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Citation (APA)
Katontoka, M., Noardo, F., Palacios-Lopez, D., Esch, T., Nourian, P., Chen, F., & Pereira Roders, A. (2024). No Report, No Densification? A Spatiotemporal Analysis of Urban Densification and Reporting Practices in World Heritage Properties. *Land*, *13*(10), Article 1646. https://doi.org/10.3390/land13101646

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No Report, No Densification? A Spatiotemporal Analysis of Urban Densification and Reporting Practices in World Heritage Properties

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Abstract: As urbanization accelerates, World Heritage properties, critical conservation areas, face a growing threat of urban densification, jeopardizing their Outstanding Universal Value (OUV). States Parties, the countries that have ratified the World Heritage Convention, are responsible for submitting periodic reports on the state-of-conservation of their World Heritage properties. These reports should explicitly address any instances of urban densification that may be occurring. But do they? This research investigates the relationship between urban densification and reporting practices in World Heritage properties over time and space. Through a spatiotemporal analysis, by analyzing changes in the built-up area within the core zones of cultural World Heritage properties from 1985 to 2015. We found that urban development, including housing, infrastructure, and tourism facilities, has significantly impacted World Heritage properties and an increase in built-up area can be observed especially in properties not reporting on urban threats.

Keywords: World Heritage; heritage properties; world settlement footprint evolution; urban built-up; land cover; UNESCO

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Citation: Katontoka, M.; Noardo, F.; Palacios-Lopez, D.; Esch, T.; Nourian, P.; Chen, F.; Pereira Roders, A. No Report, No Densification? A Spatiotemporal Analysis of Urban Densification and Reporting Practices in World Heritage Properties. *Land* **2024**, *13*, 1646. https://doi.org/10.3390/land13101646

Received: 23 August 2024
Revised: 27 September 2024
Accepted: 7 October 2024
Published: 9 October 2024

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1. Introduction

Urbanization has triggered the rapid change of landscapes, altering land cover and land-use type. For example, urban sprawl competes with areas that act as carbon sinks and agricultural spaces [1] while compact urbanization leads to the densification and consolidation of detached urban spaces [2]. In some cities, such as Abuja and Mumbai, the challenges of rapid urbanization in the recent decade led to an uncontrolled expansion of cities and subsequently to the shrinking of conservation areas, listed as heritage [1,3,4].

Urbanization has a significant impact on heritage properties, which can be either positive or negative [5]. However, it continues to pose a threat to cultural heritage properties [6–9]. Urbanization is a dynamic phenomenon that crosses multiple dimensions, such as social, economic, political, and physical, and can rapidly transform many aspects of cities and landscapes. As the demand from various stakeholders for land, accommodation,

water, and tourism, among others, continues to increase, the pressure that this has on the landscape of WH cannot be ignored [7,10]. UN-Habitat and the World Bank project that the proportion of the global population living in urban areas, currently at 55%, is expected to rise to 70% by 2050 [11,12]. Thus, as landscapes are expected to change, assessing how urban developments have been and will be influencing WH is significant, as these properties should be conserved.

In terms of the ongoing and expected rapid urbanization, which is reflected through physical urban development, "how much change is taking place in heritage properties?" is an important question to explore [13,14]. The impact of urbanization on heritage is significant, leading to the physical destruction, permanent alteration, and arbitrary reconstruction of historic areas. This phenomenon is not confined to specific locations, and even protected areas may be affected [15]. The drivers of urbanization, such as urban development, human population growth, natural/cultural attractions, and socioeconomic growth, are significant in helping cities thrive. However, the intersection of human population growth and natural/cultural attractions can lead to resource misuse. Additionally, population growth and socioeconomic pressure can result in urban sprawl, and the interaction between natural/cultural attractions and socioeconomic pressure promotes tourism expansion. If these and many other interactions overlap, they may cause significant damage to heritage properties [16]. If left unchecked, the resulting activities, such as the construction of more buildings, transportation infrastructure, and environmental pollution, threaten the conservation of cultural heritage properties, leading to the potential loss or degradation of areas with cultural significance [6] (Figure 1).

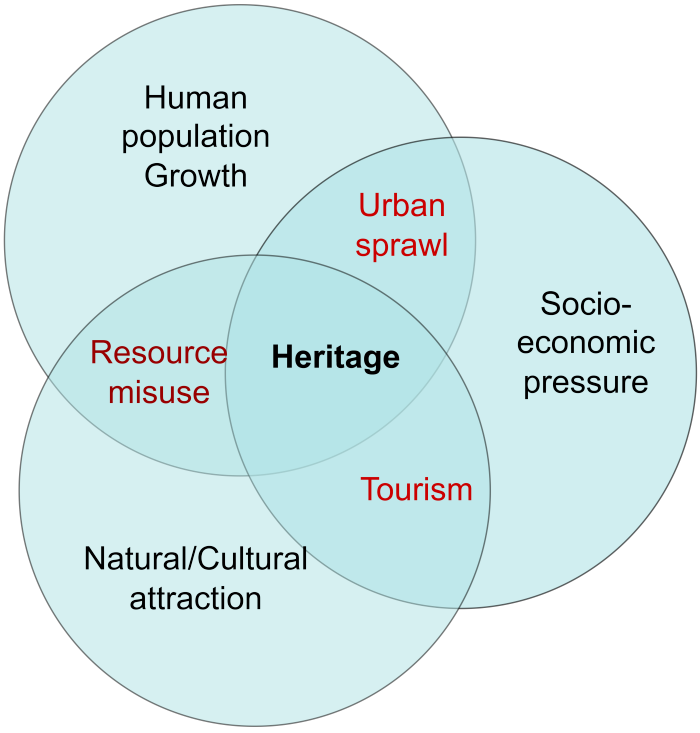


Figure 1. An illustration of interconnected challenges for sustainable development and heritage protection (adapted from [16]).

Moreover, there is very limited research on urban heritage at the global level [17,18], and there is not much analysis on spatial-temporal changes in heritage properties. Urban heritage studies today focusing on the urbanization of heritage properties generally focus on specific case studies [19–23]. Several studies aiming at quantifying change in WH properties that use land cover and land use change (LULC) as one of the main indicators are primarily found in natural heritage and focus on isolated heritage properties [21,22,24,25].

In China, quantification of land cover change detection in heritage properties using very-high-resolution images revealed significant impacts of urbanization [21]. A similar approach in India revealed that land cover change detection caused by deforestation and intensive sandstone mining negatively impacted unique cultural heritage properties [20]. An analysis of land cover and land use change in Cairo, Egypt, revealed both gains and losses of natural resources due to factors such as population growth and land value [22]. Meanwhile, a study on the Theban Temples of West Luxor assessed the impact of uncontrolled urban sprawl on heritage property. This investigation utilized multi-temporal and multi-sensor satellite data from Corona, Landsat, Spot, Quickbird, and Sentinel2A, along with spatial analysis. According to the study, the urban area of the heritage property expanded by 7.69 km^2 between 1967 and 2017. Additionally, the investigation found that the rapid urban expansion led to poor sewage networks and high groundwater levels, which had a negative impact on archaeological areas. As a result, the groundwater depth was altered [26].

A study in Angkor using GIS models revealed a 160% increase in urban development within 13 years in the city, which is partly listed in the World Heritage (WL) list. The GIS and remote sensing prediction model indicated that urbanization would destroy 19 monuments by 2030, compared to the 7 monuments that were destroyed in 2017 [13].

Several studies have employed GIS and remote sensing data to evaluate the growth of urban areas in World Heritage properties. One example is using the Global Human Settlement layer,global population grid products, and global night-time light images to develop the Urbanization Intensity Index, which measures and monitors the degree of urbanization in WH properties across China. The index indicates an increase in the degree of urbanization from 0.35 in 2000 to 0.45 in 2015, reflecting an increase in the built-up area in the 10 WH properties [14].

Land cover change detection from remotely sensed data has proven to be immensely useful in heritage studies. For instance, land-cover data, DEM, and remote sensing data can be combined to assess the risk of natural and human distance on World Heritage properties. For example, in China, a study of Mount Emei using land-cover data, DEM, and remote sensing revealed that the spatial distribution of disturbance is relatively small and that natural disasters presented a significant risk than human disturbance [24]. Additionally, combining user-contributed geospatial data to evaluate why specific heritage locations are more popular than others and what makes them attractive for tourism contributes to various approaches in investigating World Heritage properties. This realization highlights the importance of geospatial datasets and tools in heritage studies [23,27].

Additionally, some preliminary work has been devoted to creating and evaluating geospatial heritage data. For example, Protected Urban Planet, a tool available to the public, used a multisource data approach that integrates spatial data, descriptive information, and imagery to create public awareness in the monitoring of conservation areas inscribed as WH [28]. The UNESCO WH list is the most common data source for WH properties. The list provides several attributes of WH properties, including their location in longitude and latitude data formats and years of inscription, among others [29]. Multiple studies have been conducted on the WH list, supporting its creation and maintenance [30].

Finally, initiatives such as Prothego, Protected Planet, WH Outlook, Protected Urban Planet, and REScult are essential for managing WH properties [29]. However, difficulties arise when using these data sources to analyze the WH list because the initiatives are fragmented and not standardized. Additionally, the quality of the datasets and the lack of standard web semantics on the search interfaces disables its further integration and open access by future researchers, which further limits the quantification of the changes in heritage properties [31].

The changes and patterns of land cover can be measured to help in planning and preserving heritage properties [19]. This research investigates the urban densification and reporting practices in World Heritage properties. Using a relatively larger global sample

size than previous research, we conduct spatiotemporal analysis to track the growth of built-up areas in heritage properties.

2. Materials and Methods

This research used a multisource data approach, linking three datasets, as follows:

1. UNESCO's WH list for the cultural heritage property names and other data such as year of inscription and location.
2. The International Center for Space Technology on Natural and Cultural Heritage https://www.unesco-hist.org/index.php?r=en/index, (accessed on 22 August 2024) for GIS data of the boundaries of the heritage properties [20].
3. German Aerospace Center (DLR) for Remote Sensing data and the spatiotemporal analysis of the World Settlement Footprint layer at 30m resolution from 1985 to 2015 [1].

This study utilized a combination of qualitative, GIS, and remote sensing approaches, as shown in Figure 2. QGIS was the primary platform for integrating and processing shapefile data, while Python and spreadsheets were used to prepare data and assess quality. Specifically, a spatial-temporal analysis was employed to analyze the change in built-up area over time and to track the impact of urbanization on land cover and land use [32–38]. This approach is commonly used in heritage studies to reveal the transformation of conservation areas, but typically at the level of a single WH property [21,39–41].

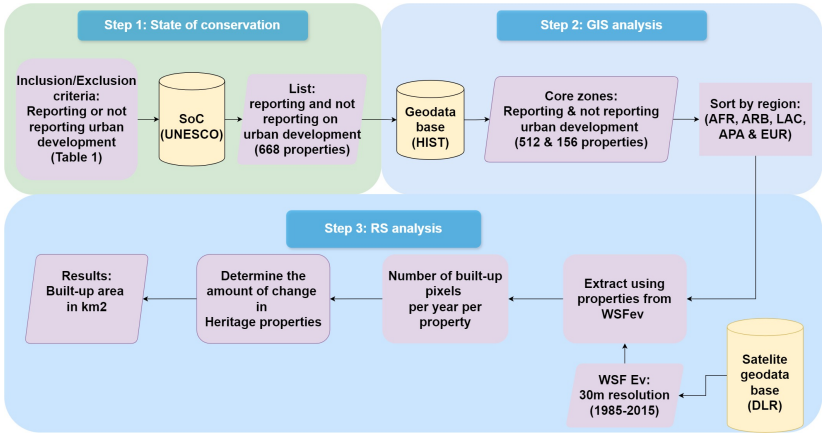


Figure 2. Conceptual workflow and method employed in the research.

In this study, changes in built-up areas were measured annually for all properties from 1985 to 2015. For properties nominated as World Heritage sites between 1985 and 2015, the year of nomination was also taken into account. The built-up area increase for each nominated property was tracked starting from its nomination year, ensuring that the analysis reflected the timing of its transformation in relation to its designation as a heritage property and subsequent conservation reporting requirements to the state of conservation. The year of nomination is critical, as it marks the point when properties are required to report on their state of conservation under World Heritage guidelines.

Although this study focuses on the changes during the nomination period, future research will be needed to assess the broader impact of heritage nomination. This would involve a comparative analysis of built-up area changes before and after nomination, which falls outside the scope of the present study.

2.1. Step 1: State of Conservation—Urban Development

The initial step was to distinguish WH properties, i.e., properties reporting and properties not reporting on urban development. Reporting properties are those that have been identified in the UNESCO State of Conservation (SoC), where the state party has identified one or more urban developments as posing a threat to the conservation areas.

Non-reporting properties are those that have not documented any urban development affecting heritage properties [42]. This step was accomplished using the SoC information system [43,44]. State parties in the state of conservation reports identified twenty-two (22) forms of urban development. These forms were used as search phrases to include and exclude properties reporting on urban development (Table 1). Furthermore, the properties were divided into the five UNESCO regions to facilitate data management and analysis and cross-regional analysis (see Figure 3).

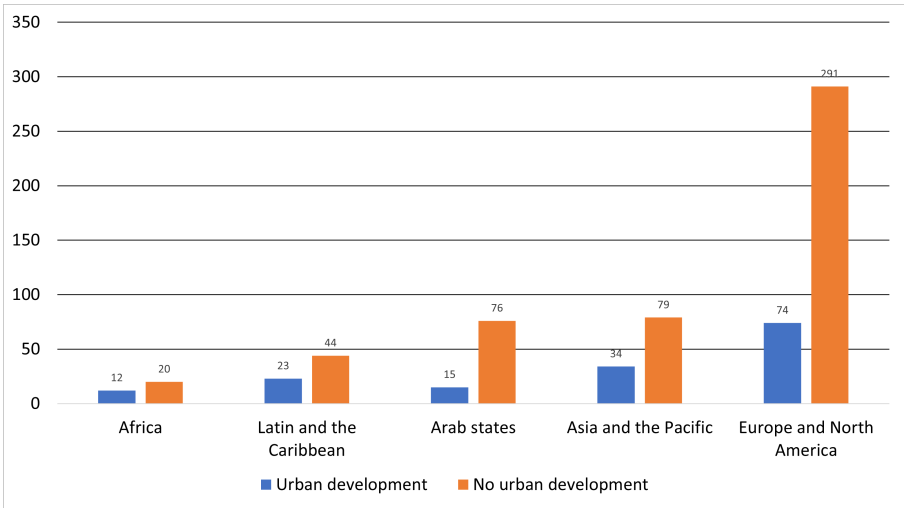


Figure 3. UNESCO's WH regions and the number of properties reporting and not reporting urban development in each region.

Table 1. The number of times urban development was reported by properties in each region.

Urban Development	LAC *n* = 62	APA *n* = 99	AFR *n* = 57	EUR *n* = 157	ARB *n* = 51	Total Frequency
1. Housing	33	47	25	74	36	215
2. Ground transport infrastructure	22	38	15	46	19	140
3. Major visitor accommodation and associated infrastructure	15	16	14	29	11	85
4. Land conversion	15	17	23	6	16	77
5. Interpretative and visitation facilities	8	19	10	23	10	70
6. Mining	8	16	20	18	1	63
7. Water infrastructure	9	16	10	7	5	47
8. Commercial development	9	18	3	11	5	46
9. Livestock, farming, and grazing of domesticated animal	11	5	19	5	5	45
10. Oil and gas	3	4	11	16	2	36
11. Localized utilities	1	5	0	11	19	36
12. Forestry wood productions	5	8	8	10	0	31
13. Major linear and utilities	5	6	4	9	3	23
14. Crop production	6	3	8	2	2	21
15. Marine transport infrastructure	7	5	2	12	4	20
16. Water extraction	1	5	3	7	1	17
17. Renewable energy facilities	3	1	2	10	1	17
18. Air transport infrastructure	3	5	3	5	0	16
19. Underground transport infrastructure	5	4	0	4	2	15
20. Quarrying	0	3	0	9	2	14
21. Industrial area	2	4	3	2	0	11
22. Nonrenewable energy	0	2	1	4	0	7

Note: LAC: Latin America and the Caribbean. APA: Asia and the Pacific. AFR: Africa. EUR: Europe and North America. ARB: Arab States. *n* refers to the number of properties per region that were reporting on urban development.

The study area included cultural World Heritage properties from all five UNESCO regions: Asia and the Pacific (APA), Latin America and the Caribbean (LAC), Africa (AFR), Europe and North America (EUR), and the Arab States (ARB). Most World Heritage properties do not provide reports on urban development. In the African region, a little over half of the properties reported on urban development, while less than half reported on urban development in the Asia and the Pacific region. In the Arab States region, only a small proportion of properties reported on urban development. In the Latin America and the Caribbean region, just over half of the properties were reporting, while Europe and North America had the highest number of properties providing reports on urban development (see Figure 3).

2.2. Step 2: GIS—Heritage Properties Boundaries

This research analyzed the geographical information of 668 WH properties. These properties were matched to the results of the state of the conservation report in Step 1. The matching process resulted in excluding properties that had no geographical information that they reported on urban development. The final result of this step was two categories of properties, all with available geographic information: those reporting on urban development and those not reporting on urban development and that had matches in the 668 geodatabases. Properties that reported on urban development but did not have available geographic information were excluded from further analysis.

The geospatial data used in the research included the boundaries of 668 WH properties (156 reporting urban development and 512 not reporting urban development). HIST created the area's extent in a shapefile by digitizing heritage maps provided by different UNESCO state parties, accessible on the UNESCO website. Furthermore, inaccuracies may exist in the area boundaries of heritage properties as a result of the digitization process of old UNESCO heritage maps. Usually, during the digitization process, geometric errors to the boundary, scale changes, and referencing alterations occur [45,46].

To combat these inaccuracies, old maps were examined and compared to the digital shapefiles to evaluate the accuracy of the boundaries. We found that the maps were generally accurate for our analysis. However, there were inaccuracies in the attribute data, such as names and other descriptive information about the heritage properties. Some data were either missing or incorrect. To address this, we combined the World Heritage data Excel file from UNESCO, which contains all the attribute information for each property, with the shapefile. Additionally, for this process, we also manually verified the data to correct any missing or inaccurate information about the properties.

2.3. Step 3: RS—World Settlement Footprint Evolution

The raster data in question possesses a temporal resolution spanning from 1985 to 2015 and a spatial resolution of 30 m. Its creation involved a sophisticated classification system that integrated open and free optical and radar satellite imagery by DLR and Google.

The WSF ev (World Settlement Footprint Evolution) was developed using an iterative approach. This was needed due to the absence of suitable archived high-resolution radar imagery. The method effectively delineated past settlement extents based solely on Landsat data acquired globally from late 1984 at a 30 m resolution. During the generation of the layer, each pixel's minimum, maximum, mean, and standard deviation of the normalized difference built-up index (NDBI) were extracted over time.

From 2015, with WSF2015 as a reference, an iterative extraction of settlement and non-settlement training samples occurred for each subsequent year. Notably, the layer assumes growth and does not account for instances of settlement shrinking [47]. However, this is a relatively minor occurrence compared to the overarching global trend of urbanization, mainly localized in impact.

The implemented approach culminated in the creation of the WSF-Evolution dataset. This dataset outlines the global settlement extent at a 30 m spatial resolution annually from 1985 to 2015 [47]. Validation of the raster data involved comparing it against 900,000 samples

generated through crowd-sourcing and photo-interpretation of very-high-resolution Google Earth imagery (VHR). For a more in-depth exploration of WSF ev, additional insights can be found in [1,48].

Because the non-built areas are not accounted for in the WSF ev, with the accumulation of built-up area each year, the amount of built-up area in the heritage property was counted cumulatively starting with 1985, as can be seen in Figure 4.

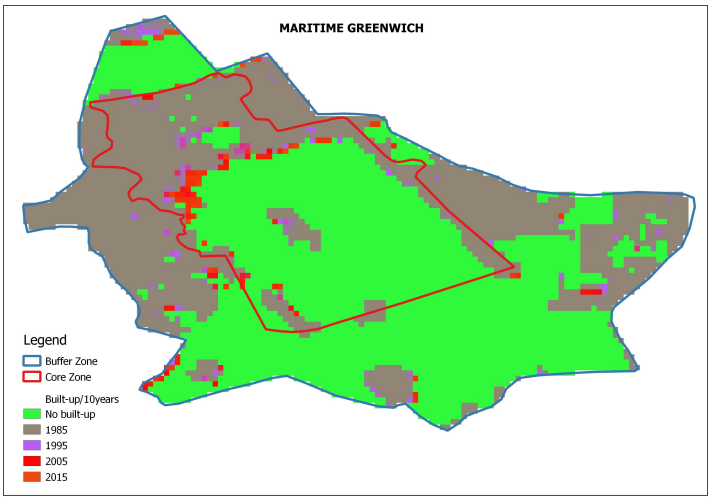


Figure 4. Illustration of WSF ev from 1985 to 2015 using the heritage property Maritime Greenwich as an example.

3. Results

3.1. State of the Conservation

The state of conservation suggests that 1/3(426) of the WH properties report urban development. The results show that regions such as Europe and North America, as well as APA, have the highest documented number of properties reporting on urbanization (see Figure 4). However, this can be attributed to the significantly high number of properties that are reporting in EUR and APA compared to other regions, as can be seen in the second row of Table 1. Furthermore, the urban development that seems to be reported frequently by WH properties is housing within and between the regions. It was reported 215 times, i.e., LAC 33, APA 47, AFR 25, EUR 74, and ARB 36 times.

The second urban development frequently reported by properties was ground transport infrastructure, which was reported 140 times, i.e., LAC 22, APA 38, AFR 15, EUR 46, and ARB 19 times. The last reported urban development was nonrenewable energy, being reported seven times in EUR and not affecting LAC and ARB (see Table 1).

3.2. Land Cover Change Detection

UNESCO recognizes the need to protect WH properties, often regulated by decreeing heritage zoning, core, and buffer areas [49]. Delineation is intended to preserve heritage properties from unwanted urban threats that may affect the OUV of heritage properties [20]. This means that monitoring the amount of transformation of heritage properties is essential. Over time, the amount of built-up in core zones indicates the transformation of WH properties. Thus, the amount of heritage coverage that changes into a built-up area after listing the heritage property can be understood as the amount of urban transformation that the core zone is experiencing [20]. This can be observed in properties reporting and those not reporting urban development within their core zones.

Figure 5 shows that the EUR and APA had almost similar built-up area increases in 1985, but this changed drastically starting in 1987. Specifically, the EUR increment in built area rose from 63 km^2 in 1985 to 2080 km^2, while APA increased from 62 km^2 in 1985 to 608 km^2 in 2015. ARB also experienced a steady increase year over year from 31 km^2 in

1985 to 84 km^2 in 2015. AFR and LAC experienced the least increments in built-up areas. For LAC, in 1985, the built-up area increase was 0.5 km^2, while in 2015, it increased to 85 km^2. On the other hand, in AFR, no increase in the built-up area was observed in 1985, while 17 km^2 of the heritage coverage changed to the built-up area in 2015. Furthermore, Figure 6 compares the percentage increase in built-up area from 1985 to 2015 for each region. The figure indicates that the LAC region experienced a significant increase of approximately 16,250% in built-up areas between 1985 and 2015. This was followed by the EUR region with a growth of 3206%, AFR with 1674%, APA with 875%, and ARB with 172%.

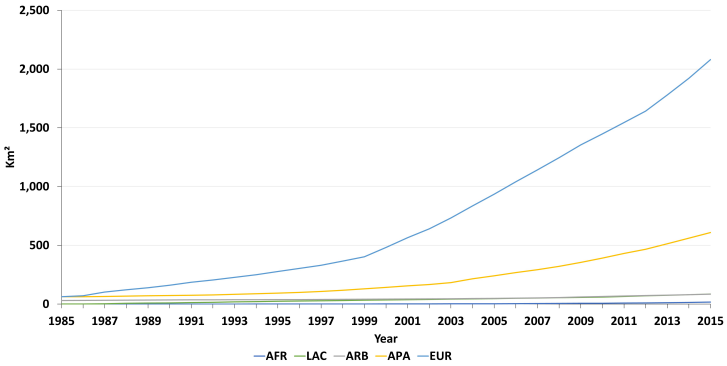


Figure 5. Comparative overview of the change in total heritage built-up area in all UNESCO regions between 1985 and 2015.

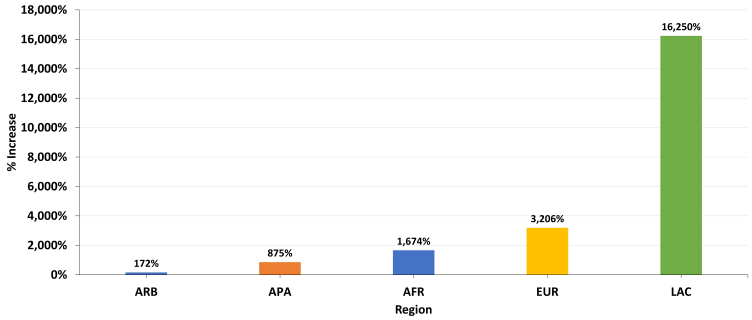


Figure 6. The total increase in built-up area by percentage for each region from the initial increase in 1985 to the final year of analysis in 2015.

Figure 7 compares the growth of built-up areas for properties reporting and not reporting on urban development between 1985 and 2015. In 1985, properties not reporting on urban development showed the largest increase in built-up areas, expanding by approximately 108 km^2. On the other hand, properties reporting on urban development grew from 49 km^2 in 1985 to 757 km^2 by 2015. By 2015, properties not reporting experienced a dramatic 1861% increase, reaching 2118 km^2, compared to a 1444.9% increase (757 km^2) for properties reporting urban development. The ratio of built-up areas between reporting and non-reporting properties was 1:2 in 1985. By 2015, this ratio shifted to 1:3, suggesting a consistent rise in built-up areas for properties not reporting on urban development.

Figure 8 show the results of the relative comparison per region in heritage coverage for properties reporting and not reporting on urban development. From the figure, it is clear that EUR has experienced a significant change in built-up areas, followed by APA. Specifically, Figure 8a shows that AFR experienced a significant increase in urban built-up areas in both categories, while in the recent two years, the properties not reporting exceeded the built-up areas of the properties reporting on urban development. The properties not reporting on urban development had strong growth, from 0.0 km^2 in 1985 to 0.1 km^2 in 2000 and 8.8 km^2 of built-up areas in 2015. On the other hand, the properties that reported on urban development in 1985 also had no change 0.0 km^2, while the first growth was seen in 1991 with about 0.10 km^2, which then increased to 80.0 km^2 in a built-up area in 2015.

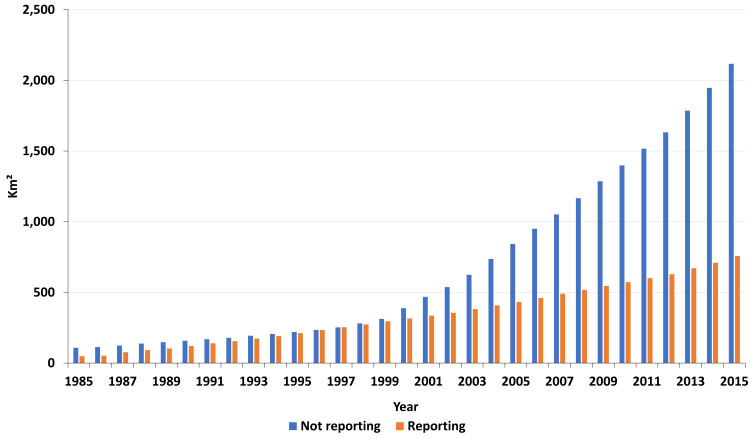
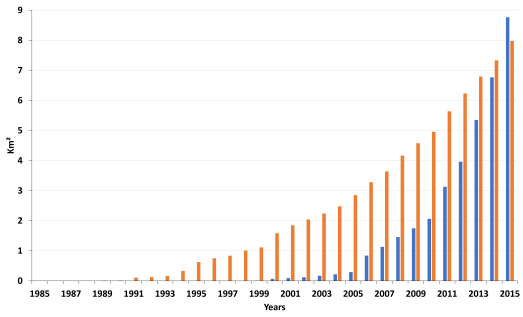
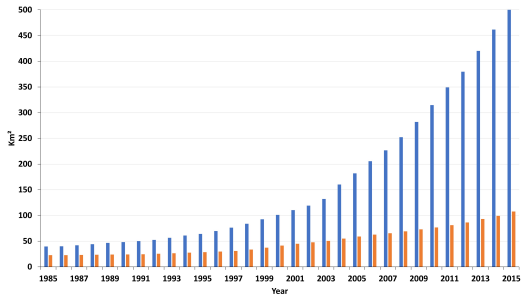


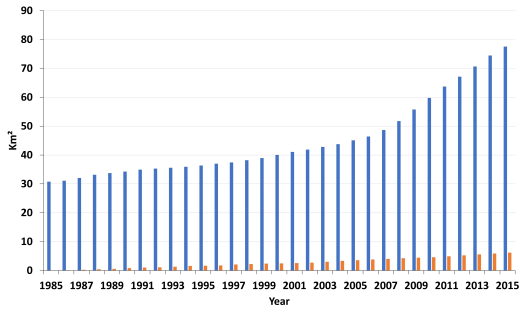
Figure 7. Comparative overview of the built-up area increase in WH properties between properties reporting and not reporting urban development between 1985 and 2015.



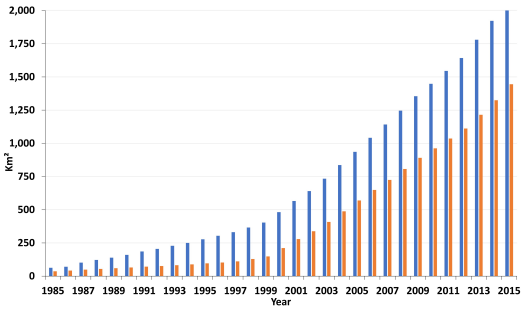
(**a**) Africa



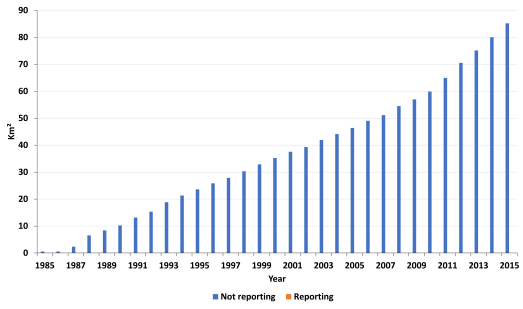
(**b**) Asia and the Pacific



(**c**) Arab States



(**d**) Europe and North America



(**e**) Latin and the Caribbean

Figure 8. Comparison in-built-up area change between not reporting and reporting properties per region (AFR, LAC, EUR, APA, and ARB).

Figure 8b shows that APA also significantly increased in built-up areas during the period of analysis. For this region, the properties that were not reported significantly increased in the built-up area from 40 km^2 in 1985 to 501 km^2, representing a 1150% change. Properties that were reporting on urban development had a lower but steady increase in built-up areas from 23 km^2 to 108 km^2 during the period compared to the properties not reporting. This represented a 369.57% increase in built-up areas for the properties reporting on urban development.

In the ARB region, it is also evident that both categories of properties that are not reported and those that are not reported on urban development display a steady increase in built-up areas. The amount of built-up areas for properties not reporting at the start of 1985 was 764 km^2 of built-up areas to 1159 km^2, while those reporting was below 73 km^2 to over 10 km^2 of built-up areas between 1985 and 2015 (Figure 8c). During this period, the properties not reporting significantly increased built-up areas by 395 km^2 higher than those reporting, which was an increase of 43 km^2.

The EUR showed that properties not reporting on urban development increased their built-up areas from 37 km^2 to 1445 km^2 between 1985 and 2015. In contrast, properties reporting on urban development experienced a relatively lesser increase in built-up area from 26 km^2 to 636 km^2 within the same period Figure 8. The increase in built-up areas represented a 3805.41% increase, while for properties not reporting, the increase represented a 2346.15% between 1985 and 2015.

Figure 8e shows the built-up increase in LAC for properties reporting and not reporting on urban development. Specifically, properties not reporting on urban development, which in 1985 had only a 1 km^2 of built-up areas, experienced an increase to over 85 km^2 in 2015. This difference accounts for an increment of about 85 km^2, which represents an 8400% increase in built-up areas.

Figure 9 presents the average annual change in built-up area from 1985 to 2015 per region for properties reporting and not reporting on urban development. The figure highlights that both reporting and not reporting properties in EUR experienced significantly higher changes than in other regions. Not reporting properties showed a relatively larger increase of 120 km^2 per year, while reporting properties changed by 53 km^2 annually. Following this, APA regions experienced yearly changes of 42 km^2 for not reporting properties and 9 km^2 for properties reporting. Additionally, the ARB states recorded an average increase of 6.5 km^2 per year for properties not reporting and 0.5 km^2 for properties reporting. In regions such as LAC, where no properties were reporting on urban development, properties not reporting saw an average increase in the built-up area of 7 km^2 per year. The region of AFR displayed the least increase, compared to other regions, with properties reporting on urban development increasing their built-up areas by 0.7 km^2 and those not reporting by 0.7 km^2 annually during the assessment period.

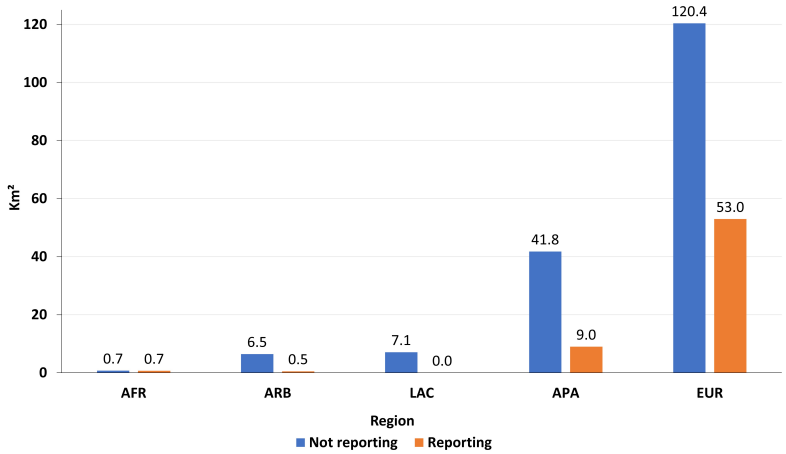


Figure 9. Average built-up area increase per year per region between 1985 and 2015.

4. Discussion

The interaction between urban space and heritage is complicated. Heritage properties can encourage urban development, but they should also be preserved to enhance urban areas [50]. It is a challenge to manage heritage properties because urban needs like energy, housing, and recreational spaces often take priority and can overshadow the need to preserve history and culture. When urban needs are met in heritage properties, it can change them and make them lose their OUV. The aim of this article was to investigate the influence of urban development between properties reporting on urban development threats and those not reporting on heritage properties by quantifying the amount of change in built-up area coverage in heritage properties between 1985 and 2015.

The study results suggest that approximately one-third (426 out of the total) of the heritage properties report on urban development. Regions such as EUR have the highest documented number of properties reporting on urbanization, followed by APA. This finding aligns with the broader consensus because these regions have high heritage area coverage, high urbanization rates, and increased urban development projects, such as housing, transport infrastructure, and power network installation [51,52].

Several major urban developments pose a threat to the preservation of heritage properties. Housing is the most frequently mentioned urban development across different regions, especially in EUR and APA, followed by ground transport infrastructure. In EUR, non-renewable energy is also frequently cited as a threat to urban heritage properties. These urban developments are closely related to the demand for housing and the movement of people and goods. The increase in population and migration to urban areas has increased the demand for housing and transportation of goods and people. As authorities work to address housing and transportation challenges, compromises may be made regarding heritage properties [53].

Thus, monitoring land cover change in WH properties is crucial for protecting them from unwanted urban threats that could impact their OUV. The built-up area changes (1985–2015) highlight that the EUR region had the largest total built-up area, with a substantial increase by 2015, followed by APA, while (LAC, ARB, and AFR) experienced the least change in their built-up areas in 1985, with steady increases. Even though the LAC region is one with the least properties and heritage coverage by area relative to its initial heritage coverage in 1985, it has shown a significantly high change during this period. This can be attributed to the high urbanization rates in these regions, a trend predicted by organizations such as UN-Habitat [54,55].

The results suggest that more properties are not reporting urban threats but can be under urban development threats. From 1985 to 2015, they experienced significant built-up area increases compared to the properties reported in the state of conservation. The significance of reporting lies in ensuring that the properties recognize and identify the threats and subsequently find solutions to prevent further development. On the other hand, properties that reported on urban development displayed a reduced increase, suggesting that the reporting and protection of heritage properties may have some impact in disabling the urbanization of heritage coverage. However, this reduction was minimal, considering that the nomination of properties to the World Heritage list suggests preserving, conserving, and protecting heritage properties for current and future generations [56]. The findings suggest a substantial and ongoing trend of urbanization in WH properties, with variations across regions. The results indicate the challenges in conserving heritage properties in the face of urban development, especially in regions such as Europe and North America. Thus, this study emphasizes the importance of monitoring built-up changes, particularly in core zones, to understand and mitigate the impact on heritage properties [57].

Furthermore, research is required in mapping the urbanization of heritage properties. For instance, in this study, the dates of heritage property inscriptions were not considered in the built-up area changes between 1985 and 2015. Thus, further investigation is required because we assume that the inscription date of a heritage property can influence the amount of built-up area and the magnitude of the change in heritage. Furthermore, these results

can be used to assess the change in a built-up area before and after the nomination and zoning of a heritage property. Furthermore, built-up areas were considered for both the buffer and core zones of heritage properties. However, a separate buffer and core zone assessment can reveal more detailed and specific results.

Our findings indicate that there has been a significant increase in urban built-up areas in both properties reporting on urban development and those that did not report on urban development. The specific reasons for not reporting are unclear and may vary from one region to another. They could be related to political instability, such as conflicts and wars, as well as reluctance by state parties to report due to the fear of losing their listing status. Additionally, these reasons may be attributed to a lack of resources or knowledge about the reporting process [58,59]. However, we recommend that UNESCO institutes a committee to conduct physical inspections of heritage properties at global or regional scales. This indeed can require a significant amount of resources to achieve and not be well taken by the state parties; however, if this is not checked and if things are left as is, heritage may be under threat. This can lead to a loss of outstanding universal value and subsequent delisting, as in the case of Dresden Valley in Germany, which was delisted because of urban development, and the Arabian Oryx sanctuary, which was delisted due to the extraction of oil in heritage properties [60,61]. The current policies and regulations mandate state parties to report on the status of properties. Furthermore, UNESCO provides enough information for reporting heritage parties. However, it seems that state parties are unable to identify threats or do not want to report them. Thus, this policy recommends follow-up efforts by UNESCO or regional managers to ensure what is reported or not being reported. By doing so, state parties will feel responsible and accountable for managing heritage properties.

While this research has shown a consistent increase in built-up areas and the transformation of heritage properties over time since their nomination, further research is still required to assess the impact of listing on heritage properties [62–64]. Specifically, a spatial-temporal analysis should be conducted to assess the impact of nominations on these properties, providing deeper insights into how they have been affected post-nomination. We recommend a 20-year comparative analysis, examining the changes both before and after a nomination, to better understand the long-term effects on heritage properties.

Furthermore, future investigations can focus on answering questions, such as why state parties are not reporting, what types of urban changes are taking place in heritage properties, and whether these changes affect the outstanding universal value and statement of nominations for heritage properties. In addition, a revisit of the analysis can be carried out at a global scale when higher-resolution data and more heritage property boundaries are available.

5. Conclusions

This research analyzed a global sample of WH properties to assess the change in land cover, with a focus on the amount of built-up areas. These results showed how heritage properties have evolved in the temporal scale of analysis, confirming several assumptions in individual properties that were researched.

The data demonstrate significant regional disparities in the growth of built-up areas. The EUR region stands out with the highest initial and overall built-up area, indicating a higher level of urban development. In contrast, regions like AFR and APA had lower initial counts and slower growth, suggesting less urbanization and potentially more preservation of heritage properties.

The comparison between properties that report on urban development and those that do not report on it reveals exciting dynamics. Properties reporting on urban development tend to have a more controlled increase in built-up areas, possibly due to regulatory measures or a focus on preserving heritage. On the other hand, non-reporting properties often experience more substantial growth, which may pose challenges to maintaining heritage property.

The average change per year highlights the intensity of urbanization. Even regions with a lower overall growth, like AFR, can have more intense changes in specific regions, potentially affecting heritage properties. This underscores the importance of monitoring not just the quantity of growth but also the rate and location of changes in built-up areas.

Regions with rapid urbanization may face more significant challenges in preserving heritage properties. Strategies for managing this growth while safeguarding cultural heritage should be prioritized. Effective regulatory measures for urban development and ones concerning heritage properties are crucial. These regulations should consider the quantity and rate of changes in built-up areas.

Ongoing monitoring and data analyses are essential for informed decision making in heritage preservation. Understanding how urbanization trends impact specific regions and properties is vital for conservation efforts. Striking a balance between urban development and heritage preservation is a complex task. Decision makers should consider the unique characteristics of each region and property when drawing up conservation policies.

Analyzing built-up areas provides valuable insights into the challenges and opportunities for heritage property preservation in different regions. It emphasizes the need for data-driven, region-specific approaches to managing urban development while safeguarding cultural heritage.

Author Contributions: Conceptualization, M.K. and A.P.R.; methodology, M.K., D.P.-L. and T.E.; data curation, F.C., M.K. and T.E.; writing—original draft preparation, M.K.; writing—review and editing, A.P.R., P.N. and F.N. All authors have read and agreed to the published version of the manuscript.

Funding: The project was funded by the European Union's Horizon 2020 research and innovation programme under the Marie 429 Sklodowska-Curie grant agreement No. 813883.

Data Availability Statement: The project repository and datasets are available at https://github.com/mkvusa/How-urban-is-world-heritage-.git (accessed on 6 October 2024).

Acknowledgments: This project collaborated with TU Delft, HIST, and DLR to collect the shapefiles of WH properties and the spatial-temporal analysis of WH properties using the World Human Settlement layer evolution generated by these institutions by formal request. The copyright of shapefiles belongs to HIST, and the World Human Settlement Layer evolution belongs to DLR. We appreciate the constructive suggestions and comments from the anonymous reviewers and editors, as well as the support from the Heriland team.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

UN	United Nations
LULC	Land use and land cover
WH	World Heritage (list)
VHR	Very high resolution
HIST	International Center for Space Technology on natural and cultural Heritage
DLR	Germany Aerospace Center
GIS	Geo-information systems
LAC	Latin America and the Caribbean
APA	Asia and the Pacific
EUR	Europe and North America
ARB	Arab States
AFR	Africa
SoC	State of conservation
QGIS	Quantum Geographic Information Systems Software
WSF Ev	World Settlement Footprint Evolution layer
OUV	Outstanding Universal Value
UNESCO	United Nations Education, Science and Cultural Organisation

References

1. Esch, T.; Asamer, H.; Bachofer, F.; Balhar, J.; Boettcher, M.; Boissier, E.; d' Angelo, P.; Gevaert, C.M.; Hirner, A.; Jupova, K.; et al. Digital world meets urban planet–new prospects for evidence-based urban studies arising from joint exploitation of big earth data, information technology and shared knowledge. *Int. J. Digit. Earth* **2020**, *13*, 136–157. [CrossRef]
2. Wilson, J.; Bayón, M. Concrete Jungle: The Planetary Urbanization of the Ecuadorian Amazon. *Hum. Geogr.* **2015**, *8*, 1–23. [CrossRef]
3. Oriye, O. Urban expansion and urban land use in Ado Ekiti, Nigeria. *Am. J. Res. Commun.* **2013**, *1*, 128–139.
4. Moore, M.; Gould, P.; Keary, B.S. Global urbanization and impact on health. *Int. J. Hyg. Environ. Health* **2003**, *206*, 269–278. [CrossRef]
5. Spennemann, D.H. The shifting baseline syndrome and generational amnesia in heritage studies. *Heritage* **2022**, *5*, 2007–2027. [CrossRef]
6. Fu, L.; Zhang, Q.; Tang, Y.; Pan, J.; Li, Q. Assessment of urbanization impact on cultural heritage based on a risk-based cumulative impact assessment method. *Herit. Sci.* **2023**, *11*, 177. [CrossRef]
7. Kiruthiga, K.; Thirumaran, K. Effects of urbanization on historical heritage buildings in Kumbakonam, Tamilnadu, India. *Front. Archit. Res.* **2019**, *8*, 94–105. [CrossRef]
8. Alnsour, J.; Arabeyyat, A.; Hyasat, A.; Al-Habees, M.; Aldweik, R. The Impact of Urbanization on Cultural Heritage Buildings in Jordan: As-Salt as a Case Study. *Future Cities Environ.* **2023**, *9*, 1–14. [CrossRef]
9. Cui, S.; Yang, X.; Guo, X.; Lin, T.; Zhao, Q.; Feng, L. Increased challenges for world heritage protection as a result of urbanisation in Lijiang City. *Int. J. Sustain. Dev. World Ecol.* **2011**, *18*, 480–485. [CrossRef]
10. Chadee, S.; Stoute, V. Development of an urban intensity index to facilitate urban ecosystem studies in Trinidad and Tobago. *J. Appl. Stat.* **2018**, *45*, 508–527. [CrossRef]
11. United Nations Human Settlement Programme. *World Cities Report 2022: Envisaging the Future of Cities*; United Nations Research Institute for Social Development: Geneva, Switzerland, 2022.
12. The World Bank. *Demographic Trends and Urbanization*; The World Bank: Washington DC, USA, 2020. Available online: https://documents1.worldbank.org/curated/en/260581617988607640/pdf/Demographic-Trends-and-Urbanization.pdf (accessed on 8 September 2024).
13. Liu, J.; Ren, H.; Wang, X.; Shirazi, Z.; Quan, B. Measuring and predicting urban expansion in the Angkor region of Cambodia. *Remote Sens.* **2019**, *11*, 2064. [CrossRef]
14. Li, Q.Q.; Li, X.X.; Ma, Y.H.; Lu, L.L.; Wang, X.Y.; Luo, L.; Cheng, Y.T.; Wu, R.C. Urbanization monitoring using big Earth Observation data for world heritage sites of China. In *IOP Conference Series: Earth and Environmental Science*; IOP Publishing: Bristol, UK, 2020; Volume 502, p. 012049.
15. Verdini, G. Planetary Urbanisation and the Built Heritage from a Non-Western Perspective: The Question of 'How' We Should Protect the Past. *Built Herit.* **2017**, *1*, 73–82. [CrossRef]
16. Opschoor, H.; Tang, L. Growth, world heritage and sustainable development: The case of Lijiang City, China. *Int. J. Sustain. Dev. World Ecol.* **2011**, *18*, 469–473. [CrossRef]
17. Guo, H.; Chen, F.; Tang, Y.; Ding, Y.; Chen, M.; Zhou, W.; Zhu, M.; Gao, S.; Yang, R.; Zheng, W.; et al. Progress toward the sustainable development of world cultural heritage sites facing land-cover changes. *Innovation* **2023**, *4*, 2666–6758. [CrossRef]
18. Chrastina, P.; Hronček, P.; Gregorová, B.; Žoncová, M. Land-use changes of historical rural landscape—Heritage, protection, and sustainable ecotourism: Case study of Slovak Exclave Čív (Piliscsév) in Komárom-Esztergom County (Hungary). *Sustainability* **2020**, *12*, 6048. [CrossRef]
19. Chen, B.; Iannone, B.V., III FRAGSTATS: A Free Tool for Quantifying and Evaluating Spatial Patterns. *EDIS* **2020**, *2020*, 9. [CrossRef]
20. Tang, Y.; Chen, F.; Yang, W.; Ding, Y.; Wan, H.; Sun, Z.; Jing, L. Elaborate Monitoring of Land-Cover Changes in Cultural Landscapes at Heritage Sites Using Very High-Resolution Remote-Sensing Images. *Sustainability* **2022**, *14*, 1319. [CrossRef]
21. Banerjee, R.; Srivastava, P.K. Reconstruction of contested landscape: Detecting land cover transformation hosting cultural heritage sites from Central India using remote sensing. *Land Use Policy* **2013**, *34*, 193–203. [CrossRef]
22. Salem, M.; Tsurusaki, N.; Divigalpitiya, P. Land use/land cover change detection and urban sprawl in the peri-urban area of greater Cairo since the Egyptian revolution of 2011. *J. Land Use Sci.* **2020**, *15*, 592–606. [CrossRef]
23. Karayazi, S.S.; Dane, G.; Vries, B.d. Utilizing urban geospatial data to Understand heritage attractiveness in Amsterdam. *ISPRS Int. J. Geo-Inf.* **2021**, *10*, 198. [CrossRef]
24. Huang, S.; Hu, Q.; Wang, S. A Risk Assessment Approach of World Heritage Sites Based on RS and GIS: The case studies of Mount Emei. In Proceedings of the 2021 28th International Conference on Geoinformatics, Nanchang, China, 3–5 November 2021; pp. 1–4.
25. Halim, M.K.; Ahmad, A.; Rahman, M.Z.; Amin, Z.M.; Khanan, M.F.; Musliman, I.A.; Kadir, W.H.; Jamal, M.H.; Maimunah, D.S.; Wahab, A.K.; et al. Land use/land cover mapping for conservation of UNESCO Global Geopark using object and pixel-based approaches. *IOP Conf. Ser.: Earth Environ. Sci.* **2018**, *169*, 012075. [CrossRef]
26. Elfadaly, A.; Attia, W.; Qelichi, M.M.; Murgante, B.; Lasaponara, R. Management of cultural heritage sites using remote sensing indices and spatial analysis techniques. *Surv. Geophys.* **2018**, *39*, 1347–1377. [CrossRef]

27. Vileikis, O.; Escalante Carrillo, E.; Allayarov, S.; Feyzulayev, A. Documentation for preservation: Methodology and a GIS database of three World Heritage cities in Uzbekistan. In Proceedings of the ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, ISPRS, Ottawa, ON, Canada, 28 August–1 September 2017; Volume 4, pp. 311–318.
28. Verbruggen, R.; Pereira Roders, A.; Stash, N.; Leony, D.; Bra, P.D. Protected Urban Planet: Monitoring the Evolution of Protected Urban Areas Worldwide. In Proceedings of the ERSA 54th Congress Regional Development & Globalisation: Best Practices, Saint Petersburg, Russia, 26–29 August 2014.
29. Valese, M.; Noardo, F.; Pereira Roders, A. World heritage mapping in a standard-based structured geographical information system. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.—ISPRS Arch.* **2020**, *43*, 81–88. [CrossRef]
30. Rao, K. A new paradigm for the identification, nomination and inscription of properties on the World Heritage List. *Int. J. Herit. Stud.* **2010**, *16*, 161–172. [CrossRef]
31. Nishanbaev, I.; Champion, E.; McMeekin, D.A. A survey of geospatial semantic web for cultural heritage. *Heritage* **2019**, *2*, 1471–1498. [CrossRef]
32. Tewabe, D.; Fentahun, T. Assessing land use and land cover change detection using remote sensing in the Lake Tana Basin, Northwest Ethiopia. *Cogent Environ. Sci.* **2020**, *6*, 1778998. [CrossRef]
33. Campiani, A.; Lingle, A.; Lercari, N. Spatial analysis and heritage conservation: Leveraging 3-D data and GIS for monitoring earthen architecture. *J. Cult. Herit.* **2019**, *39*, 166–176. [CrossRef]
34. Hao, S.; Zhu, F.; Cui, Y. Land use and land cover change detection and spatial distribution on the Tibetan Plateau. *Sci. Rep.* **2021**, *11*, 7531. [CrossRef]
35. Das, S.; Angadi, D.P. Land use land cover change detection and monitoring of urban growth using remote sensing and GIS techniques: A micro-level study. *GeoJournal* **2022**, *87*, 2101–2123. [CrossRef]
36. Zhu, Q.; Guo, X.; Deng, W.; Guan, Q.; Zhong, Y.; Zhang, L.; Li, D. Land-use/land-cover change detection based on a Siamese global learning framework for high spatial resolution remote sensing imagery. *ISPRS J. Photogramm. Remote Sens.* **2022**, *184*, 63–78. [CrossRef]
37. Lv, Z.; Liu, T.; Benediktsson, J.A.; Falco, N. Land cover change detection techniques: Very-high-resolution optical images: A review. *IEEE Geosci. Remote Sens. Mag.* **2021**, *10*, 44–63. [CrossRef]
38. Lv, R.; Liu, Y.; Zhang, L.; Kong, D. Urban historic heritage buffer zone delineation: The case of Shedian. *Herit. Sci.* **2022**, *10*, 1–15. [CrossRef]
39. Agapiou, A. UNESCO World Heritage properties in changing and dynamic environments: Change detection methods using optical and radar satellite data. *Herit. Sci.* **2021**, *9*, 64. [CrossRef]
40. Willis, K.S. Remote sensing change detection for ecological monitoring in United States protected areas. *Biol. Conserv.* **2015**, *182*, 233–242. [CrossRef]
41. Zomer, R.J.; Ustin, S.L.; Carpenter, C.C. Land cover change along tropical and subtropical riparian corridors within the Makalu Barun National Park and Conservation Area, Nepal. *Mt. Res. Dev.* **2001**, *21*, 175–183. [CrossRef]
42. Veillon, R. *State of Conservation of World Heritage Properties. A Statistical Analysis (1979–2013)*; UNESCO, United Nations Educational, Scientific and Cultural Organization: Paris, France, 1972. Available online: https://whc.unesco.org/en/documents/134872 (accessed on 6 October 2024)
43. Bergesen, H.O.; Parmann, G.; Thommessen, O.B. Year Book of International Co-Operation on Environment and Development. In *Year Book of International Co-operation on Environment and Development*, 1st ed.; Routledge: London, UK, 1998; pp. 1–374. [CrossRef]
44. UNESCO. *State of Conservation Information System*; UNESCO: Geneva, Switzerland, 2023.
45. Novak, A.; Ostash, V. Digitizing historical maps and their presentation in online map collections. *e-Perimetron* **2022**, *17*, 33–44.
46. Tuno, N.; Mulahusić, A.; Kogoj, D. Improving the positional accuracy of digital cadastral maps through optimal geometric transformation. *J. Surv. Eng.* **2017**, *143*, 05017002. [CrossRef]
47. Marconcini, M.; Metz-Marconcini, A.; Esch, T.; Gorelick, N. Understanding current trends in global urbanisation-the world settlement footprint suite. *GI_Forum* **2021**, *9*, 33–38. [CrossRef]
48. Marconcini, M.; Metz-Marconcini, A.; Üreyen, S.; Palacios-Lopez, D.; Hanke, W.; Bachofer, F.; Zeidler, J.; Esch, T.; Gorelick, N.; Kakarla, A.; et al. Outlining where humans live, the World Settlement Footprint 2015. *Sci. Data* **2020**, *7*, 1–14. [CrossRef]
49. Yastrebova, N.; Eterevskaya, I.; Stetsenko, S. Urban Zoning as a Method to Protection and Develop Historic Settlements (within the Volgograd Region). *IOP Conf. Ser. Earth Environ. Sci.* **2022**, *988*, 042075. [CrossRef]
50. Oevermann, H.; Mieg, H.A. Urban development planning and world cultural heritage: Two perspectives of planning practice dealing with industrial heritage. *Plan. Pract. Res.* **2021**, *36*, 430–441. [CrossRef]
51. Maciulyte-Sniukiene, A.; Butkus, M. Does infrastructure development contribute to EU countries' economic growth? *Sustainability* **2022**, *14*, 5610. [CrossRef]
52. Becker, W.; Domínguez-Torreiro, M.; Neves, A.R.; Moura, C.T.; Saisana, M. Exploring the link between Asia and Europe connectivity and sustainable development. *Res. Glob.* **2021**, *3*, 100045. [CrossRef]
53. Yu, J.; Safarov, B.; Wang, C.; Buzrukova, M.; Janzakov, B. The Effect of Transportation Networks on Heritage Tourism and New Urbanization—Empirical Research Based on Rich Heritage Sites in a Chinese Province. *Heritage* **2023**, *6*, 7293–7315. [CrossRef]
54. Un-Habitat. *State of the World's Cities 2008/9: Harmonious Cities*; Earthscan: London, UK, 2008. Available online: https://sustainabledevelopment.un.org/content/documents/11192562_alt-1.pdf (accessed on 6 October 2024).

55. Ekeocha, D.O. Urbanization, inequality, economic development and ecological footprint: Searching for turning points and regional homogeneity in Africa. *J. Clean. Prod.* **2021**, *291*, 125244. [CrossRef]
56. Otero, J. Heritage conservation future: Where we stand, challenges ahead, and a paradigm shift. *Glob. Challenges* **2022**, *6*, 2100084. [CrossRef]
57. Guzmán, P.; Pereira Roders, A.; Colenbrander, B. Bridging the gap between urban development and cultural heritage protection. In Proceedings of the IAIA14 Conference Proceedings, Viña del Mar, Chile, 8–11 April 2014.
58. Brown, N.E.; Liuzza, C.; Meskell, L. The politics of peril: UNESCO's list of world heritage in danger. *J. Field Archaeol.* **2019**, *44*, 287–303. [CrossRef]
59. Dumper, M.; Larkin, C. The politics of heritage and the limitations of international agency in contested cities: A study of the role of UNESCO in Jerusalem's Old City. *Rev. Int. Stud.* **2012**, *38*, 25–52. [CrossRef]
60. Gaillard, B. *Conflictive Delisting Process of a World Heritage Site in Germany: The Case of the Dresden Elbe Valley*; Brandenburg University of Technology Cottbus–Senftenberg: Senftenberg, Germany, 2014.
61. Albrecht, E.; Gaillard, B. Procedure for Delisting a Site From the World Heritage List: Is Delisting With Consent or Against the Wish of a State Party Possible? *J. Tour. Hosp. Manag.* **2015**, *3*, 15–21. [CrossRef]
62. Duval, M. To what degree does a UNESCO World Heritage Site listing improve the conservation of heritage sites? Insights from the case of the Maloti-Drakensberg World Heritage Site (South Africa-Lesotho). *Int. J. Herit. Stud.* **2022**, *28*, 376–399. [CrossRef]
63. Buckley, R. Tourism and Natural World Heritage: A Complicated Relationship. *J. Travel Res.* **2018**, *57*, 563–578. [CrossRef]
64. Cao, J.; Li, T. Analysis of spatiotemporal changes in cultural heritage protected cities and their influencing factors: Evidence from China. *Ecol. Indic.* **2023**, *151*, 110327. [CrossRef]

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