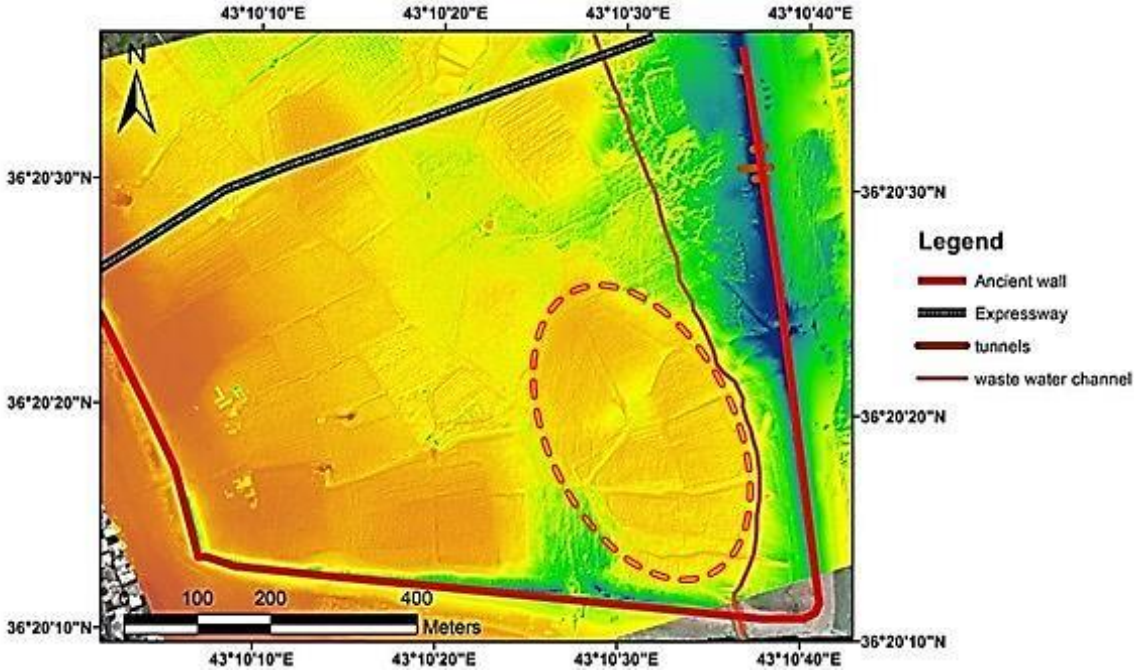


Figure 11- DSM of the Archaeological zone. New exploration is shown in the red circle.

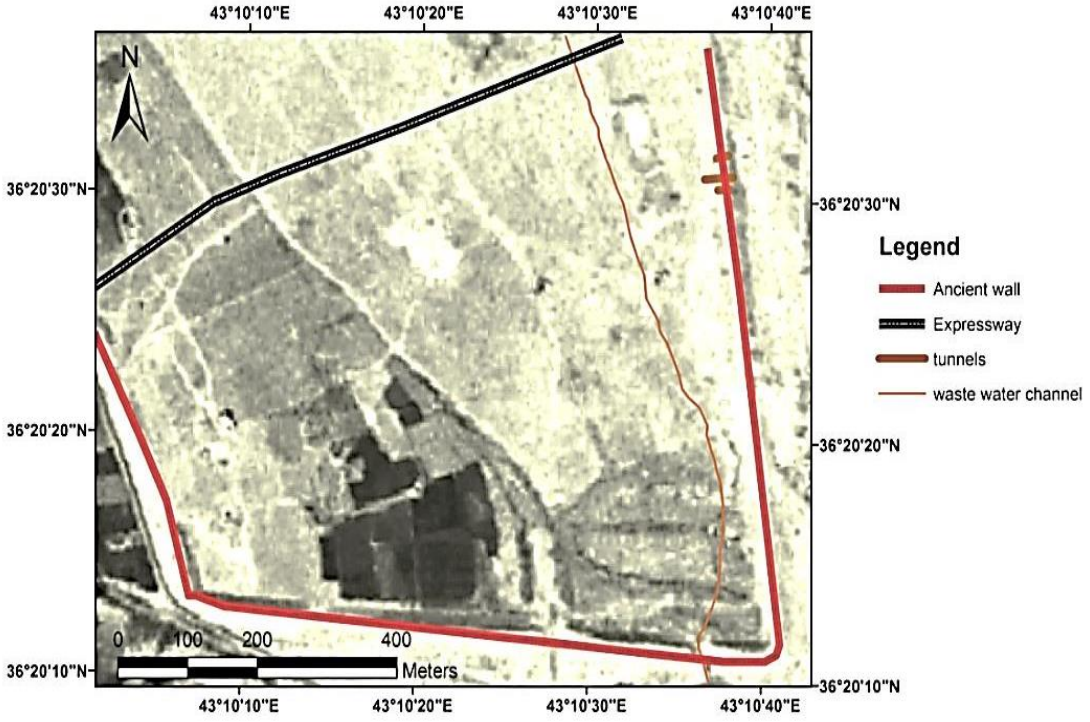


Figure 12- Corona-satellite imagery dated 1964 for the study area.

Conclusions

Drones represent one of the emerging technologies in photogrammetry. This technology is suitable for innumerable applications such as exploration and saving the historic building, heritage preserve, and the maintenance of city infrastructures. In this research, modern drone technology was used for the first time in Nineveh Governorate to survey and exploration of ancient archaeological lands and takes advantage of the high resolution of discrimination that such technology provides. The discoveries of a new archaeological structure in the studied area have not been determined before, and this structure was recognized by analyzing and

interpreting the deformation at the land morphology of the study area. Moreover, some man-made tunnels have been determined on the eastern protective wall of the archaeological site. While human impacts were clear on the archaeological site through the new motorway and the waste-water channel, those new changes might affect the site directly by the time. Therefore, it would advisable to consider those changes by the local authorities and study the long-term impact on the archaeological site in the future. This study concluded also the importance of using the new UAVs technology for archaeological surveys and encourages the local authorities and the Antiquities Authority to use such technologies in their work.

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