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Dynamic Monitoring of Yin Xu Site by Remote Sensing

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Abstract. Yin Xu, dates back more than 3,300 years, is the first relic of the capital of the Shang Dynasty literally recorded and confirmed by oracle bone scripts and the archaeological excavation in China. Located in Anyang City of Henan Province (northwestern suburbs of Huanhe banks) it covers an area of around 36 km². According to the characteristics of Yin Xu, remote sensing has shown its great capabilities to solve many issues in different fields, e.g. visual interpretations of aerial photo were used to identify the feature of Yin Xu site in 1972, 1984, 1998, 2005 and 2010. Using the classification validated by field investigations, the change information such as the monitoring index of settlements, riverway, main roads, factory and green area can be extracted in heritage site. According to the monitoring results of land cover and the surrounding environment, we conclude that the protection planning system is effective, and the rapid expansion of neighboring building area has playing a negative role in Yin Xu protection.

1. Introduction
Great ruins, the complex of ontology and its associated environmental vectors, have rich information. To monitor those phenomena, the key point is quantitative acquisition and then spatial-temporal analysis. Nowadays the development of modern spatial information technologies, in particular remote sensing and geographic information system, provides new technical means for monitoring great ruins. Yin Xu, a relic in Anyang, was comprehensively analyzed jointly using the multi-source remote sensing images as well as topographic information in a spanning period of 1972 to 2010. The extracted environmental factor, particularly its evolution in more than 40 years, provides a good precursor for further scientific research in archaeology.¹

2. Study Area and Datasets
Yin Xu, the first relic of the capital of the Shang Dynasty, is literally recorded and confirmed by oracle bone scripts as well as archaeological excavations in China. It dates back more than 3,300 years. Located in Anyang City of Henan Province (northwestern suburbs of Huanhe banks), Yin Xu covers an area of around 36 km², consisting of three parts: the Relic of Shang Dynasty City in the north of Huanhe River, the Relic of Royal Tombs and the Relic of Palaces and Ancestor Temples. Due to the

¹ Science and Technology Research Project of National Heritage Conservation (ID: 20110126) & Henan-CAS Scientific and Technological Achievements Transfer and Transformation Project (ID: 2012109) Sponsor
high value of history, culture, science and art, Yin Xu was listed in the first key cultural relics under state-protection in 1961, inscribed on the UNESCO list of World Heritage Sites in 2006, and selected as a national archaeological site park in 2010 (see figure 1).

![Geographical location and the remote sensing image of Yin Xu](image1)

Figure 1. Geographical location and the remote sensing image of Yin Xu

In this study, multisource data are applied, including black and white photos in 1972, topographic map of 70s, color infrared photo in 1984, topographic map of 90s, black and white photos in 1998, color infrared photo in 1999, LANDSATE ETM images in 2005, IKONOS image with 1 meter resolution in 2006, SOPT5 image with panchromatic of 2.5 meter and multispectral of 10 meters, and Google image in 2010. The data process includes geometric correction, image registration, spatial adjustment, ARCGIS interpretation, ARCGIS inspection and then correction, etc. (see figure 2).

![The processing diagram of extracting information of Yin Xu](image2)

Figure 2. The processing diagram of extracting information of Yin Xu

The aerophotograph of 1972, aerophotograph of 1984, aerophotograph of 1998, IKONOS image of 2006 have been separately reprojected and adjusted, which is useful to eliminate the distortion in geometric registration. Note that, The UTM projection (Northern Hemisphere No. 50 band), and the ellipsoid is WGS - 84 is selected.

3. Change Extraction and Analysis

3.1. Information Interpretation

According to the characteristics of remote sensing data and the distribution of the monitoring target, the interpreting standards of multisource data in time domain i were established. Through visual interpretation, results were digitalized with the aid of ARCGIS software, and then the interpretation classification of the heritage was retrieved. Referring to the heritage plan, Google Earth images and
field investigations, we further validated the interpretation result.

3.2. Information Extraction and Analysis

3.2.1 Extraction and analysis of residential area in the boundary of construction restrictive zone

Figure 3. Distribution of residential area in the construction restrictive zone of Yin Xu during 1972-2010

Table 1. Statistics of residential area in the construction restrictive zone of Yin Xu

<table>
<thead>
<tr>
<th>Year</th>
<th>Min. patchiness</th>
<th>Minimum Area(m²)</th>
<th>Largest Area(m²)</th>
<th>Perimeter(m)</th>
<th>Total Area(m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972</td>
<td>50</td>
<td>313</td>
<td>406,571</td>
<td>36,017</td>
<td>1,971,590</td>
</tr>
<tr>
<td>1989</td>
<td>72</td>
<td>104</td>
<td>608,515</td>
<td>68,919</td>
<td>3,388,541</td>
</tr>
<tr>
<td>1998</td>
<td>94</td>
<td>440</td>
<td>635,489</td>
<td>92,785</td>
<td>5,998,622</td>
</tr>
<tr>
<td>2005</td>
<td>92</td>
<td>584</td>
<td>635,946</td>
<td>85,373</td>
<td>5,300,521</td>
</tr>
<tr>
<td>2010</td>
<td>71</td>
<td>880</td>
<td>628,385</td>
<td>75,890</td>
<td>5,037,678</td>
</tr>
</tbody>
</table>

From the figure 4 and Table 1, it is clear that the change of Yin Xu area in the last 40 years: after a fast expansion, that is three times from the 1970s to the 1990s, the area tended to decrease. The site protection planning policy has played an important role from 2005, when the application for listing Yin Xu as world heritage started. In order to understand the spatial-temporal variation characteristics of the residential area around the ancient sites in the last nearly 40 years, especially the change before and after the application, we analyzed the compactness and spreading rate of the residential area within the construction restrictive zone of Yin Xu.

(1) The spatial distribution characteristics - Analysis of compactness index

Figure 4. (a) Statistics of residential space compactness in the construction restrictive zone of Yin Xu, (b) Statistics of residential expansion rate in the construction restrictive zone of Yin Xu
The bigger of the compactness, the better of the space compact characteristic of the residential area. In figure 4(a), compactness index of the residential area within the built control scope decreased at the early stage and then increased; that is, 0.138 in 1972, and then fell to 0.0936 in 1998. The result was consistent with the previous analysis of residential area plaque data and the observed increased area. Compactness has rebounded in 1998-2010, which was directly related to the protection planning policy of the residential area relocation during the period of the world heritage list application. At the same time, it showed that the spatial distribution has become more rational after the entry of Yin Xu on world heritage list.

(2) The temporal characteristics - Analysis of expansion rate
As seen from figure 4(b), the expansion pace of the residential area in the construction restrictive zone is overall showing an up-down-up trend. By the year of 1998, the average annual expansion rate is positive 8.38%. However, from 1998 to 2010, the expansion rate dropped to the negative, which indicated that the residential area was reducing. The decreasing amplitude reached the largest point in the spanning of 1998 to 2005, and then again expanded in the year of 2005 to 2010. It is clear that the temporal evolution of the residential area was consistent with the changes of its spatial compactness, getting better and better as a whole.

3.2.2 Extraction and analysis of Anyang steel factory in the boundary of construction restrictive zone

From figure 5, it can be seen that Anyang steel factory expanded constantly to the east and the north from 1972 to 2010, close to the core site area. Through the area statistics, in 1972, the land that Anyang iron and steel company used is limited to the western edge of the sites, occupying only 78,611 m². Then the company spreaded around in the original foundation with an area of 254,847 m² from 1972 to 1984. The growth rate was 224.19%, the peak of the study period. In the spanning of 1984 to 1998, the company continually spread to the west, but the growth rate dropped to 88.42%. After the basic construction work in the decades of 60s to 90s, the company developed to the east area through constantly annexing villages. By 2005 the factory occupied 1,112,916 m² of the building control range, accessing to the palace and ancestral temple ruins core protected areas. In 2005-2010, the growth rate fell sharply to 1.04%, the main reason was that Yin Xu successfully become the world cultural heritage, which played a role in limiting the development of the company. The building growth of the company area in the site presented a down-up-down trend.

3.2.3 Extraction and analysis of riverway in the boundary of construction restrictive zone
It was shown in Table 2 that not only the riverway extended step by step but also the shape changed a lot from 1972 to 2010. The bending modulus declared sharply from 1.65 in 1998 to 1.40 since the riverway straightly run to the north and east of Relics of Hougang. This phenomenon occurred because the government of Anyang cleared the riverway of Huanhe River. However, this kind of activity made a big difference to the underground site located in the border of north Hougang Relics and Huanhe River. It showed that the river bend to the southeast of Sites of Palace and Royal Ancestral Shrines was straightened as well.

### 3.2.4 Extraction and analysis of road in the boundary of construction restrictive zone

![Figure 6](image.png)

**Figure 6.** Distribution of main roads in the construction restrictive zone of Yin Xu

As it can be seen from figure 6, the main roads of Yin Xu in protected areas in the period of 1972-2010 have been changing: (1) The Beijing-Guangzhou Railway has already been there in 1918, when the Yin Xu has not been designated as a key national heritage sites. The Beijing-Guangzhou Railway (in N-E direction) runs across the ruins area, not only occupy a certain range of the protected area in the site, but also affects its overlying landscape of Yin Xu. In addition to the Beijing-Guangzhou railway, there is the AN-LI railway route through the ruins, from east Anyang to west Linzhou. (2) Subsequently, there were 107 national highways across Middle Shang City North of the Huanhe River, Anyang Iron and Steel Avenue; 301 provincial highways surrounding the protected area of the Yin Xu.

### Table 2. Statistics of the change of the Huanhe riverway in the Construction restrictive Zone

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of center line (m)</td>
<td>8,864</td>
<td>8,889</td>
<td>7,558</td>
<td>7,528</td>
<td>7,551</td>
</tr>
<tr>
<td>Length of valley (m)</td>
<td>5,424</td>
<td>5,370</td>
<td>5,398</td>
<td>5,405</td>
<td>5,405</td>
</tr>
<tr>
<td>Bending modulus</td>
<td>1.6311</td>
<td>1.6553</td>
<td>1.4002</td>
<td>1.3930</td>
<td>1.3970</td>
</tr>
</tbody>
</table>

### Table 3. Statistics of main roads in the construction restrictive zone of Yin Xu

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of road</td>
<td>63</td>
<td>88</td>
<td>94</td>
<td>113</td>
<td>138</td>
</tr>
<tr>
<td>Length of road (m)</td>
<td>51,797</td>
<td>62,306</td>
<td>68,189</td>
<td>74,367</td>
<td>86,169</td>
</tr>
<tr>
<td>Growth rate (%)</td>
<td>20.29</td>
<td>9.44</td>
<td>9.06</td>
<td>15.87</td>
<td></td>
</tr>
</tbody>
</table>
20.29%. Growing road itself changed the landscapes of heritage sites, simultenously its construction process also impacted remains below the surface, and thus split surface landscape and heritage sites. In addition, the accompanying gas station, auto repair stations and other service businesses occupied protected areas, generated waste to affect the bearing capacity of its environment as well.

### 3.2.5 Extraction and Analysis of Green Land in the Boundary of Construction restrictive Zone

The main green land scattered in the Sites of Royal Tombs, Sites of Palace and Royal Ancestral Shrines. As we known Yin Xu applied to join UNESCO's World Heritage List in 2001, and succeeded in 2006. Due to the Plan of Protecting Anyang Yin Xu published on June of 2003, the area of green land increased from 412,391m² in 1998 to 904,112m² in 2005. In this plan, the government also claimed to breed green land for at least 200,000m². After Yin Xu joined the World Heritage List in 2006, the area of green land grew to 1,048,512m² by improving the surrounding and planting trees and grass in order to reach the strict request of site protection.

### 4. Conclusions

Using multi-platform and multi-temporal remote sensing data, we monitored the dynamic change of residential area, factories, channel, road and main green area within the Anyang heritage building control scope in the spanning of 1972-2010; the conclusion can be summarized as follows: (1) The space distribution of residential areas in the whole area within the scope of building control becomes more reasonable; (2) In 1972-2010, the area of the Anyang steel plant within the scope of building control presents a reduction - increase - reduction trend, the overall growth rate is fast, which has affected the core site in the recent forty years; (3) In the period of 1972 to 2010, the river across the north and east of the Relics of Hougang makes channel bending modulus smaller. In addition, the channel located in the south-east of Sites of Palace and Royal Ancestral Shrines is going to cutoff; (4) As the number and length of roads within the scope of building control continuously increasing, road construction itself has produced certain destruction to the underground ruins, and thus the service enterprises has formed a huge challenge to the capacity of the Yin Xu site; (5) The change of main green land in the site shows evident increase, particularly after the application of listing Yin Xu into the world heritage.

### References