Land Use Change and Cultural Heritage Preservation in Trowulan: A Spatial Analysis of Majapahit Legacy

Dimas Nugroho[1,2], Adi Wibowo[1]

[1] Department of Geography, Faculty of Mathematics and Natural Science, University of Indonesia, Depok, Indonesia
[2] Research Center for Prehistory and Historical Archaeology, BRIN, Gedung Widya Graha, Jl. Jenderal Gatot Subroto No. 10, DKI Jakarta, 12710, Indonesia

dima027@brin.go.id

Abstract. The Trowulan National Cultural Heritage Area, once the capital centre of the Majapahit Kingdom, is rich in cultural and archaeological remains. Covering six sub-districts and fifty villages across Mojokerto and Jombang Regencies, the area is legally protected under Indonesia's Cultural Heritage Law No. 11/2010. Nevertheless, rapid changes in land use and land cover (LULC) have increasingly posed threats to the preservation of cultural heritage, particularly to archaeological data still buried beneath the ground. This study aims to analyse LULC changes within the Trowulan heritage area between 2011 and 2024 by employing Google Earth satellite imagery combined with spatial digitisation techniques. A comparative spatial–temporal analysis was carried out to identify the extent of built-up expansion, agricultural land conversion, and the proliferation of brick-making industries that are directly linked to the degradation of the cultural landscape. The findings reveal a significant increase in built-up land, particularly in peri-urban zones, alongside a decline in agricultural areas and an intensification of small-scale extractive industries. These dynamics highlight an escalating risk of disturbance to archaeological contexts and the potential permanent loss of cultural memory. The study emphasizes the necessity of conservation-based spatial planning, community awareness, and stricter development control. By integrating geospatial data with heritage management strategies, this research contributes to the sustainable preservation of Trowulan as one of Indonesia's most valuable cultural heritage landscapes.

Keywords: Cultural Heritage Preservation, Archaeological Landscape, Majapahit Kingdom, Land Use and Land Cover (LULC), Spatial Analysis, Google Earth.

1 Introduction

The dynamics of land use and land cover (LULC) in spatial studies refer to aspects of land use carried out by humans. Land use can be defined as the methods or activities carried out by humans to utilize land, while land cover can be defined as the physical

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formations that cover the Earth's surface [1]. Land use and land cover are analyzed together because these two aspects are closely related, where human activities affect the natural features that cover the land [2], [3]. The phenomenon of LULC dynamics in a region sometimes occurs quickly, where the spatial-temporal changes that occur in LULC are caused by various development activities in urban areas and anthropogenic activities [4]. The phenomenon of LULC dynamics in urban areas has a faster intensity of change, where population growth influences the speed of development in an area [5]. Therefore, LULC analysis can also be used as a medium to evaluate the development of a region [6].

One area requiring intensive development monitoring is the cultural heritage area located in residential areas. One such area is the Trowulan National Cultural Heritage Area. The Trowulan area is identified as a former settlement or urban area during the Majapahit Kingdom, which flourished from the 13th to 15th centuries AD [7]. The characteristics of residential areas and land use in the past show the characteristics of massive settlements, which show the characteristics of urban areas in the past, and rural characteristics [7], [8]. This is supported by written data from the Nagarakertagama manuscript, which describes the central settlement of Majapahit city as Nagara, which is thought to refer to the area around Trowulan [9].

The Trowulan area has been designated as a national-level Cultural Heritage Area based on the Regulation [10] which covers an area of 92.6 km^2, including 49 villages, four sub-districts and two regencies. The regulations on the boundaries of the area were then revised through regulations [11], expanding the area and regions included in the Cultural Heritage area to include 50 villages, six sub-districts, and two districts. This area is protected by Cultural Heritage Law No. 11 of 2010, which mandates careful development and land use management to prevent damage to archaeological remains.

One of the monitoring efforts that can be carried out is by utilizing remote sensing technology and geographic information systems (GIS) [12]. Through these two techniques and with the development of geomatic techniques, a methodological approach to archaeological data-based studies has been produced [13], and can also be developed for cultural heritage management [14], [15]. Through this spatial approach, the process of monitoring cultural heritage management and research can be maximized.

One of the applications of cultural heritage monitoring through remote sensing methods is carried out by utilizing the Google Earth application, which is effective for identifying and analyzing the landscape and environment around archaeological sites [16], [17]. Up to the analysis of ancient structures through the comparative techniques of remote sensing results [18]. The application of more complex analysis using remote sensing on archaeological data can also be done using Google Earth Engine, which also has the capability of using geographic data in remote sensing applications [19], [20]. Remote sensing can be used to interpret archaeological data related to past human activities [21]. Utilization of remote sensing data through the Google Earth application can improve the quality of research and protection of archaeological data.

The use of the Google Earth application itself, since its launch in 2005, has continued to develop and is used in various scientific fields for analysis processes and is used in journal publications [22]. Spatial analysis using Google Earth media has the advantage

of having a temporal database that can provide information regarding the temporal context of land cover [23]. The Google Earth application, which is based on remote sensing in the form of easily accessible satellite imagery, will simplify the process of analyzing land use and cover (LULC) and is freely available [24], [25]. Based on various descriptions of the use of remote sensing data accessed through Google Earth, this study aims to apply the LULC analysis method in the Trowulan National Cultural Heritage Area using Google Earth image data.

Research conducted in the Trowulan area previously related to land use aspects was carried out by [26], who conducted a mapping of the brick industry in the Trowulan District. However, this research did not address the comprehensive aspects of land use in the cultural heritage area. Therefore, this study will attempt to answer the dynamics of changes in land use and land cover in the Trowulan area over the past few decades, as well as the extent to which changes in land use affect the potential loss of archaeological data in the area.

This research aims to provide spatial-based data to support cultural resource management in the Trowulan cultural heritage area. Through LULC analysis, it is hoped that this research will provide insights and identify potential damage to archaeological data that has not yet been discovered in the soil layers.

2 Method

The research was conducted on the boundary of the Trowulan cultural heritage area, as seen in Figure 2. The research data will utilize remote sensing data, which will be analyzed spatially and temporally, using imagery from 2011 and 2024. This research utilizes satellite imagery data obtained from Google Earth. Land boundary information was obtained from the land use certificate, which was then georeferenced using the coordinate boundary information contained in the certificate. The digitized data was then processed using Geographic Information System (GIS) data management software.

This research is quantitative and uses a spatial approach. The spatial approach employed includes land use change analysis using manual digitization in Google Earth. The manual digitization process was chosen because a guided classification process would not allow for comparison of activities and infrastructure development, aimed at conserving archaeological data or identifying land use changes that endanger archaeological data.

Data collection was carried out by downloading Google Earth Pro satellite image data taken for the years 2011 and 2024. Determining the image period is an essential step in finding the dynamics of LULC changes [27]. This study uses a descriptive spatial analysis method. Descriptive analysis is conducted to describe the results of the digitization. Spatial-temporal analysis is undertaken to understand changes that occur over time within a predetermined timeframe. This analysis is also performed to analyze the relationship between geographic location or spatial aspects of the Earth's surface and objects, phenomena, and every element within an area [28], [29].

The land changes that will be observed will only focus on two aspects: first, the change in land for residential purposes, and second, the change for industrial use, brick industry and mining. Based on the analyzed LULC data, an estimate will be made of the potential disturbance to archaeological data still present in the soil layers and not yet further investigated. For example, residential development, brick-making, and mining will result in excavations that could potentially eliminate archaeological data. Given that this location is a former urban settlement, the density of archaeological remains in this area is very high. These findings will then be linked to area management policies. **Fig. 1.** shows the research workflow.

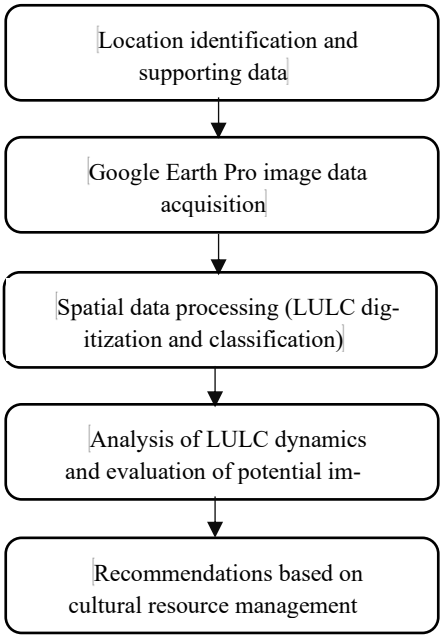

Fig. 1. Research workflow for analyzing land use and land cover (LULC) dynamics and their implications for archaeological site preservation in the Trowulan Cultural Heritage Area (Source: Dimas Nugroho, 2025).

3 Data and Interpretation

3.1 Research Area

This research was conducted in the Trowulan cultural heritage area, which spans 50 sub-districts across six districts: Jatirejo, Puri, Trowulan, Sooko, Mojowarno, Mojoagung, and Sumobito.

The area covers 92.6 km². The Ngonto River borders it to the north, the Jombang Forest Management Unit (KPH) to the south, the Brangkal River to the east, and the Gunting River to the west [11]. **Fig. 2.** shows the boundaries of the Trowulan cultural heritage area along with the boundaries of the sub-districts within the region.

The cultural heritage area is mostly located in Mojokerto Regency. Pleistocene plains, alluvial deposits, and alluvial facies dominate the geological characteristics of this region. This area has an average elevation of 22 meters above sea level, which can be categorized as a lowland [30]. Meanwhile, the characteristics of the Jombang region can be divided into three categories, namely limestone mountain areas, flat agricultural land, and land with characteristics suitable for plantation areas [31]. The geological characteristics of these two areas are not significantly different. Both areas contain several archaeological sites that have been recorded in the Trowulan Cultural Heritage Area designation.

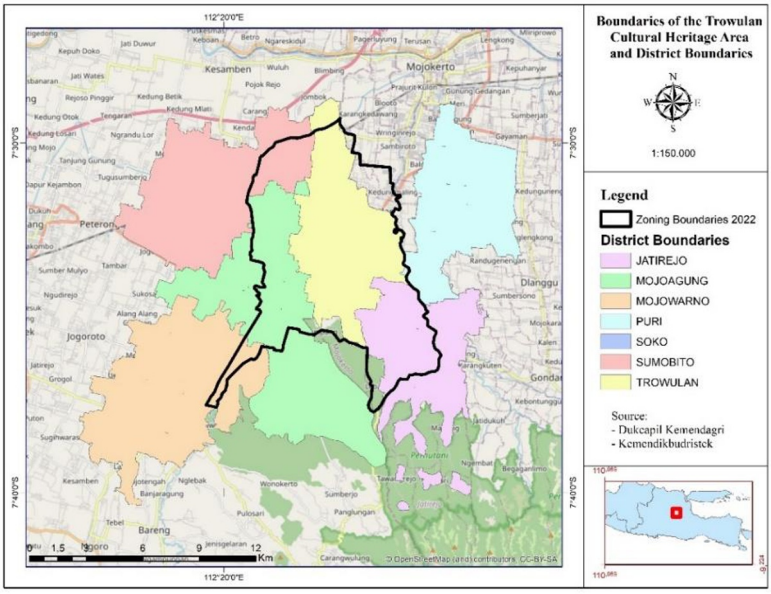

Fig. 2. Spatial boundaries of the Trowulan Cultural Heritage Area and its administrative districts, showing zoning delineation and district divisions (Source: Dukcapil Kemendagri and Kemendikbudristek).

3.2 Results of Digitization Processing and Analysis of Land Use and Land Cover (LULC)

The focus of the digitized data processing was to determine the potential extent of archaeological data loss, particularly that still within the soil layers. Therefore, the basis for the digitization, as previously explained, was changes in land use and land cover caused by two factors. The first factor was changes resulting from the development of new settlements and road infrastructure. The second factor was changes in land use and land cover for industrial, brick-making, and mining purposes.

This research focuses solely on these two factors because they are considered to have the potential to damage or lose archaeological data, particularly that still stored under-

ground. Land that has been built on by residential areas will certainly result in the underlying soil layers losing the opportunity for further study through archaeological excavation. Meanwhile, regarding industrial factors, specifically the brick-making industry carried out by residents, which involves moulding bricks from excavated soil. This soil excavation process often causes the archaeological data stored within to be lifted from its matrix, lost, or even unreported by the brick makers. Therefore, to determine the potential "disruption" to archaeological data, especially that still underground, these two factors will be used as the focus of classification.

Unlike research on land use and land cover change analysis, which is generally conducted to detect changes in land cover from tree-covered areas to agricultural areas, this aspect was not included in the digitization because it was considered to have a minor impact on the potential damage to archaeological data still stored in the soil. This is because agricultural and plantation activities, especially sugarcane plantations, do not involve land cultivation without digging to a certain depth, which has the potential to disturb potential archaeological finds still stored in the soil layers below. The division of potential levels of disturbance to archaeological data can be seen in **Tabel 1.**

Table 1. Land use distribution and level of potential disturbance to archaeological data .

Land Cover Type	Potential Disturbance Level	Color Description
Agriculture, Plantations, and Forests	Low	-
Settlements, infrastructure, and highways	Medium	Yellow
Industry, brick industry and mining	High	Red

Based on the division of potential damage levels, the following are the results of satellite image data processing taken from the Google Earth Pro application that collected image data between 2011 and 2024. The following **Fig. 3.** is a comparative map of the development of LULC in the Trowulan cultural heritage area. This comparison shows quite significant changes in several parts of the area, especially in the transition of vegetation to built-up areas. These results also provide an initial picture of the dynamics of development pressure on the cultural heritage area over time. The discovery of land changes in the Trowulan Cultural Heritage area can be an essential basis in efforts to preserve and maintain the historical and archaeological value of the area. These findings also highlight the spatial concentration of development pressures in areas that are closely associated with known archaeological sites, indicating a higher risk of disturbance to subsurface cultural remains. Integrating spatial planning and zoning into cultural heritage management becomes essential to reduce potential impacts and support long-term preservation of the Trowulan Cultural Heritage Area.

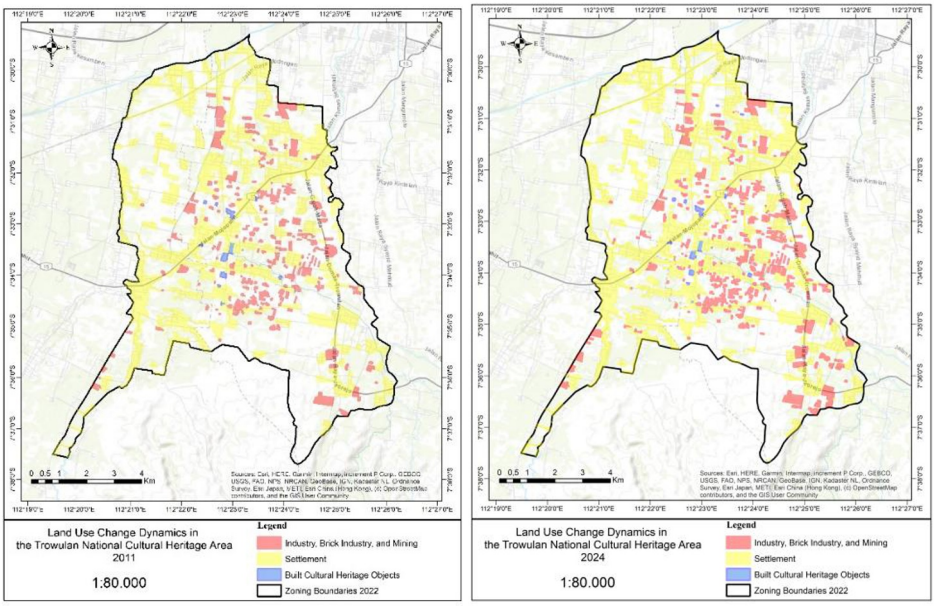

Fig. 3. Comparison of land use changes and their relationship to potential damage to archaeological data (Source: Dimas Nugroho, 2025).

Satellite imagery data was digitized using the Google Earth Pro database, taken on May 28th in 2011, using Landsat and Copernicus imagery. Satellite imagery data from May 16th, 2024, was sourced from Airbus satellite imagery. The digitization process for the imagery data was carried out at the boundary of the Trowulan National Cultural Heritage Area. The imagery data can be seen in **Fig. 4**.

Fig. 4. Satellite images of the study area in 2011 and 2024 (Source: Landsat, Copernicus, Airbus).

Based on the analysis of satellite imagery data through land use and land cover change analysis as well as spatial-temporal comparison analysis through manual digitization process, there is an increase in residential areas that occurred between 2011 and 2024. This increase indicates an increase in the number of residents inhabiting the area

included in the Trowulan cultural heritage area, which can be caused by the increasing flow of urbanization due to the increase in economic activities in the area. This is supported by data on the increase in the number of buildings related to industrial activities in the area.

Based on satellite imagery data analysis, it is known that there has been an increase in the area of industrial areas, particularly those located in the Jatirejo sub-district. The industrial area in this area has continued to grow over the past decade, both through the expansion of existing factories and the construction of new industrial buildings **Fig.5**.

This increase in the LULC, from previously empty rice fields or green areas, can lead to the potential loss of archaeological data that has not been discovered or is still stored underground. The land surface covered by buildings also blocks opportunities for conducting archaeological research within it. Therefore, development in cultural heritage areas, especially the core area, should be preceded by a review by a team of experts to confirm that the area to be developed is free of potential archaeological data.

Land use changes in the Trowulan area that pose a serious threat to archaeological data include brick-making and mining activities within the cultural heritage area. These brick-making activities are carried out by local residents on agricultural land. The soil quality in this area, considered suitable for brick-making, is visible mainly in the central part of the area, particularly in the districts of Trowulan, Mojoagung, and Jatirejo.

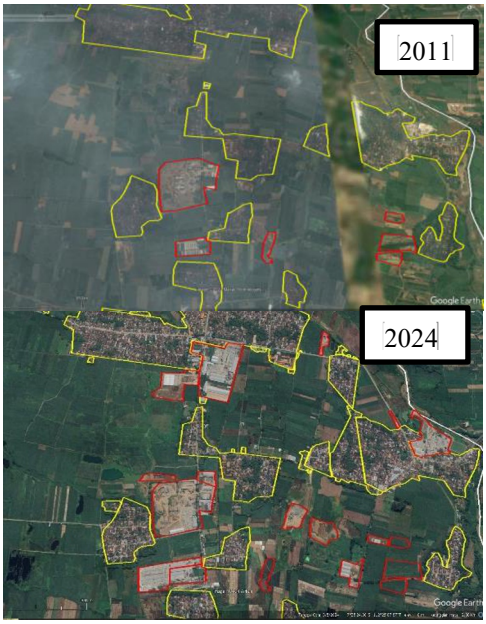

Fig. 5. Development of industrial facilities in Jatirejo sub-district from 2011 (top) and 2024 (bottom) (Source: Landsat, Copernicus, Airbus).

The brick industry is said to have a high potential for damage because the process from start to finish, which can take several years, can cause the transport or loss of soil

material to a depth of 1-2 meters. In carrying out this activity, residents typically construct semi-permanent structures that function as temporary residences and as kilns for the bricks they have made (Figure 6). In some cases, this activity often yields structures and artifacts correlated with the Majapahit era. Therefore, in the process of digitizing satellite imagery data observing changes in land from previously brick industries to being abandoned and then repurposed as rice fields, it is still categorized as land with high potential for disturbance (red color).

Fig. 6. Semi-permanent building of brick-making industry (Source: National Archaeological Research Center, Ministry of Education, Culture, Research, and Technology, 2019).

The trend of brick-making industry activity within the Trowulan cultural heritage area can be said to be quite declining when comparing 2011 and 2024. The pattern of brick-making industry activity in 2011 was carried out in a reasonably large area consisting of several buildings in a nearby location. In 2024, it was seen that several places that were previously used as brick-making industries had been abandoned and re-purposed as rice fields or abandoned land. This pattern of brick-making industry activity is also slightly different, where many brick-making industry sites are found with only one semi-permanent building, indicating that brick-making activities are carried out by individuals rather than in groups.

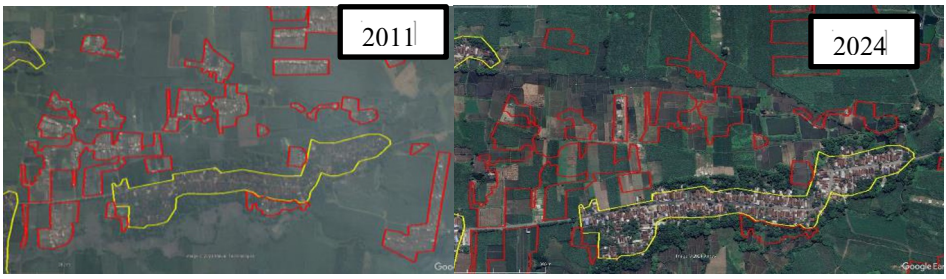

Fig. 7. Former brick industry land has been converted back into rice fields and the number of brick industries has decreased (Source: Landsat, Copernicus, Airbus).

Fig. 7. shows an example of land that has been abandoned by previous brick makers and a new brick industry that has developed in the surrounding area. The decline in the number of brick-making industries is also widely seen in the northern side of Trowulan District, where many former industrial areas have been re-purposed as rice fields. This is likely related to the economic development and other industries around the region and the reduction in the number of brick-making industry players.

Several changes in the LULC discussed previously through spatial analysis indicate that most areas undergoing modifications have the potential to affect archaeological sites that may not yet be discovered in the area. These changes in land use can disrupt the archaeological context, particularly the brick industry's activities involving the extraction of land materials, which can cause archaeological data still stored in the soil to be removed from its historical context and matrix. Therefore, the dynamics of LULC changes in the Trowulan cultural heritage area pose serious challenges in the management of cultural heritage areas in a broad scope.

Several steps can be taken to protect and preserve archaeological sites in this area, including developing a sustainable spatial plan. The use of remote sensing and GIS technology in monitoring area management needs to be maximized. Furthermore, public education is required in order to raise awareness of conservation. Management of the Trowulan cultural heritage area must take into account various spatial dynamics. A data-driven approach, the use of technology that supports more effective monitoring, and the participation of multiple stakeholders can achieve better management.

Land use changes in the Trowulan cultural heritage area also need to be understood within the context of spatial planning and regional development policies. The zoning regulations established by the government through the National Cultural Heritage Area Zoning System, based on Cultural Heritage Law Number 11 of 2010, should serve as a reference for controlling community activities and investment around the site's core area. However, its implementation in the field still faces various challenges, ranging from limited oversight to low public awareness and conflicts of economic interest between preservation and development. Economic factors are a key factor contributing to the significant changes in this area. Therefore, more sustainable utilization and development of activities, such as more intensive development of the tourism sector, could be an alternative. This condition demonstrates the need for more potent synergy between stakeholders, including the central government, local governments, relevant government agencies, and local communities, so that protection policies do not stop at the administrative level, but are implemented concretely in spatial management at the site level.

Furthermore, a community-based participatory approach can be an effective strategy for ensuring the sustainability of the Trowulan site. The involvement of local communities as key actors in maintaining, monitoring, and wisely utilizing the area will foster a sense of ownership of the existing cultural heritage. These community-based conservation efforts can be combined with innovative spatial technologies such as regular monitoring of land use changes through satellite imagery, interactive geographic information systems, and digital databases of archaeological sites. Thus, the integration of policy, technology, and social participation will strengthen Trowulan's position not

only as a national cultural heritage area but also as a model for sustainable cultural heritage preservation in Indonesia.

3.3 Quantitative Estimation of Built-up Expansion

The quantitative analysis was conducted using Python-based image processing (OpenCV and NumPy libraries) to perform pixel-counting classification on digitized LULC maps, which were cropped to the official heritage boundary. This method allowed the calculation of relative area proportions (in %) and conversion into absolute values (km²) for both 2011 and 2024 imagery, providing a reproducible and transparent workflow for temporal comparison.

Based on the results of pixel-based spatial analysis using Google Earth Pro imagery for the years 2011 and 2024, the total built-up area (consisting of residential and industrial–brickmaking zones) within the Trowulan National Cultural Heritage boundary has increased from 10.55% (9.77 km²) in 2011 to 12.34% (11.43 km²) in 2024. This expansion represents an addition of approximately 1.66 km², equivalent to a 17% relative increase in built-up land area over thirteen years. The most significant changes occurred in the central and southern parts of the heritage zone, particularly in Trowulan and Jatirejo districts, which exhibit intensive residential growth and small-scale industrial development.

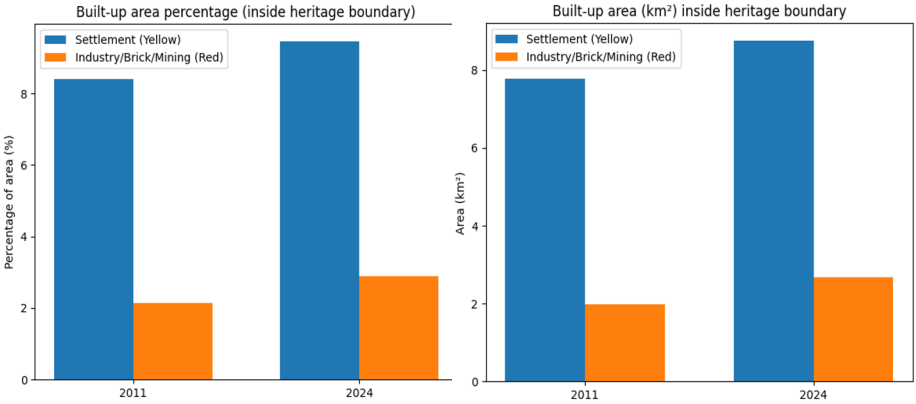

Fig. 8. Proportion and Spatial Extent of Built-up Area Changes in the Trowulan Cultural Heritage Zone (Source: Dimas Nugroho, 2025).

The rise in built-up and industrial land directly correlates with the ongoing transformation of the cultural landscape and increased risk to buried archaeological deposits. Continuous spatial monitoring through remote sensing and GIS analysis is therefore essential for balancing heritage preservation with contemporary development pressures.

4 Conclusion

This research shows that changes in land use and land cover have significantly impacted the preservation of cultural heritage and archaeological data in the Trowulan cultural heritage area. Land use changes over several years show a trend of shifting from rice fields to trees, then settlements to industrial use, as well as increased brick-making and mining activities. The conversion of agricultural land to mining and brick-making activities has the potential to threaten the existence of undiscovered archaeological data significantly. The significant increase in infrastructure development must also be based on prior research.

The results of this research are expected to contribute to the development of policies for cultural resource management and the conservation of cultural areas. All development planning and supervision of cultural heritage areas must be based on the principle of balance in meeting needs and preserving cultural assets and archaeological data. Development based on cultural resource management can be an option for integrating site preservation aspects with regional spatial planning.

5 Authors' Contributions

Dimas Nugroho designed the research concept, collected spatial data, analyzed and interpreted the results of land-use change using satellite imagery, and wrote the article. Adi Wibowo contributed to the methodology, provided supervision and guidance, and edited the final manuscript. All authors read and approved the final manuscript for publication

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7 References

[1] B. L. Turner and W. B. Meyer, *Change in Land Use and Land Cover: A Global Perspective*. Cambridge: Cambridge University Press, 1994.

[2] S. Ullah, K. Ahmad, R. U. Sajjad, A. M. Abbasi, A. Nazeer, and A. A. Tahir, "Analysis and simulation of land cover changes and their impacts on land surface temperature in a lower Himalayan region," *J. Environ. Manage.*, vol. 245, pp. 348–357, Sep. 2019, doi: 10.1016/j.jenvman.2019.05.063.

[3] K. Mishra, H. L. Tiwari, and V. Poonia, "An integrated approach of machine learning methods coupled with cellular automation for monitoring and forecasting of land use

and land cover," *J. Arid Environ.*, vol. 226, p. 105293, Jan. 2025, doi: 10.1016/j.jaridenv.2024.105293.

[4] S. M. Zaidi, A. Akbari, A. Abu Samah, N. Kong, and J. Gisen, "Landsat-5 Time Series Analysis for Land Use/Land Cover Change Detection Using NDVI and Semi-Supervised Classification Techniques," *Pol. J. Environ. Stud.*, vol. 26, no. 6, pp. 2833–2840, Nov. 2017, doi: 10.15244/pjoes/68878.

[5] K. I. N. Rahmi, A. Ali, A. A. Maghribi, S. Aldiansyah, and R. Atiqi, "Monitoring of land use land cover change using google earth engine in urban area: Kendari city 2000-2021," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 950, no. 1, p. 012081, Jan. 2022, doi: 10.1088/1755-1315/950/1/012081.

[6] S. Gaur and R. Singh, "A Comprehensive Review on Land Use/Land Cover (LULC) Change Modeling for Urban Development: Current Status and Future Prospects," *Sustainability*, vol. 15, no. 2, p. 903, Jan. 2023, doi: 10.3390/su15020903.

[7] Y. Eriawati, D. Nugroho, and dan M. F. S. Intan, "Grogol Village: Majapahit Settlement in Trowulan," 2023, pp. 495–505. doi: 10.2991/978-2-38476-070-1_45.

[8] N. Rangkuti, "Batas Kota Majapahit," in *Majapahit Batas Kota dan Jejak Kejayaan di Luar Kota*, I. Andrisijanti, Ed., Yogyakarta: Kepel Press, 2014, pp. 3–20.

[9] S. Satari, "Some Data on A Former City of Majapahit," in *The Legacy of Majapahit*, J. N. Miksic and E. S. H. Soekatno, Eds., Singapore: National Heritage Board / National Museum of Singapore, 1995, p. 33.

[10] Republik Indonesia, *SK Menteri Pendidikan dan Kebudayaan RI nomor 260/M/2013 tentang Penetapan Satuan Geografis Trowulan sebagai Kawasan Cagar Budaya Nasional*. Indonesia, 2013.

[11] Republik Indonesia, *Keputusan Menteri Pendidikan, Kebudayaan, Riset, dan Teknologi Republik Indonesia Nomor 140/M/2023 Tentang Sistem Zonasi Kawasan Cagar Budaya nasional Trowulan*. 2023.

[12] B. Liu, C. Wu, W. Xu, Y. Shen, and F. Tang, "Emerging trends in GIS application on cultural heritage conservation: a review," *Herit. Sci.*, vol. 12, no. 1, p. 139, May 2024, doi: 10.1186/s40494-024-01265-7.

[13] D. Ebolese, M. Lo Brutto, and G. Dardanelli, "UAV Survey for the Archaeological Map of Lilybaeum (Marsala, Italy)," *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, vol. XLII-2/W11, pp. 495–502, May 2019, doi: 10.5194/isprs-archives-XLII-2-W11-495-2019.

[14] F. Monna *et al.*, "Deep learning to detect built cultural heritage from satellite imagery. - Spatial distribution and size of vernacular houses in Sumba, Indonesia -," *J. Cult. Herit.*, vol. 52, pp. 171–183, Nov. 2021, doi: 10.1016/j.culher.2021.10.004.

[15] S. H. Parcak, *Satellite Remote Sensing for Archaeology*. London and New York: Routledge, 2009.

[16] Mei Yang and Zhaoyang Feng, "Comparative Study on Spatial Forms of Ancient Waterside Towns Based on Google Earth Pro－Taking the Example of Qingmuchuan, Fenghuang and Houliu in Southern Shaanxi, China," *Journal of Environmental Science and Engineering B*, vol. 9, no. 1, Feb. 2020, doi: 10.17265/2162-5263/2020.01.002.

[17] L. Luo *et al.*, "Google Earth as a Powerful Tool for Archaeological and Cultural Heritage Applications: A Review," *Remote Sens. (Basel).*, vol. 10, no. 10, p. 1558, Sep. 2018, doi: 10.3390/rs10101558.

[18] D. Kaimaris, O. Georgoula, P. Patias, and E. Stylianidis, "Comparative analysis on the archaeological content of imagery from Google Earth," *J. Cult. Herit.*, vol. 12, no. 3, pp. 263–269, Jul. 2011, doi: 10.1016/j.culher.2010.12.007.

[19] K. E. Herndon *et al.*, "Google Earth Engine for archaeologists: An updated look at the progress and promise of remotely sensed big data," *J. Archaeol. Sci. Rep.*, vol. 50, p. 104094, Aug. 2023, doi: 10.1016/j.jasrep.2023.104094.

[20] H. Tamiminia, B. Salehi, M. Mahdianpari, L. Quackenbush, S. Adeli, and B. Brisco, "Google Earth Engine for geo-big data applications: A meta-analysis and systematic review," *ISPRS Journal of Photogrammetry and Remote Sensing*, vol. 164, pp. 152–170, Jun. 2020, doi: 10.1016/j.isprsjprs.2020.04.001.

[21] L. Luo, X. Wang, and H. Guo, "Transitioning from remote sensing archaeology to space archaeology: Towards a paradigm shift," *Remote Sens. Environ.*, vol. 308, p. 114200, Jul. 2024, doi: 10.1016/j.rse.2024.114200.

[22] J. Liang, J. Gong, and W. Li, "Applications and impacts of Google Earth: A decadal review (2006–2016)," *ISPRS Journal of Photogrammetry and Remote Sensing*, vol. 146, pp. 91–107, Dec. 2018, doi: 10.1016/j.isprsjprs.2018.08.019.

[23] R. Chen *et al.*, "Spatiotemporal Continuous Impervious Surface Mapping by Fusion of Landsat Time Series Data and Google Earth Imagery," *Remote Sens. (Basel).*, vol. 13, no. 12, p. 2409, Jun. 2021, doi: 10.3390/rs13122409.

[24] A. KC, N. Wagle, and T. D. Acharya, "Spatiotemporal Analysis of Land Cover and the Effects on Ecosystem Service Values in Rupandehi, Nepal from 2005 to 2020," *ISPRS Int. J. Geoinf.*, vol. 10, no. 10, p. 635, Sep. 2021, doi: 10.3390/ijgi10100635.

[25] Y. Ban, P. Gong, and C. Giri, "Global land cover mapping using Earth observation satellite data: Recent progresses and challenges," *ISPRS Journal of Photogrammetry and Remote Sensing*, vol. 103, pp. 1–6, May 2015, doi: 10.1016/j.isprsjprs.2015.01.001.

[26] P. W. Sejati, "Pemetaan Industri Batu Bata Merah di Kawasan Cagar Budaya Trowulan Kecamatan Trowulan Kabupaten Mojokerto," *Swara Bhumi*, vol. 4, no. 3, pp. 6–15, 2017.

[27] R. P. Nagara and A. Wibowo, "Identifying the Impact of Shoreline Change on Land Use in Bedono Village with Google Earth," *Journal of Community Based Environmental Engineering and Management*, vol. 8, no. 8, pp. 27–34, Mar. 2024, doi: 10.23969/jcbeem.v8i1.11382.

[28] H. Rakuasa and P. C. Latue, "Analisis Spasial Daerah Rawan Banjir Di DAS Wae Heru, Kota Ambon," *Jurnal Tanah dan Sumberdaya Lahan*, vol. 10, no. 1, pp. 75–82, Jan. 2023, doi: 10.21776/ub.jtsl.2023.010.1.8.

[29] F. A. Prasetya, "Analisis Spasial-Temporal Perubahan Penggunaan Lahan Akibat Pembangunan Bandara Internasional Dhoho Kediri Berbasis Data Google Earth," *Geodika: Jurnal Kajian Ilmu dan Pendidikan Geografi*, vol. 8, no. 1, pp. 65–74, May 2024, doi: 10.29408/geodika.v8i1.25731.

[30] Badan Pusat Statistik Kota Mojokerto, "Kota Mojokerto Dalam Angka 2024," Mojokerto, 2024.

[31] Badan Pusat Statistik Kabupaten Jombang, "Kabupaten Jombang Dalam Angka 2024," Jombang, 2024.