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Detection of Ancient Tombs Destruction in Mesopotamian Using Remote Sensing Data and GIS

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Abstract

Geographic Information Systems (GIS) and remote sensing were used in this project to assess and monitor Umm Khashm Cemetery, one of Iraq's most significant ancient cemeteries. Over 140,000 incidents of grave robbing were found throughout the studied area, highlighting the pervasive problem of looting. By examining soil irregularities and the shadows produced by robbed tombs, satellite imagery, including high-resolution datasets from WorldView-2 and Google Earth, was utilized to identify instances of theft. The study shows how well remote sensing and GIS work to record and evaluate cultural heritage site deterioration, offering important information for conservation initiatives. The findings highlight these technologies' importance in safeguarding and conserving Iraq's rich archeological legacy. Although the CORONA dataset (2.75m resolution) offered historical background, its lower resolution and greyscale imaging made it less helpful in identifying minute soil problems. Although it was constrained by spectral resolution, QuickBird (0.61 m resolution) enhanced the identification of small-scale disturbances. Using spectral analysis of soil disturbances, WorldView-2 (0.46 m resolution, multispectral) provided the best accuracy in detecting plundered tombs and differentiating between excavated and non-excavated sites.

Although it lacked spectral depth, Google Earth (0.3 m resolution) was helpful for visual confirmation. WorldView-2 produced the most accurate findings, but integrating all datasets guaranteed thorough identification and verification of looting incidents.

Keywords: Umm Khashm Cemetery, Remote Sensing, GIS, Looting, Archaeological Heritage.

الكشف عن دمار المقابر القديمة في بلاد الرافدين باستخدام بيانات الاستشعار عن بعد ونظم المعلومات الجغرافية

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الخلاصة

تم استخدام أنظمة المعلومات الجغرافية والاستشعار عن بعد في هذا المشروع لتقييم ومراقبة مقبرة أم خشم، وهي واحدة من أهم المقابر القديمة في العراق. تم العثور على أكثر من (140.000)حادثة سرقة قبور في جميع أنحاء المنطقة المدروسة، مما يسلط الضوء على مشكلة النهب المنتشرة. من خلال فحص مخالفات التربة والظلال التي تنتجها المقابر المسروقة، تم استخدام صور الأقمار الصناعية – بما في ذلك مجموعات البيانات عالية الدقة من WorldView–2 وGoogle Earth – لتحديد حالات السرقة. تُظهر الدراسة مدى نجاح الاستشعار عن بعد ونظم المعلومات الجغرافية في تسجيل وتقييم تدهور مواقع التراث الثقافي، مما يوفر معلومات مهمة لمبادرات الحفاظ. تسلط النتائج الضوء على مدى أهمية هذه التقنيات في حماية وحفظ التراث الأثري الغني في العراق.على الرغم من أن مجموعة بيانات القمر كورونا (دقة مكانية 2.75 م) قدمت خلفية تاريخية، إلا أن دقتها المنخفضة وتصويرها بالتدرج الرمادي جعلها أقل فائدة لتحديد مشاكل التربة الدقيقة. وعلى الرغم من تقييده بالدقة الطيفية، فقد عزز برنامج QuickBird (بدقة مكانية 0.61 متر) من تحديد الاضطرابات الصغيرة النطاق. وباستخدام التحليل الطيفي لاضطرابات التربة، قدم برنامج WorldView–2 (بدقة مكانية 0.46 متر، متعدد الأطياف) أفضل دقة في اكتشاف المقابر المنهوبة والتمييز بين المواقع المحفورة وغير المحفورة. وعلى الرغم من افتقاره إلى العمق الطيفي، فقد كان برنامج Google Earth (بدقة مكانية 0.3 متر) مفيدًا للتأكيد البصري. وبأخذ كل شيء في الاعتبار، فان نتائج المتحصلة من استخدام برنامج WorldView–2 أكثر دقة، لكن تم دمج جميع مجموعات البيانات ضمن تحديد دقيق وللتحقق من حوادث النهب.

1. Introduction

Understanding the development of contemporary cultures and the evolution of society is made easier by studying historical civilizations, which showed how earlier societies influenced the present. Our common past must be preserved for future generations, and this heritage must be protected from threats like looting [1, 2, and 3]. Recent cases from war-torn areas of the Middle East reveal some aspects of this problem [4] and [5]. Earth monitoring and remote sensing are vital elements of a comprehensive strategy for eventually dealing with the problem. The literature contains recent instances of both passive and optical remote sensing technologies that demonstrate the benefits and accuracy of the data when mapping endangered archeological sites [6] and [7]. In a few cases, earth observation was the only means of documenting the destruction inflicted by looters [8]. In other circumstances, geophysical techniques such as seismic refraction, electrical resistivity, and GPR have also been employed [9].

Remote sensing technologies are used for mapping and monitoring; these technologies cannot stop looters. Local investors can use the results of the picture analysis to alert the scientific community about unauthorized excavations and gather all the required measurements for future limitations.

It is worth noting that a lot of the research that has been published so far has focused on employing remote sensing technologies for large-scale stolen zones, where hundreds of markers of theft are visible from space [8], [9], and [10]. Deodato et al. (2016) tracked archaeological looting at the Apamea site in Syria using radar (SAR) imaging. Because of its poor spatial resolution, traditional SAR imaging has not been extensively utilized. Nonetheless, the ST mode is appropriate for identifying looting characteristics because of its unparalleled azimuth resolution of 0.24 meters. To detect and measure looting activities, the study examines a time series of five ST scenes from October 2014 to June 2015, concentrating on variations in radar backscattering. The authors developed a conceptual model of "looting marks," recognizable patterns of light and shadow in SAR imaging. The

results showed that by October 2014, more than 45 percent of the site had been robbed, with most new thefts occurring at the margins of the previously looted areas [8].
Using Ikonos imagery, Margarete van Ess et al. (2006) examined high-resolution satellite pictures to monitor and protect archaeological sites in Iraq, concentrating on the ancient city of Uruk-Warka. The study used pre- and post-war IKONOS data, historical aerial photos, geophysical surveys, and a geographical information system (GIS). In the northern suburbs of Uruk, the researchers detected looting activities by comparing satellite footage acquired before and after the combat. The researchers also assessed semi-automated image analysis technologies to enhance the recognition of archaeological features and looting trends [12].
Stone (2008) examines the trends of looting archaeological sites in southern Iraq. Using high-resolution satellite imagery, the study investigates over 1900 sites to determine the extent, timing, and factors influencing looting activities. The results show that lotting concentrated on large site areas and from eras rich in artifact examples, such as cylinder seals, cuneiform tablets, and early money. The most robbed areas are the sites between deserts and inhabited areas [5]. In (2019), Tapete and Francesca explore the visible and near-infrared spectral profiles and suitability of multi-temporal change detection techniques after forty-seven peer-reviewed publications and viewing grey literature. Another point is the difficulties in automating looting assessment [14].

In (2014), Casana and Panahipour revealed the devastating impact of the Syrian civil conflict on the destruction of the 30 significant archeological sites in Syria using high-resolution satellite imagery using Google Earth data, which is publicly available, Bing Maps, GeoEye, and finally WorldView for years 2012 and 2013, mainly the Military and looting Activities damaged these sites [15]. Parcak et al. 2016 conducted a study using high-resolution satellite photography determining the theft extent of archeological sites in Egypt using satellite imagery from (2002 to 2013) at 1,100 archeological sites, and the damaged sites 267, showing a sharp rise in the area affected by encroachment and the number of looting pits the increase in 2009 after domestic economic concerns [16]. Using multispectral satellite photos, Lauricella et al. (2017), besides principal component analysis (PCA) in a semi-automated way and relying on laborious human comparisons of satellite photos, these methods provided improvement in speed and accuracy of looting monitoring over time, which is a strong instrument for protecting cultural assets in war zones and this consider to be an advancement over human methods [17].

The research's main aim is mapping and assessing the Umm Khashm Cemetery in Iraq; recently, many looting activities were discovered by using pre-existing data collected from several sensors and sources, and these were used for identifying and documenting the indicators of looting, especially recent large-scale theft attempts. In this study case, the limitation is by the threat's magnitude an accessible image captured from space and the air [18].

2. Study area:

Umm Khashm Cemetery is situated within the administrative boundaries of the Al-Manathira District in An-Najaf, central Iraq. The religious importance of An-Najaf is well known. The studied site has a rich history spanning more than 1,800 years over a vast expanse of more than 2.5 sq. km and is located between longitudes of 40°30′07′′- 44°31′3′′ east and latitudes of 31°51′52′′- 31°52′77′′ north, Figure 1. The investigated site is considered the biggest Christian cemetery in Iraq. Both in earlier times and more recently, looted graves were found in this area. Due to their underground location, around 1.15-1.5 m below the

surface, undisturbed tombs are difficult to find using satellite image data. On the other hand, it is more likely that evidence of looted tombs will be seen and recognized in this way.

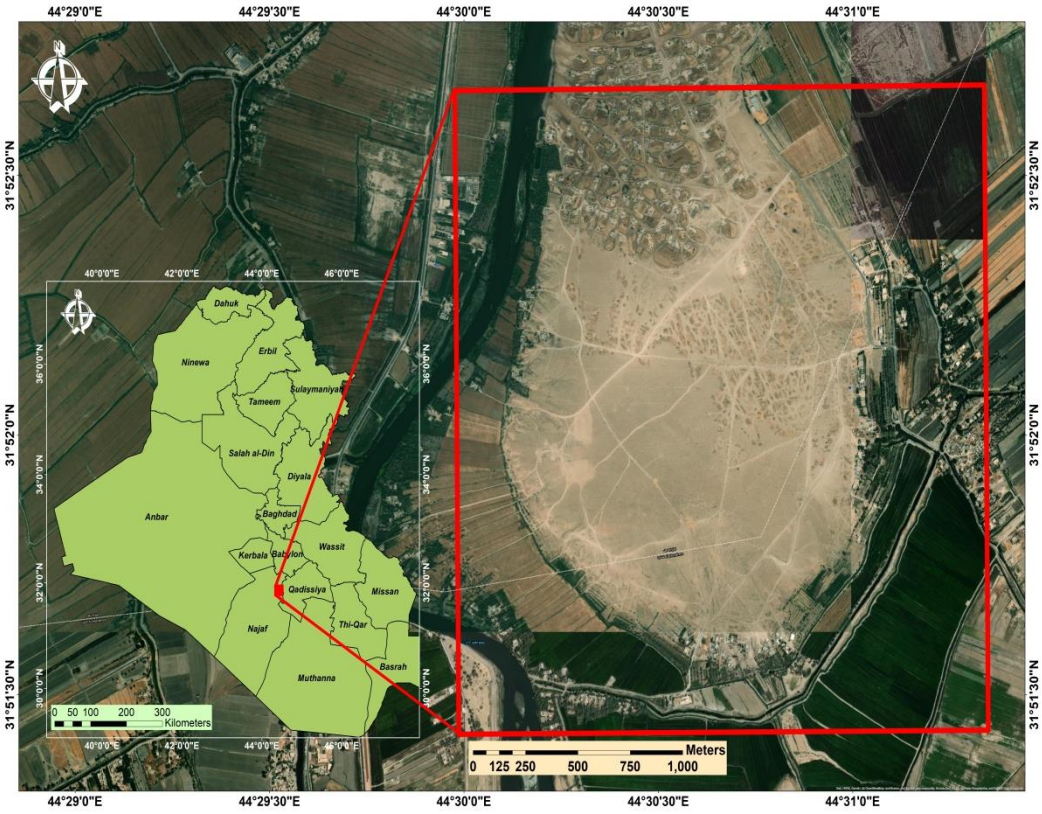

Figure 1: Map indicates the study area, and the red polygon indicates the cemetery.

3. Materials and Methods

Three types of satellite images were analyzed in this study: Corona, WorldView-2 multispectral, and Google Earth images (Figures 2, 3, and 4), Table 2. Although CORONA is no longer helpful for intelligence gathering thanks to newer satellite systems, it was released in 1995 because of its possible worth for academic study. Eight hundred thousand photos are currently accessible online for previewing.

Older satellite photos are valuable in archeology, where historical data may offer crucial insights into previous landscapes and changes over time, even though they may not be as relevant for intelligence reasons [19]. A greyscale, 2.75 m spatial resolution Corona Satellite orthophoto captured in 1969—before any looting incidents—was used as a reference (Figure 2).

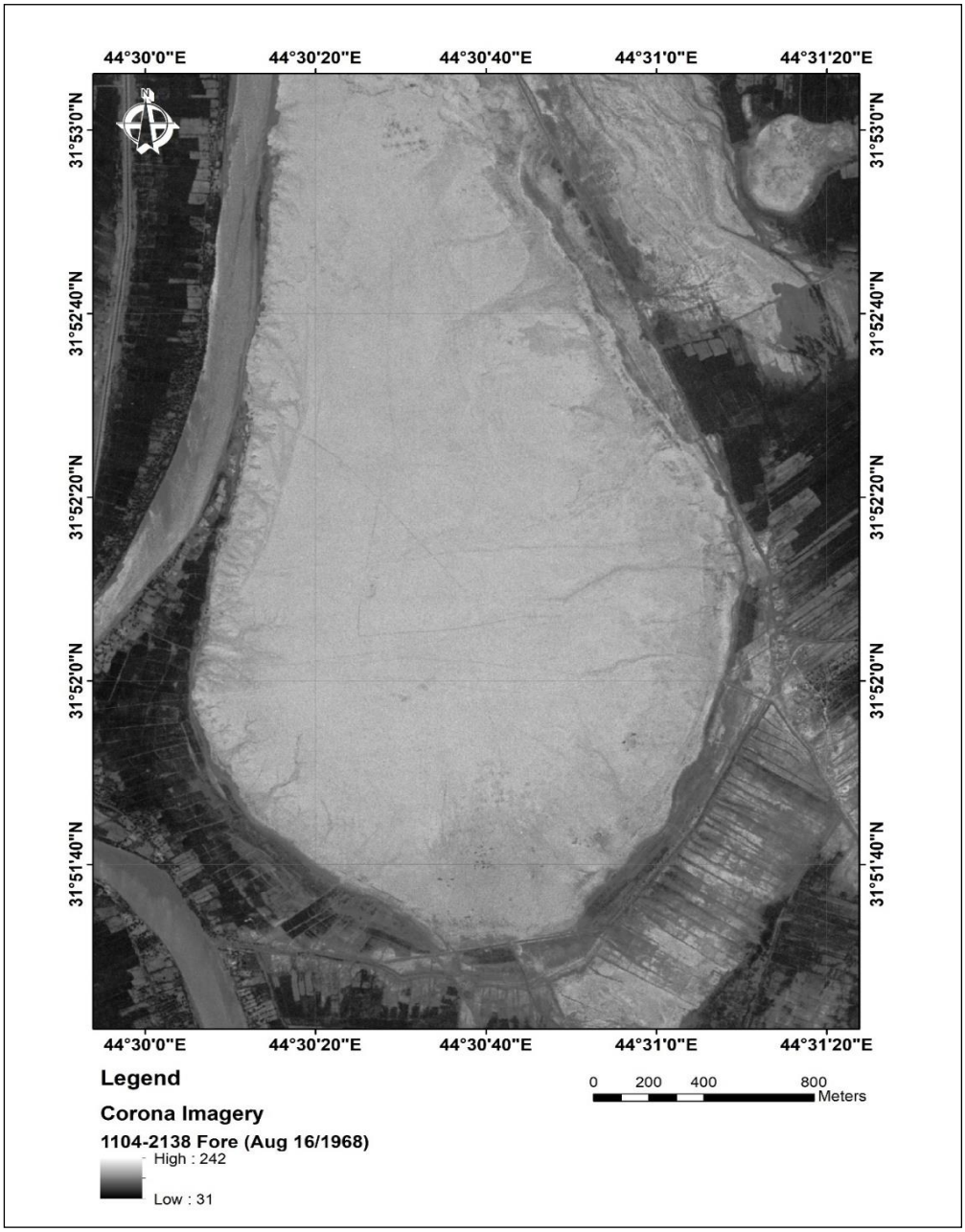

Figure 2: CORONA satellite photograph of Umm Khashm Cemetery, which was captured in Aug. 1968.

The objectives of this study were met by utilizing archival satellite datasets, including a WorldView-2 multispectral satellite image obtained on June 5, 2021 (Figure 3) and Google Earth photographs (Figure 4). Table 1 contains a comprehensive inventory of all the data that were utilized. The methodology used in this investigation is shown in Figure 5. This study uses the thresholding method to detect shadows in WorldView-2 images to identify robbed graves. The spectral region was a threshold used to detect looted graves. After that, threshold images with a (0 and 1) structure were converted to vectors using the ArcGIS program to determine the number of looted graves.

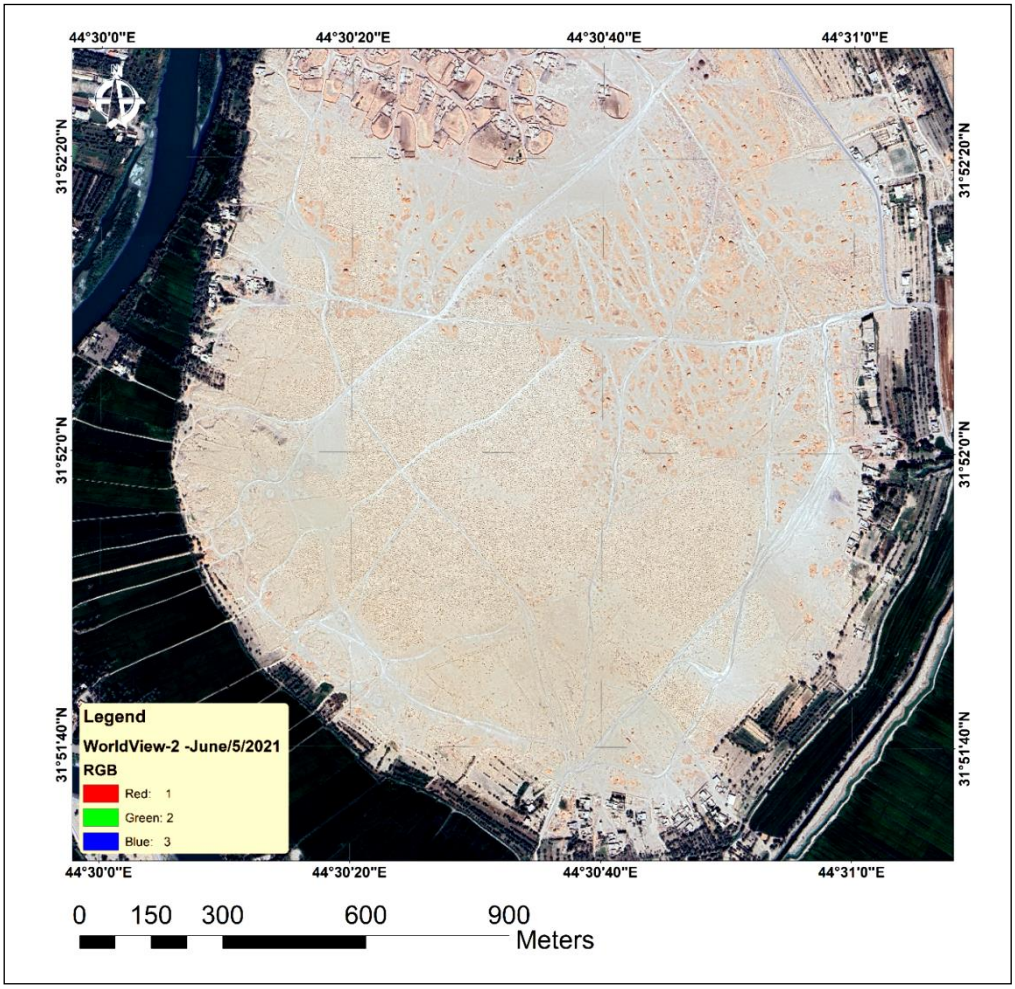

Figure 3: WorldView-2 satellite image of Umm Khashm Cemetery.

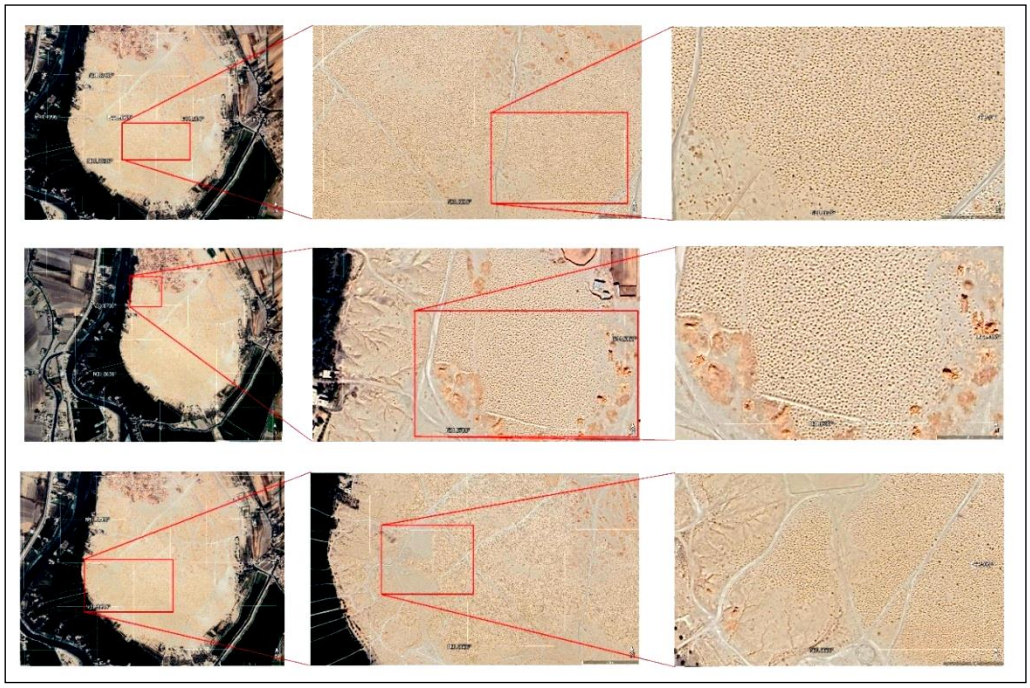

Figure 4: Google Earth images of the site under study; the red squares represent looted tombs.

Table 1: Datasets employed in this study.

No.	Satellite Image	Date of Acquisitions	Type	Spatial Resolution (m)
1.	CORONA J-1 KH-4A	Aug/16/1968	Orthophoto	2.75
2.	QuickBird	June/25/2006	Multi-spectral imagery	0.61
3.	WorldView-2	June/5/2021	Multi-spectral imagery with panchromatic	0.46
4.	Google Earth	Feb /10/2022	RGB	0.3

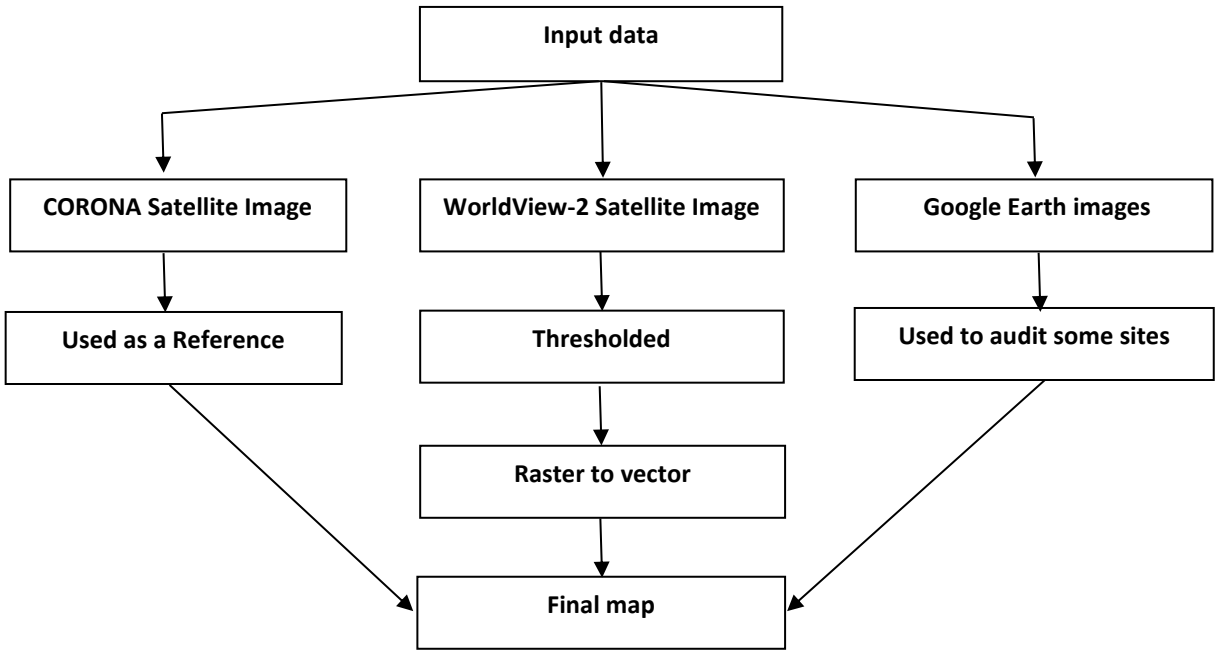

Figure 5 : shows the flow chart for the methodology used in this investigation.

4. Results and Discussion

The Christian cemeteries serve as a living testament to Iraq's rich cultural diversity, Christian heritage, and civilization. Umm, Khashm Cemetery and the al-Manabir Christian Cemetery are two of those graveyards. One of the largest Christian cemeteries in the Middle East, Umm Khashm Cemetery has the potential to equal or surpass the standing of the Christian cemetery at the Vatican." One of the site's main enemies was looters. Vandalism and unauthorized excavations have destroyed Umm Khashm (Figure 5). Thieves steal goods interred beside the dead. These include antiques, relics, and sentimental objects like perfume bottles or crosses. Sadly, antiquities thieves were unethically and illegally excavating this area.

Figure 5: Looted graves (Dec. 2009).

Image thresholding is a regular activity in many applications related to remote sensing, graphics, and computer vision. Remote sensing images are classified using image thresholding based on a pixel characteristic (e.g., intensity value) [20]. The aim is to create a binary image representation and assign each pixel to one of two groups, for example, bright or dark. This is a standard task in many computer graphics and image processing programs. The most straightforward thresholding technique is selecting and comparing every pixel to a set threshold value. Numerous threshold values were used to characterize and assess these methods in detail [21].

To identify shadows in WorldView-2 photos, a thresholding technique was employed to identify plundered tombs and to locate the looted graves by utilizing The spectral region as a threshold, and tombs represented between 30-160 digital numbers data with intervals between 0and 255 thresholded(figure 6and 7) .compelling finds and evidential that shadows are correctly identified .in order to determine the looted graves number, using the Arc GIS tool the structure of the shoulder pictures with (0 and 1) are converted to vectors(Figure 8).

The effectiveness of remote sensing and GIS in identification and mapping looting activities in Umm Khashm Cemetery is demonstrated in this research. One hundred thirty-eight thousand looted graves were identified, and soil disturbances and shadows associated with looted tombs were discovered by the researchers analyzing high-resolution satellite photography, including WorldView-2 and Google Earth data, for the precise separation of plundered and untouched areas by using image's spectrum analysis. The remote sensing

technique provides a practical means of preventing illegal excavations and preserving cultural property by highlighting the need to use GIS and satellite data for comprehensive archeological assessments and conservation efforts.

Google Earth images were used to examine the looting phenomenon in the research region (Figure 9). Looting incidents were identified using satellite data. Therefore, the disruption of the earth brought about by these illegal activities acted as a stand-in for the plundered tombs, and the shadows generated by the robbed graves served as a key for interpretation. In contrast to the nearby non-excavated area, the excavated soil was positioned relatively close to the stolen tombs, offering a target with a homogeneous spectral profile compared to the nearby unexcavated area. Data Base built for (138000) robbed graves in the study area (Figure 10); the database contains ID station, X and Y Geographic coordinates of each grave. The results showed that satellite image analysis may identify and distinguish modern towns and tell sites in the investigated area.

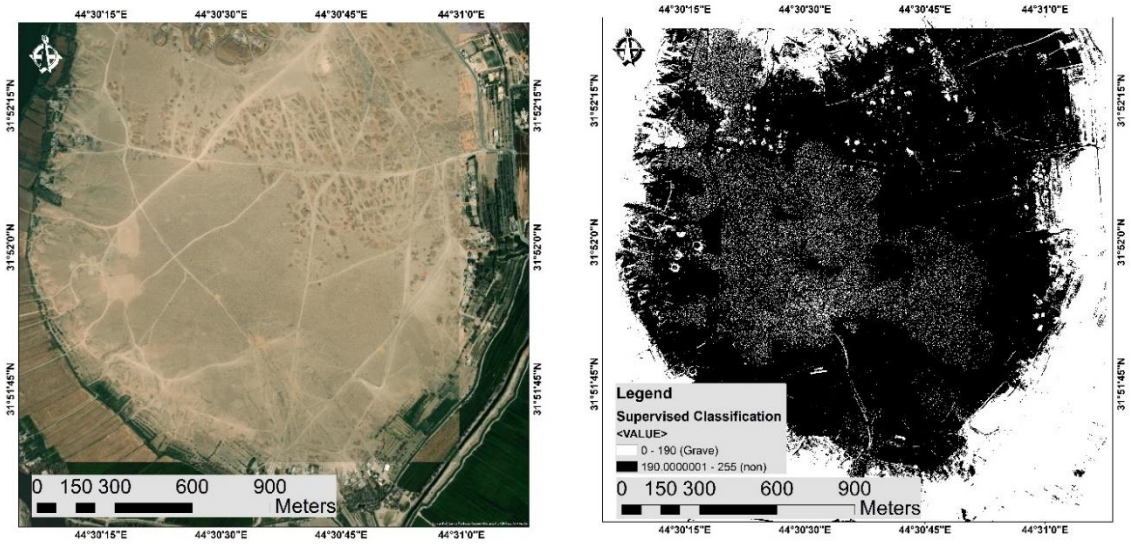

Figure 6: Spectral region of shadows to identify tombs that were robbed; white is a color that symbolizes stolen graves.

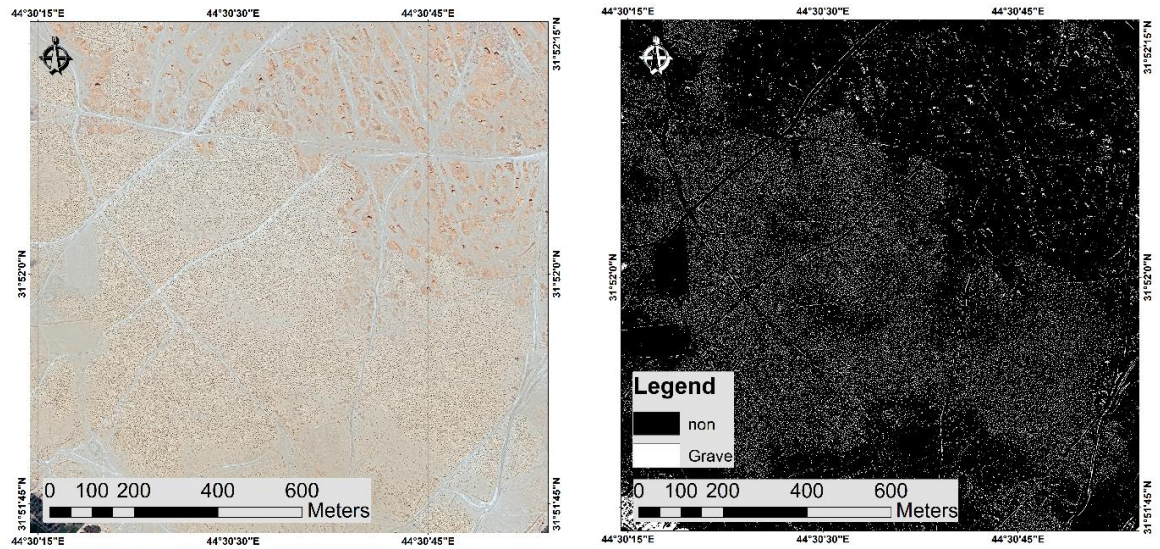

Figure 7 :Threshold images of the site under study.

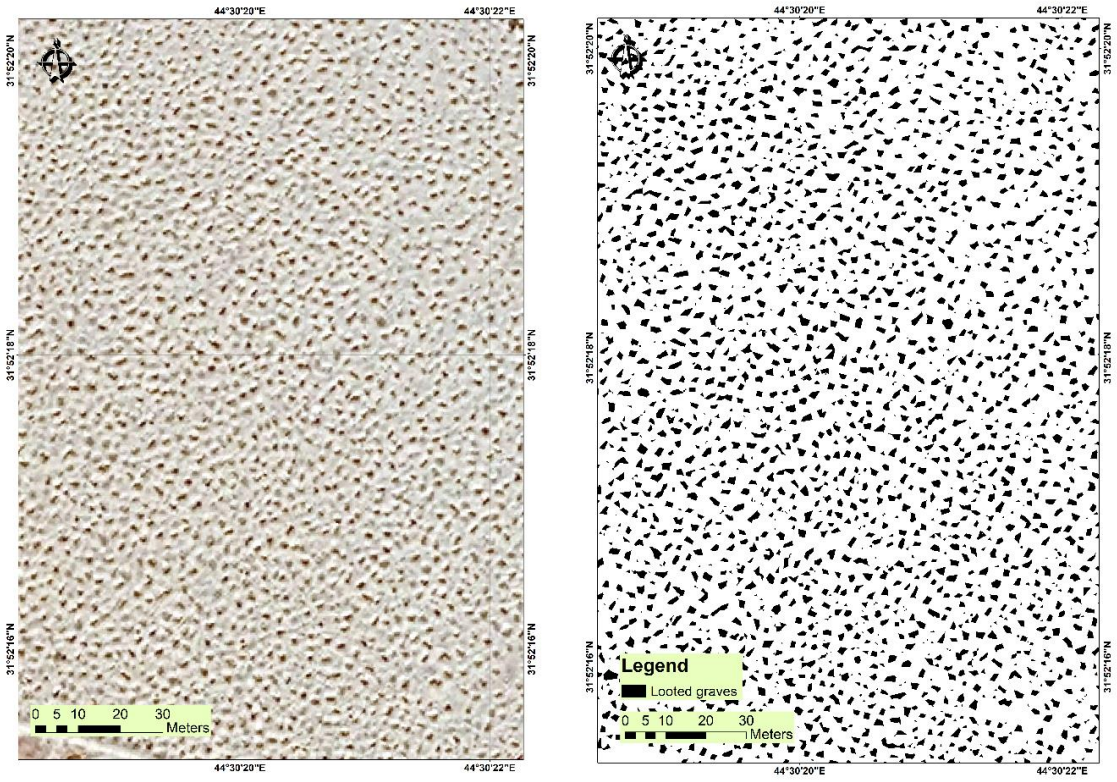

Figure 8: Vector of looted tombs.

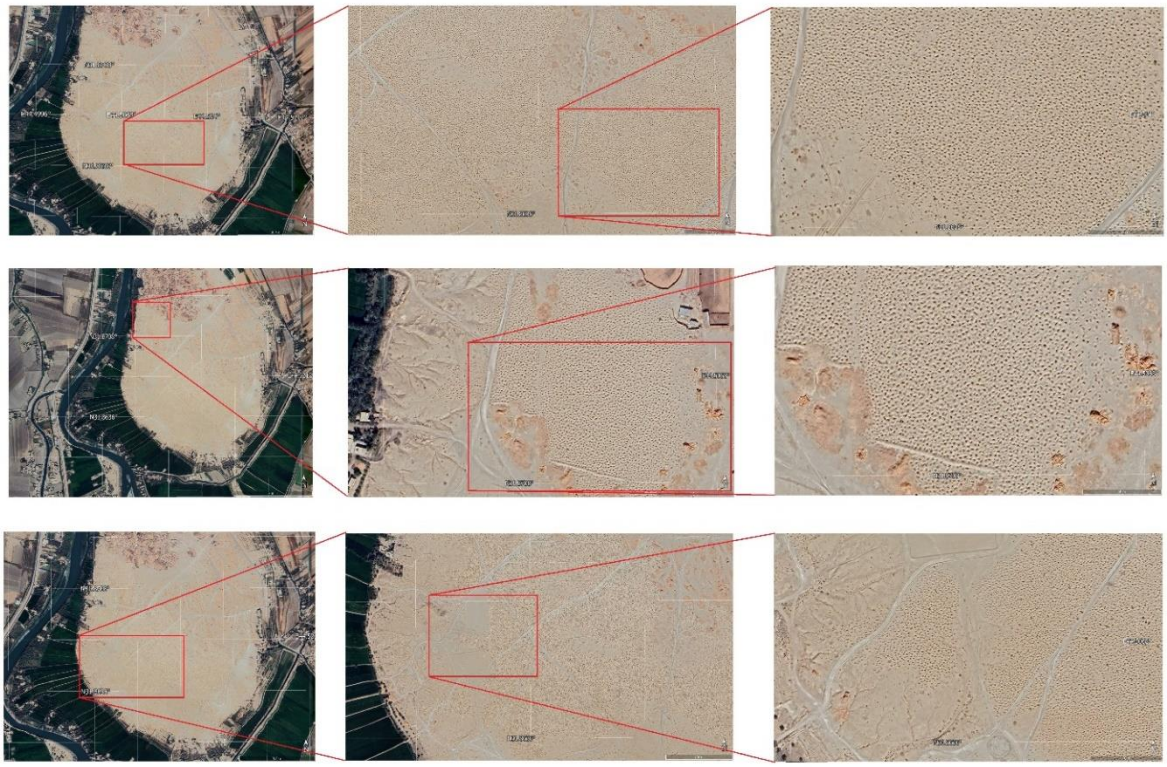

Figure 9: Google Earth images of the site under study; the red squares represent looted tombs.

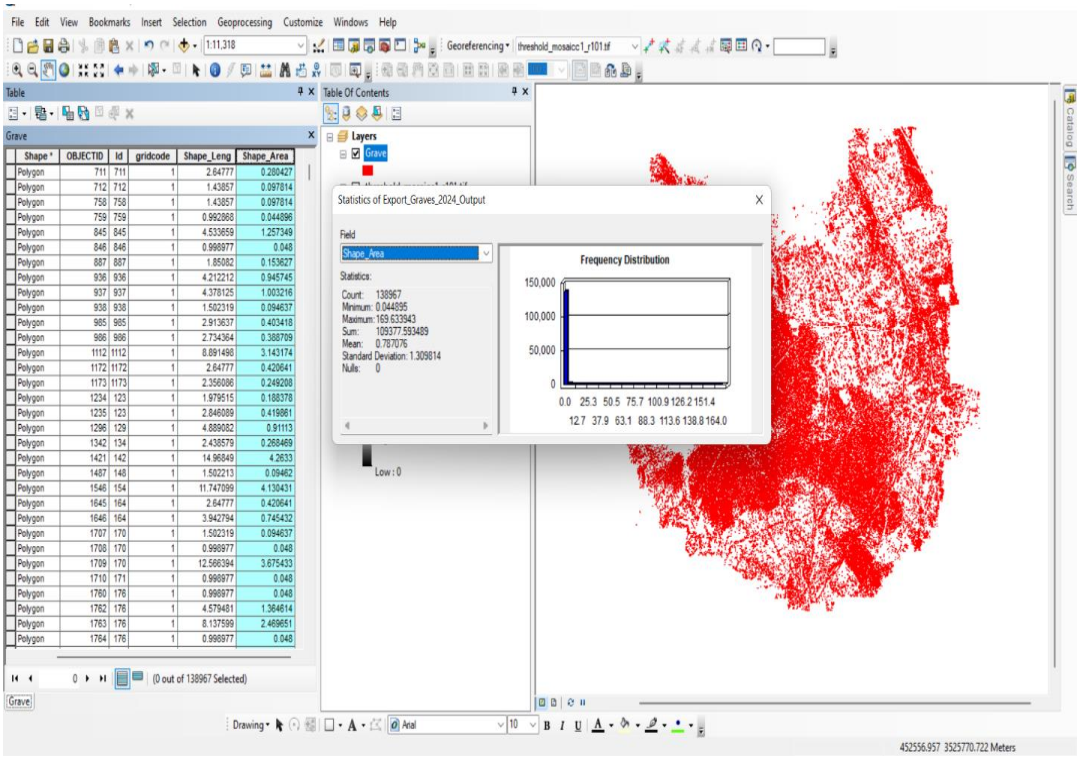

Figure 10: Database of looted tombs.

5. Conclusions

The study aims to demonstrate how various remote-sensing datasets may be utilized to find signs of looting. There were extensive signs of looting in this area, and no scheduled satellite images were provided to track this occurrence. Numerous images and processing methods were used to investigate the possibility of looting attempt detection. These systematic and ordered phenomena were identified using satellite imagery and archive data. The image analysis used Corona, high-resolution Quikbird, WorldView-2, and Google Earth photos.

Overall, the results showed that Earth observation dataset imagery may be utilized effectively to follow illegal excavations with high precision and detect signs of looting in larger areas. The Google Earth RGB-compressed images are a great way to start interpreting the region. Some linear histogram enhancements and adjustments to brightness and contrast were applied to these images. This study explored automatic extraction based on object-threshold classification and image processing. According to the general interpretation of the image analysis results, ground truthing and in situ inspections are crucial for verification. Because the phenomena fluctuate over time and several datasets (with varying spectral and spatial properties) were employed, a quantitative evaluation of the total results was conducted with a detailed database created with the geographic coordinates of 138,000 stolen graves that were located and documented. The accurate distinction between places that had been plundered and those that had not was made possible by the spectral analysis of the picture, which showed a clear signature of disturbed soil.

6. Statements on compliance with ethical standards and standards of research involving animals

“This article does not contain any studies involving animals performed by any authors.”

7. Disclosure and conflict of interest

“Conflict of Interest: The authors declare no conflicts of interest.”

References

[1] UNESCO, "Convention on the Means of Prohibiting and Preventing the Illicit Import, Export and Transfer of Ownership of Cultural Property; UNESCO," UNESCO, Paris, France, 1970.

[2] S. Campana, M. Sordini, S. Berlioz, M. Vidale, R. Al-Lyla, A. Al-Araj and A. Bianchi, "Remote sensing and ground survey of archaeological damage and destruction at Nineveh during the ISIS occupation," *Antiquity,* pp. 436- 454, 14 February 2022.

[3] UNIDROIT, "Convention on Stolen or Illegally Exported Cultural Objects," UNIDROIT, Rome, Italy, 1995.

[4] D. Cerra, S. Plank, V. Lysandrou and J. Tian, "Cultural heritage sites in danger Towards automatic damage detection from space," *Remote Sens.,* vol. 871, 2016.

[5] E. Stone, "Patterns of looting in southern Iraq," *Antiquity,* pp. 125-138, 2008.

[6] A. Agapiou and V. Lysandrou, "Remote sensing archaeology: Tracking and mapping evolution in European scientific literature from 1999 to 2015," *J. Archaeol. Sci,* p. 192–200, 2015.

[7] D. I. Negula, R. Sofronie, A. Virsta and A. Badea, "Earth observation for the world cultural and natural heritage," *Agric. Sci. Procedia,* no. 6, p. 438–445, 2015.

[8] D. Tapete and F. Cigna, "Detection of Archaeological Looting from Space: Methods, Achievements and Challenges," *Remote Sensing,* pp. 1-43, 2019.

[9] F. A. Chase, Z. D. Chase, F. J. Weishampel, B. J. Drake, L. R. Shrestha, L. C. Slatton, J. J. Awe and E. W. Carter, "Airborne LiDAR, archaeology, and the ancient Maya landscape at Caracol, Belize," *J. Archaeol Sci.,* p. 387–398, 2011.

[10] D. A. Contreras and N. Brodie, "The utility of publicly-available satellite imagery for investigating looting of archaeological sites in Jordan," *Journal of Field Archaeology,* pp. 101-114, 2010.

[11] M. van Ess, H. Becker, ö. Fassbinder, R. Kiefl, I. Lingenfelder, G. Schreier and A. Zevenbergen, "Detection of Looting Activities at Archaeological Sites in Iraq using Ikonos Imagery," *AGIT Symposium,* pp. 669-678, 2006.

[12] J. Casana and M. Panahipour, "Satellite-Based Monitoring of Looting and Damage to Archaeological Sites in Syria," *Journal of Eastern Mediterranean Archaeology and Heritage Studies,* pp. 128-151, 2014.

[13] S. Parcak, D. Gathings, C. Childs, M. Greg and E. Cline, "Satellite evidence of archaeological site looting in Egypt: 2002–2013," *Antiquity,* pp. 188 - 205, 2016.

[14] A. Lauricella, J. Cannon, S. Branting and E. Hamm, "Semi-automated detection of looting in Afghanistan using multispectral imagery and principal component analysis," *Antiquity,* pp. 1344 - 1355, October 2017.

[15] R. Ishaq, History of Iraqi Christian, 208, 1948.

[16] D. A. Day, J. M. Longson and B. Latell, Eye in the Sky: The Story of CORONA Spy Satellites., Washington: DC: Smithsonian Institution Press., 1998.

[17] A. A. Hasan, F. M. Ali, L. Anis , A. Amine, L. H. Abdullah and C. M. Dallos, "The study of drainage patterns distortion in the Iraqi western desert using remote sensing data," *AIP Conf. Proc.,* 17 August 2022.

[18] T. Balaji and M. Sumathi, "Effective Features of Remote Sensing Image Classification Using Interactive Adaptive Thresholding Method," in *International Conference on Intelligent Computing Applications - ICICA 2014*, 2014.

[19] Z. AL-Saedi and A. AL-Muthan, "Change Detection in Hour-Ibn Nnjam / Middle of IRAQ by Using WaterIndex (W.I) Algebra," *Iraqi Journal of Science,* 2012.

[20] H. A. Jasim, L. E. George and M. I. Abd-almajied, "Frame-Based Change Detection Using Histogram and Threshold to Separate Moving Objects from Dynamic Background," *Iraqi Journal of Science,* pp. 4139-4148, 30 7 2024.