Comprehensive Survey and Heritage Value Evaluation of Weiyuan Settlement Remains onChina's Jianghan Plain

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Abstract

The Jianghan Plain in the middle reaches of the Yangtze River was covered mainly by the ancient Yunmeng Marsh for an extended period. Many primitive residential forms related to water, such as Ganlan (elevated sheds), Haopai (wormwood rafts), and Weiyuan (circular embankments), emerged as early humans developed this vast region. They used Ganlan to settle at the lake edges, Haopai to explore deeper waters, and eventually mastered Weiyuan construction techniques. They discovered that building Weiyuan embankments could permanently secure parts of the swamp, leading to the creation of early Weiyuan settlements. Over millennia, Weiyuan evolved from water conservancy structures in prehistoric settlements into complex residential units during the Ming and Qing dynasties. These units formed water conservancy commonwealths, developing into micro-hydraulic societies. Recent urbanisation has severely damaged Weiyuan, posing a risk of complete disappearance, necessitating urgent surveys and protection. The vast Jianghan Plain makes it challenging to discover Weiyuan remains. This study employed machine vision to identify 210 villages (towns) with potential Weiyuan remains. After comparing them with historical maps, 136 Weiyuan settlement samples were selected and classified into 4 grades (A, B, C, and D) based on their integrity. Field investigations identified six towns and seven villages with well-conserved Weiyuan remains. Specific measures for protecting and optimising contemporary Jianghan Plain villages and towns centred on "Yuan" are proposed.

Keywords
Jianghan Plain, Weiyuan, machine vision, cultural heritage, value evaluation

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INTRODUCTION

UNDERSTANDING WEIYUAN: A WATER MANAGEMENT SYSTEM

"Weiyuan" refers to a closed area created for production and living by constructing embankments around river or lake shoals, sandbars, and coastal beaches, providing easy access to water (Water Resources Construction and Management,2020). This system includes Yuan embankments, water systems, ditches, culverts and floodgates, pumping stations, Yuan fields, and Yuan settlements. The term "Weiyuan" is a compound word derived from two synonymous characters, "Wei" and "Yuan", which are used respectively in the middle and lower reaches of the Yangtze River (Zhang JM and Lu XQ,2011). Both terms refer to embankments designed to protect farmland and homes from floods (Zhang JM and Lu XQ,2011). Circular embankments are known as "Yuan embankments", and the fields they enclose are called "Yuan fields". These embankments are equipped with culverts and floodgates, and pumping stations for water storage and discharge. People typically settle on high ground within these embankments, forming natural villages.

Historically, the Yangtze River basin experienced frequent flooding, necessitating effective water management for agricultural development. Consequently, constructing embankments, often made of soil and stone, became the primary water conservancy measure. Weiyuan emerged as crucial water management facilities. Residents along the Yangtze River and its lakes built Weiyuan by enclosing low-lying, fertile sedimentary soil with embankments, using pumping stations, culverts, and floodgates to introduce water from external sources for irrigation and daily needs (Wang DY et al.,2023).

On the Jianghan Plain, located in the middle reaches of the Yangtze River, while river and lake embankments are widely distributed and commonly seen today, Yuan embankments, once prevalent, are now rare. Thet were initially built to protect water conservancy fields, a defining element of the local agricultural landscape. Over time, as people were attracted to live in these facilities, they evolved into complex residential units. By the Qing dynasty (1644–1911), the Weiyuan system on the Jianghan Plain had transformed into numerous hydraulic commonwealths or miniature hydraulic societies based on shared water management interests. This system significantly influenced the social and cultural aspects of life in the region (Lu XQ,2013). A dual structure of state water control and regional social self-governance developed, with Yuan as the administrative unit (Luo D,2020). Additionally, the Yuan system became the basis for levying taxes and labour services by the Qing regime (Zhang JM and Lu XQ,2011). As residents within the Yuan engaged in water management, they gradually developed a shared belief in water gods. Yuan temples, primarily built to suppress floods and ensure the safety of the embankments, became centres of worship and ritual activities (Lu XQ,2013). Clan forces, based on blood relationships, played a significant role in the development of Weiyuan in this region, leaving behind numerous ancestral shrines as spatial representations of clan organisations (Fang Y,2016).

The following subsections will delve into the historical evolution of the Weiyuan system on the Jianghan Plain and explore its natural, social, and cultural significance. This comprehen-

sive analysis will highlight the importance of considering various elements when identifying Weiyuan remains, including Yuan settlements, Yuan patterns, Yuan embankments, Yuan fields, roads, water systems, culverts and floodgates, watercourse mouths, Yuan temples, and ancestral shrines.

HISTORICAL EVOLUTION OF THE WEIYUAN SYSTEM ON THE JIANGHAN PLAIN

The origins of the Weiyuan system on the Jianghan Plain can be traced back to the Neolithic Period, when people began constructing primitive Weiyuan in low-lying river valleys to protect their settlements from flooding (Liu JG et al.,2023). According to the meteorological history of China written by Zhu Kezhen, the Eastern Jin dynasty (317–420) coincided with the second of four Little Ice Age periods in Chinese history. During this time, the Yangtze River's water levels decreased, floods receded, and the ancient Yunmeng Marsh disintegrated, giving rise to the Jianghan lake group. New settlements gradually formed on the high ground exposed in the lakes and marshes. Silt deposition from the upper reaches of the Yangtze and Han Rivers led to the gradual formation of land on the Jianghan Plain, which was continuously enclosed by embankments (Chen YH,2008). Regarding the development scope and scale of Weiyuan on the Jianghan Plain before the Ming dynasty (1368–1644), historical records suggest that even during the Shaoxing period of the Southern Song dynasty (1127–1279), the Jing-Hubei Circuit still had "vast barren land". This indicates that from the mid-1st century, when historical records for this region begin, until the early and mid-Ming dynasty (15th century), despite some development—such as the large-scale immigration from the Central Region during the Southern Song dynasty—the lake area in Jianghan Plain remained sparsely populated overall (Chen X,2004).

However, during the Ming dynasty, Weiyuan on the Jianghan Plain experienced a comprehensive development period, which can be further divided into three stages: steady growth in the early Ming, with Weiyuan emerging across the region; rapid expansion in the mid-Ming, with Weiyuan proliferating quickly; and accelerated growth in the late Ming, with high saturation of Weiyuan in the region (Zhang GX,1989). The spatial changes of Weiyuan were also notable in the three stages: distribution along both banks of the main streams and major tributaries of the Han and Jing Rivers in the early Ming dynasty; continued expansion along the Yangtze and Han tributaries in the riverside and lakeside areas in the mid-Ming dynasty; and further expansion into the swampy, low-lying lake areas and silted rivers and harbours in the late Ming dynasty.

The Weiyuan on the Jianghan Plain during the Qing dynasty also went through three stages: early Qing restoration, mid-Qing prosperity to saturation, and late Qing oscillation between aggressive reclamation and abandonment (Zhang GX,1989). The spatial evolution of Weiyuan in the Qing dynasty was characterised by the following stages: in the early Qing, there was a restoration of Weiyuan that had been damaged and abandoned due to war and natural disasters at the end of the Ming dynasty, bringing development back to mid-Ming levels. After diligent restoration by the local people, the area entered a period of significant development after Kangxi's reign, leading to an unprecedented scale of reclamation. Reclamation promot-

ed sediment deposition, which in turn facilitated new enclosures, peaking in the mid-Qing dynasty. During this period, the expansion extended from enclosing lakes within the Yuan to enclosing river sandbars and shoals outside the embankment, resulting in numerous new sandbar and shoal Yuan. In the late Qing dynasty, despite saturation, predatory draining of lakes for farming and blind enclosure of sandbars and shoals continued, leading to a cyclical pattern of aggressive reclamation and abandonment.

From the late Qing dynasty period to the Republic of China (1912–1949), internal warlord battles and external invasions, coupled with neglected water conservancy and embankments left is disrepair, led to continuous floods and waterlogging disasters, leaving people in misery. With no other economic resources, people relied on building private Yuan to eke out a living. In the event of severe natural disasters, they had to survive the entire year without a harvest. The quality and scale of Weiyuan were poor due to the limited workforce and resources.

While the Weiyuan was less resilient to floods, people responded by building even more Weiyuan. Despite the declining economic and water conservancy values, the number of Weiyuan increased significantly (Li S,2019).

After the founding of the People's Republic of China in 1949, under the "taking grain as the key link" policy during the Great Leap Forward, three large-scale campaigns of enclosing lakes and creating farmland occurred in 1957–1962, 1963–1971, and 1971–1976. The "marching toward desolate lakes and planting rice seedlings to the heart of the lake" movement led to the disappearance (Chen Lake, San Lake, Datong Lake, Bailu Lake, Liantong Lake, and Dasha Lake), shrinking (Wangjiada Lake, Wu Lake, Diaocha Lake, and Paihu Lake), or disintegration (Baishuitan Lake, Gu Lake, and Chong Lake) of numerous lakes on the Jianghan Plain (Zhao Y et al.,2000). Large-scale enclosure of lakes for farmland caused significant damage to the water system landscape of the Jianghan Plain, and the rivers, lakes, and water systems of Jianghan were reduced and blocked (Zhang Y et al.,2009).

In the 1980s, under the central government's guidance, local governments in the Jianghan Plain undertook initiatives to return reclaimed farmland to lakes. These efforts gained significant momentum after the catastrophic Yangtze River flood in 1998, leading to the large-scale disappearance of Weiyuan under the directive to "flatten Yuan for flood discharge" (Bulletin of the State Council of the People's Republic of China, 1999). The opening of the Three Gorges Dam in 2003 was another pivotal event. It reduced water and sediment from the upper reaches, increasing downstream riverbed deposition and sandbar development (Yang YP et al.,2018). Coupled with modern water conservancy facilities, agricultural production on the Jianghan Plain gradually became detached from Weiyuan, rendering these structures agriculturally obsolete (Ma Q et al.,2019).

THE CULTURAL HERITAGE ATTRIBUTES OF WEIYUAN ON THE JIANGHAN PLAIN

The rise, prosperity, and decline of Weiyuan on the Jianghan Plain in the middle reaches of the Yangtze River resulted from the interplay of natural and human factors (Fang Y,2016). It was a survival strategy adopted by the people of Jianghan in response to the changing

water systems and frequent floods in the natural environment. Weiyuan were initially introduced to the Jianghan Plain as water conservancy facilities to develop Yuan fields and agriculture. As they evolved into large settlements centred on the "Yuan", they shaped the unique economic, social, and cultural landscapes of the Jianghan Plain. Even today, the core areas of Weiyuan, such as Tianmen, Qianjiang, Mianyang, and Jianli, maintain distinct local dialects, culinary traditions, and cultural practices, representing a significant branch of Jing-Chu culture.

The Weiyuan settlements on the Jianghan Plain possess three key categories of attributes: historical and cultural towns and villages, traditional Chinese villages, and agricultural heritage. Relevant authorities in Hubei Province have gradually recognised the first two categories, declaring four historical blocks within the province as Chinese historical and cultural towns[1] and two locations as traditional Chinese villages[2]. However, the agricultural heritage value of Weiyuan on the Jianghan Plain has not yet been fully acknowledged or appreciated by the relevant authorities. As a result, under the pressure of new urbanisation, villages and towns in the region are losing this crucial category of cultural attributes and increasingly conforming to the homogeneous "one face for a thousand villages" model of development (Kang CC et al.,2023). According to the "Hubei Province Urbanisation and Urban Development Strategy Plan" completed by the China Academy of Urban Planning and Design, Hubei Province's urbanisation rate was 46.0% in 2009. The plan projects that by 2020, the urbanisation level will reach approximately 54%–55%, and by 2030, it will climb to 63%–65%, with an annual increase of 0.8–1 percentage points (Hubei Provincial People's Government,2012).

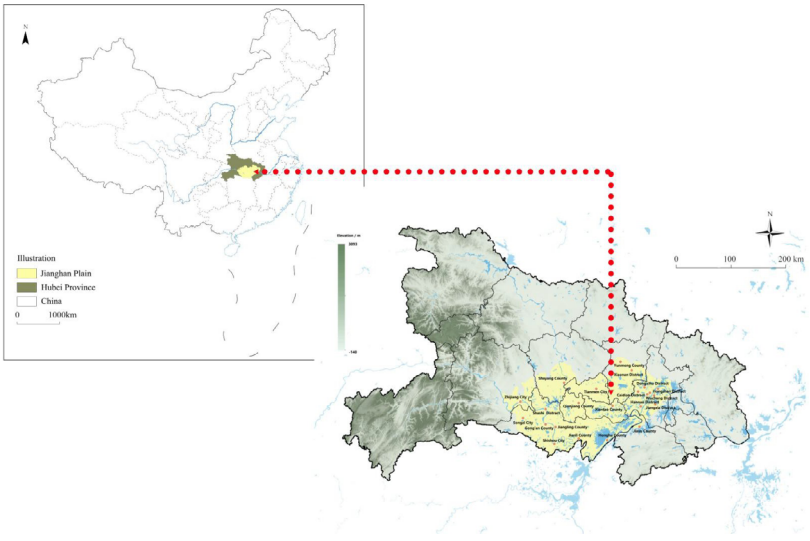


Fig. 1. Jianghan Plain Study Area. The study area of this paper includes not only the area within the contour line of 50 metres above sea level, but also covers the granitic land within 50-90 metres above sea level in West E, and the hills within 50-70 metres above sea level in East E, with a total area of about 46,000 square kilometres.

As major national strategies, such as integrated urban-rural development and the construction of a new socialist countryside, are implemented, the urbanisation process in the Jianghan Plain is expected to accelerate further. Faced with the impact of urbanisation, many villages and towns are experiencing a shift in residential landscapes deprived of regional characteristics (Chen T,2018). In the ongoing village and town construction, Weiyuan remains are disappearing at an accelerated pace. Conducting a comprehensive survey of Weiyuan settlement remains and evaluating their heritage value, thus enabling more people to recognise and protect the agricultural heritage value of Weiyuan, is a crucial initiative for the current cultural heritage protection endeavour on the Jianghan Plain.

RESEARCH MATERIALS AND METHODS

OVERVIEW OF THE STUDY AREA

The Jianghan Plain is located in southern Hubei Province, north of Dongting Lake, spanning the Yangtze and Han Rivers. It is a basin-shaped area with high surroundings and a low centre, dipping slightly from northwest to southeast. The study area includes the river and lake alluvial plain between the Yangtze and Han Rivers, and the platform and hilly land on the inner edge of the basin, roughly within the 50-meter contour line and between the 50–90-meter contour lines, respectively, with an average elevation of around 27 meters.

DESCRIPTION OF THE MACHINE VISION ALGORITHM

Machine vision studies how computers understand the content in digitised images or videos. The machine vision algorithm used in this study is a segmentation model based on YOLO, utilising differences in building materials, architectural forms, and construction techniques in traditional buildings to identify traditional buildings and further identify traditional villages and towns based on the density of the concentrated distribution of traditional buildings.

The YOLOv5 model is an object detection model used to identify and locate objects in videos or images. It is the latest version of the YOLO algorithm, using convolutional neural networks to learn object features in videos or images and employing segmented geographic scale grids to locate and detect targets.

Since the heyday of Weiyuan on the Jianghan Plain was mainly during the Ming and Qing dynasties, and China did not have advanced geodetic surveying capabilities at that time, the earliest standardised geodetic survey was the 1:50000 topographic map "Ten-Year Rapid Survey Plan" (hereinafter referred to as the "Republican 1:50000 topographic map") implemented by the Republican government in 1917–1925, which is also the topographic map with the most comprehensive Weiyuan information. Therefore, this study is mainly based on the Republican 1:50000 topographic map, while also using historical maps of the Ming and Qing dynasties and satellite images since 1944 as references.

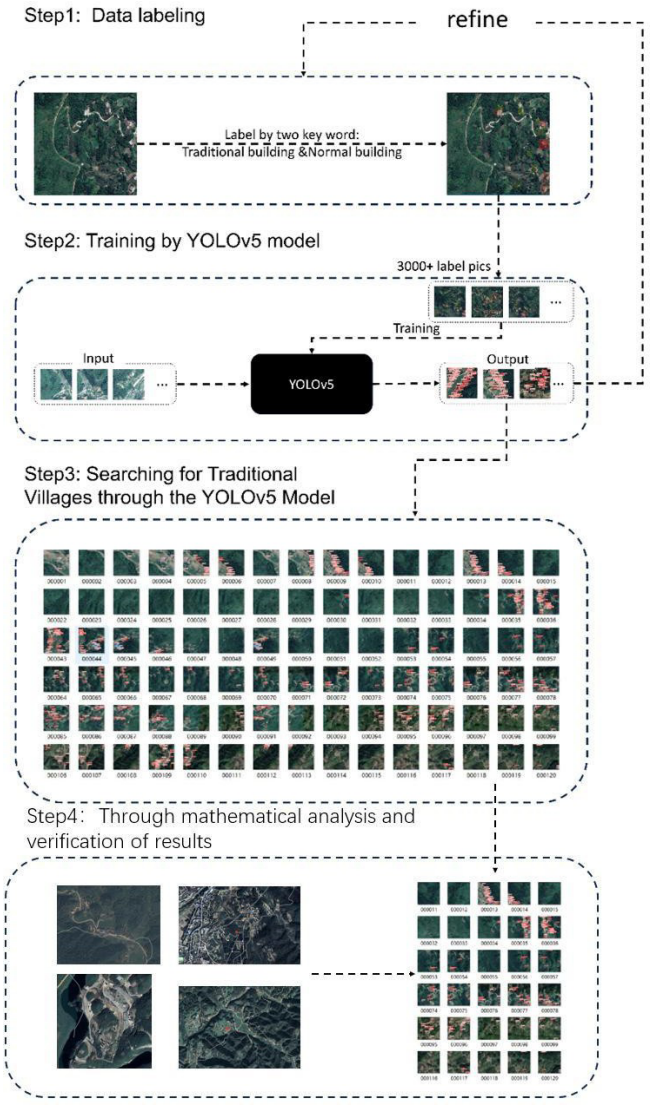


Fig. 2. Workflow for identifying traditional villages through machine vision. After many experiments, it is confirmed that when the image scale is 500m*500m, the accuracy of machine vision can be guaranteed, and at the same time, the planar texture of traditional settlements can be preserved as much as possible.

DATA SOURCES FOR REMAINS SURVEY

Data Acquisition Year	Data Type	Data Description
1917–1925	Topograph ic map	Involving field survey, scale 1:50000, in the 2nd year of the Republic of China, the General Staff Headquarters issued the "Ten-Year Rapid Survey Plan" for 1:100000 survey maps and 1:50000 topographic maps. The Hubei Survey Bureau began surveying in 1917 and ended in 1946, completing a total of 403 sheets of 1:50000 topographic maps. The survey work in the Jianghan Plain was completed in 1917–1925, with 96 sheets; Chinese annotation, detailed legend, but incomplete survey elements, no coordinate system and projection parameters, but longitude and latitude identification.
1944–1945	Topograph ic map	Aerial map, compiled by the U.S. Army Map Service in 1954, scale 1:250000, transverse Mercator projection.
1968	KH-8	Images obtained by the U.S. military's "Key Hole" (KH-8) military satellite in November–December 1968, with a spatial resolution of 1.8m.
2023	Landsat 8	Google Earth satellite data, WGS84 latitude and longitude projection, image resolution of 1m.

Table 1. Summary of data sources for remains survey.

DATA TREATMENT FOR REMAINS SURVEY

2. Summarise the characteristics of Weiyuan on the Jianghan Plain and the elements for identifying Weiyuan remains through a literature review.
3. Use the neural network model constructed by U-Net to perform character detection tasks on ancient maps; input the individual characters detected into an optical character recognition system for place name recognition on ancient maps. This system can recognise both traditional and simplified Chinese characters.
4. Utilise neural network machine vision supplemented by human assistance and correction. Specifically, the YOLOv5 algorithm is used to identify ancient buildings, which are used to spot traditional villages (Yuan settlements), further leading to the discovery of Weiyuan systems. By matching the Republican 1:50000 topographic map of Hubei Province, which includes both Weiyuan settlements and associated systems, with contemporary Google satellite images, the present-day locations and place names of these Weiyuan settlements can be revealed. Field surveys are then conducted at these locations to search for Weiyuan settlement remains, ultimately establishing a database of these remains.

The following example illustrates the identification process for the Weiyuan settlement remains of Chengji Ancient Town. As mentioned earlier, the key elements in identifying Weiyuan settlement remains on the Jianghan Plain include Yuan settlements, Yuan embankments, Yuan fields, roads, water systems, ancient culverts and floodgates, ancient watercourse mouths, Yuan temples, ancestral shrines, and Yuan patterns. Employing the neural network machine vision YOLOv5 algorithm, the identification process starts from the unique trait of black roofs on traditional buildings in Yuan settlements on the Jianghan Plain. Identifying clusters of buildings with black roofs and comparing them with Google satellite images and drone aerial images confirms whether they are traditional settlements. To further verify the existence of Weiyuan remains, other elements such as the surrounding water systems, Yuan

embankments, and culverts and floodgates are also considered.

- Step 1: Label the certified traditional villages on the Jianghan Plain and divide their satellite images into separate 500m×500m geographic scale images.
- Step 2: Train the YOLOv5 model by continuously adjusting data parameters to establish a model that accurately identifies traditional villages and towns.
- Step 3: Divide the satellite images of the Jianghan Plain into separate 500m×500m geographic scale images, with each individual image overlapping by 50%, and input them into the YOLOv5 model for identification.
- Step 4: Differentiate the identification results through mathematical analysis to isolate images of traditional villages.
- Step 5: Locate the traditional settlements on the Republican 1:50000 topographic map, search for indications of associated Weiyuan systems, and compare them with Key Hole satellite images and remote sensing images to find potential Weiyuan remains.

REMAINS SURVEY RESULTS

Following the working principles and methods described above, this study conducted an extensive survey of Weiyuan settlement remains on the Jianghan Plain. The results of the neural network machine vision survey of Weiyuan settlement remains are as follows: through machine vision, 210 villages (towns) with potential Weiyuan remains were identified. After comparing historical and modern maps, 136 villages and towns with Weiyuan remains were confirmed (49 towns and 87 villages).

HERITAGE VALUE EVALUATION OF WEIYUAN SETTLEMENTS ON THE JIANGHAN PLAIN

CONSTRUCTION OF A SYSTEM OF AGRICULTURAL HERITAGE VALUE EVALUATION INDICATORS FOR WEIYUAN SETTLEMENTS

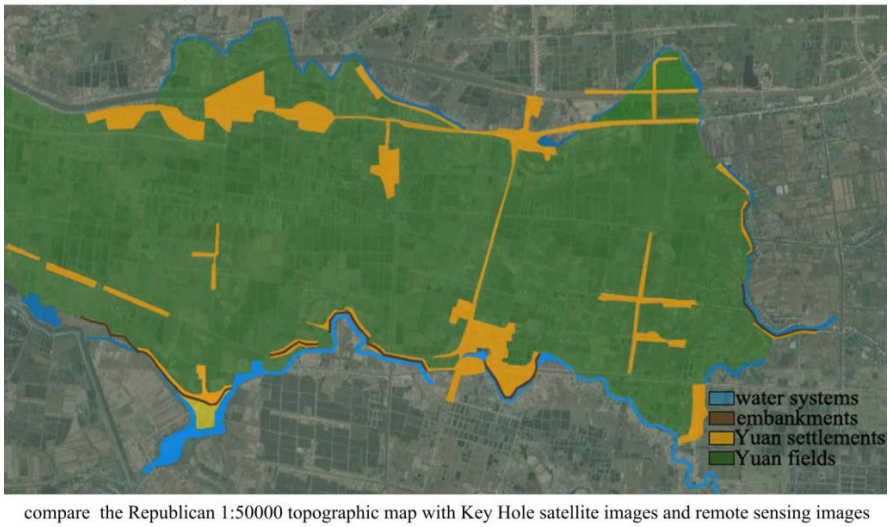
To conserve and responsibly utilise Weiyuan settlements, a rigorous evaluation of their agricultural heritage value is essential. The evaluation system should be complete, systematic, comprehensive, universal, and operable. In building this system, the study drew from the "Evaluation Index System for Chinese Historical and Cultural Towns (Villages)" and the "Evaluation and Recognition Index System for Traditional Villages" issued in China, as well as the concept and meaning of agricultural heritage proposed by the Globally Important Agricultural Heritage Systems (GIAHS) initiative. Specifically, the study considered the attributes of Weiyuan settlements in terms of water conservancy, society, and culture. Basic traits and core requirements of completeness, antiquity, integrity, harmoniousness, and representativeness were incorporated into a customised evaluation system to present the heritage value of Weiyuan settlements on the Jianghan Plain in the middle reaches of the Yangtze River.

Workflow diagram of the neural network machine vision algorithm Image source: Created by the authors

Chengji Town identified by machine vision

Google satellite image of Chengji Town

Bird's-eye view of Chengji Town



compare the Republican 1:50000 topographic map with Key Hole satellite images and remote sensing images to find potential Weiyuan remain

Fig. 5. An example of results from the neural network machine vision algorithm.The case of Chengji ancient town in the Jianghan Plain, China, where the dike is located.

DESCRIPTION OF THE SYSTEM OF EVALUATION INDICATORS

The study analysed the "Evaluation Index System for Chinese Historical and Cultural Towns (Villages)", the "Evaluation and Recognition Index System for Traditional Villages", and the recognition indicators of GIAHS to gather information and insights. The Delphi method was

then used to determine the weights for the criteria through expert consultation. The system of evaluation indicators was structured into three main criteria: heritage type, heritage traits, and value system. Regional indicators were included as allowed by data availability to reflect the regional characteristics of Jianghan Plain Weiyuan heritage. Ultimately, 35 indicators were selected to construct the system of evaluation indicators for Jianghan Plain Weiyuan heritage.

HERITAGE TYPE

The heritage type criterion includes two sub-criteria: tangible cultural heritage and intangible cultural heritage. Tangible cultural heritage covers indicators such as ancient towns, ancient villages, ancient buildings, residential forms, land use systems, agricultural landscapes, agricultural tools, and agricultural flora and fauna. Intangible cultural heritage encompasses indicators like agricultural techniques, agricultural knowledge, agricultural folklore, songs and dances, handicrafts, and cuisine.

HERITAGE TRAITS

The heritage traits criterion consists of indicators evaluating the completeness of Weiyuan elements, antiquity, integrity of layout, environmental harmony, and representativeness of regional characteristics. The completeness of Weiyuan elements assesses the conservation of the 10 key elements carried by the remains: ancient villages and towns, Yuan patterns, Yuan embankments, Yuan fields, roads, water systems, ancient culverts and floodgates, ancient watercourse mouths, Yuan temples, and ancestral shrines. Remains with more conserved

elements are considered to have higher heritage value. Antiquity assesses how far back in history the existing Weiyuan elements in the remains can be traced. Remains with elements dating back to earlier historical periods are considered to have higher heritage value. Integrity of layout evaluates the remains based on four aspects: overall appearance around the Yuan, street and lane system within Yuan settlements, traditional public spaces within the Yuan, and supporting facilities within the Yuan. Better-conserved remains are assigned higher heritage value. Environmental harmony considers the degree of natural environmental protection around the remains and the level of disturbance caused by construction projects. Remains with better environmental protection and less disturbance from construction projects are regarded as having higher heritage value. Representativeness of regional characteristics assesses whether the various elements of the Weiyuan remains represent the local regional cultural characteristics and possess distinct engineering and technical representativeness. Remains with more evident regional characteristics and stronger engineering representativeness are considered to have higher heritage value.

VALUE SYSTEM

The value system criterion includes two main sub-criteria: existence value and potential value. Existence value comprises carrier value, product value, ecological value, scientific and

technological value, social value, aesthetic value, cultural value, historical value, spiritual value, and brand value. Potential value primarily refers to the future positive effects of the heritage systems.

WEIGHTS FOR EVALUATION INDICATORS

This study used the analytic hierarchy process to determine the weights for the evaluation indicators by establishing a hierarchical structure model and comparing the relative importance of each indicator through pairwise comparison, setting the creation of a system of heritage value evaluation indicators for Weiyuan settlements on the Jianghan Plain in the middle reaches of the Yangtze River as the overall goal (A).

Three criteria (Bn, n = 1,2,3) were identified: heritage type (B1), heritage traits (B2), and value system (B3). Heritage type (B1) includes two sub-criteria (Cn, n = 1,2): tangible cultural heritage (C1) and intangible cultural heritage (C2). Heritage traits (B2) comprises five sub-criteria (Cn, n = 3,4,5,6,7): completeness of Weiyuan elements (C3), antiquity (C4), integrity of layout (C5), environmental harmony (C6), and representativeness of regional characteristics (C7). Value system (B3) consists of two sub-criteria (Cn, n = 8,9): existence value (C8) and potential value (C9). These 9 sub-criteria (Cn, n = 1,2,3,4,5,6,7,8,9) were further divided into 35 indicators (Dn, n = 1,2,3,…,35). The relative importance between the sub-criteria (Cn) and indicators (Dn) is represented by judgment matrices obtained through expert evaluations. The characteristic vectors were calculated using the Yaahp software to obtain the weight values Wi (i = 1,2,3…35) of the evaluation indicators. The consistency of the judgment matrices for both single-level ranking and overall ranking at each level was verified through consistency tests.

GRADING CRITERIA

Based on the Weiyuan settlement cultural heritage value system constructed in the previous subsection, each factor was scored. The comprehensive evaluation score of Weiyuan settlement cultural heritage value was calculated using a multi-objective linear weighting function, as follows:

$$Z = W_1A_1 + W_2A_2 + \ldots + W_iA_i = \sum_{i=1}^{n} W_iA_i, \quad W_i > 0$$

where Z is the total score of the cultural heritage evaluation for the Weiyuan settlement villages and towns, Ai is the score value of a single criterion i of the criteria level Bn, and Wi is the weight of the i-th criterion in the evaluation criteria. According to the scoring results, Weiyuan settlement heritage can be classified into four grades: Grade I (first-tier representative villages and towns): Well-conserved remains, high heritage value, score range [80–100]; Grade II (second-tier representative villages and towns): Relatively well-conserved remains, relatively high heritage value, score range [60–79]; Grade III (third-tier representative villages and towns): Moderately conserved remains, moderate heritage value, score range [50-59]; and Grade IV (fourth-tier representative villages and towns): Poorly conserved remains, low heritage value, score range [0–49].

Goal Level An	Criteria Level Bn	Sub-criteria Level Cn	Indicators Level Dn	First Grade (8–10 points)	Second Grade (5–7 points)	Third Grade (2–4 points)	Fourth Grade (0–1 points)
The system of heritage value evaluation indicators of Weiyuan settlements on the Jianghan Plain in the middle reaches of the Yangtze River A	Heritage type B1	Tangible cultural heritage C1	Ancient towns D1	Well-conserved	Moderately-conserved	Poorly-conserved	Neglected
			Ancient villages D2	Well-conserved	Moderately-conserved	Poorly-conserved	Neglected
			Ancient buildings D3	Well-conserved	Moderately-conserved	Poorly-conserved	Neglected
			Residential forms D4	Highly distinctive	Moderately distinctive	Ordinary	None
			Land use systems D5	Very typical	Moderately typical	Ordinary	None
			Agricultural landscapes D6	Very rich	Moderately rich	Ordinary	None
			Agricultural tools D7	Highly distinctive	Moderately distinctive	Ordinary	None
			Agricultural flora and fauna D8	Highly distinctive	Moderately distinctive	Ordinary	None
		Intangible cultural heritage C2	Agricultural techniques D9	Highly representative	Moderately representative	Ordinary	None
			Agricultural knowledge D10	Very high level	Moderately high level	Ordinary	None
			Agricultural folklore D11	Highly distinctive	Moderately distinctive	Ordinary	None
			Songs and dances D12	Highly distinctive	Moderately distinctive	Ordinary	None
			Handicrafts D13	Highly distinctive	Moderately distinctive	Ordinary	None
			Cuisine D14	Highly distinctive	Moderately distinctive	Ordinary	None
Cuisine		Completeness of Weiyuan elements C3	Yuan settlements, Yuan patterns, Yuan embankments, Yuan fields, roads, water systems, ancient culverts and floodgates, ancient watercourse mouths, Yuan temples, and ancestral shrines D15	8–10 elements conserved	5–7 elements conserved	2–4 elements conserved	0–1 elements conserved
	Heritage traits B2	Antiquity C4	Construction period of Weiyuan, the period when existing sites of Yuan settlements were formed, and the period when the traditional buildings within Yuan were first built D16	Ming dynasty or earlier	Qing dynasty	Republican era	After the founding of the People's Republic of China
		Integrity of layout C5	Overall appearance of core elements (Yuan embankments+Yuan fields+settlements+water systems+roads) D17	Well-conserved overall	Moderately-conserved	Poorly-conserved	Neglected
			Traditional street and lane systems within Yuan settlements D18	Complete layout, rich space, and pleasant scale	Ordinary	Relatively poor	Poor
			Traditional public spaces within the Yuan D19	Well-conserved	Moderately-conserved	Poorly-conserved	Neglected
			Supporting facilities like ancient culverts and floodgates, ancient watercourse mouths, and ancient ferry ports D20	Well-conserved	Moderately-conserved	Poorly-conserved	Neglected
		Environmental harmony C6	Degree of natural environment protection around the remains D21	Well-protected	Moderately-protected	Poorly-protected	Neglected
			Level of disturbance caused by nearby construction projects D22	No construction projects, or projects with no environmental impact	Projects with moderate impact	Significant impact	Very significant impact
		Representativeness of regional characteristics C7	Representativeness of regional cultural characteristics D23	Good	Moderate	Ordinary	None
			Engineering and technical representativeness D24	Very high level	Moderate level	Ordinary	None
Ecological	Value type B3	Existence value C8	Carrier value D25	Very high	Moderately high	Ordinary	None
			Product value D26	Very high	Moderately high	Ordinary	None
			Ecological value D27	Very high	Moderately high	Ordinary	None
			Scientific and technological value D28	Very high	Moderately high	Ordinary	None
			Social value D29	Very high	Moderately high	Ordinary	None
			Aesthetic value D30	Very high	Moderately high	Ordinary	None
			Cultural value D31	Very high	Moderately high	Ordinary	None
			Historical value D32	Very high	Moderately high	Ordinary	None
		Potential value C9	Spiritual value D33	Very high	Moderately high	Ordinary	None
			Brand value D34	Very high	Moderately high	Ordinary	None
			Future positive effects D35	Very significant	Moderately significant	Ordinary	None

Fig. 6. The system of heritage value evaluation indicators of Weiyuan settlements on the Jianghan Plain in the middle reaches of the Yangtze River.

HERITAGE VALUE EVALUATION RESULTS OF WEIYUAN SETTLEMENTS ON THE JIANGHAN PLAIN

OVERVIEW OF WEIYUAN SETTLEMENT REMAINS

Based on the indicator system and evaluation indicator weights constructed in the previous subsection, an empirical evaluation and preliminary classification of the 136 village and town Weiyuan settlement remains were carried out.

EVALUATION CRITERIA

Based on the evaluation indicator system constructed in the previous subsection, a comprehensive judgment was made on the 9 sub-criteria and 35 indicators, quantifying multiple qualitative indicators. Grade scores were assigned according to the evaluation indicator weights. Finally, through the superposition calculation of factors, the heritage value evaluation results of Weiyuan settlement remains by villages and towns were obtained.

EVALUATION RESULTS

According to the heritage value evaluation indicator system and indicator weights for Weiyuan settlements on the Jianghan Plain in the middle reaches of the Yangtze River constructed in the previous subsection, 136 Weiyuan settlement remains were scored and evaluated by villages and towns, completing the total heritage value score and sub-criteria scores for the surveyed Weiyuan settlement remains. The heritage value scores of Weiyuan settlement remains on the Jianghan Plain were ranked to provide a general picture of their heritage value. Among the scores of 48 Weiyuan settlement remains at the "town" level, the comprehensive scores ranged from 37 to 87 points. Four towns were in the first tier with scores of [80–100]: Chengji Town (Jianli City, Jingzhou City), Zhoulaozui Town (Jianli City, Jingzhou City), Qujiawan Town (Honghu City, Jingzhou City), and Xiongkou Town (Qianjiang City), corresponding to Grade I. Twenty towns were in the second tier with scores of [60–79], corresponding to Grade II. Fourteen towns were in the third tier with scores of [50–59], corresponding to Grade III. Ten towns were in the fourth tier with scores of [0–49], corresponding to Grade IV. Among the scores of 80 Weiyuan settlement remains at the "village" level, the comprehensive scores ranged from 40 to 85 points. Four villages were in the first tier with scores of [80–100]: Yufan Village (Xiantao City), Miaosan Village (Jianli City), Hengdi Village (Jianli City), and Sunqiao Village (Qianjiang City), corresponding to Grade I. Six villages were in the second tier with scores of [60–79], corresponding to Grade II. Thirty-six villages were in the third tier with scores of [50–59], corresponding to Grade III. Thirty-four villages were in the fourth tier with scores of [0–49], corresponding to Grade IV.

DISCUSSION

This study constructed a system of cultural heritage value evaluation indicators for Weiyuan settlements on the Jianghan Plain, considering various types and characteristics of Weiyuan remains and highlighting their heritage value. Both qualitative and quantitative indicators

were incorporated. Through its comprehensive survey of Weiyuan settlement remains on the Jianghan Plain and empirical analysis of 136 sample villages and towns, this study plays a crucial role in the recognition and exploration of the heritage value of these settlements. The evaluation results can inform the graded and classified conservation and responsible use of Weiyuan settlement cultural heritage on the Jianghan Plain.

The survey and heritage value evaluation of Weiyuan settlement remains on the Jianghan Plain revealed that Weiyuan are mainly distributed in the river and lake areas of the Jianghan Plain and the surrounding hilly river valley areas, along major rivers and their tributary harbours and streams, in the shape of fish scales or grapevines, which is consistent with historical records.

This study found that villages and towns located within the same Weiyuan shared the same social attributes, not only in terms of enjoying the same water conservancy resources and bearing common water conservancy maintenance responsibilities and obligations, but also in economic and cultural aspects. This has made the Jianghan Plain the granary of all of China since the Ming dynasty due to the prosperity of Yuan field agriculture, with a developed commodity economy and trade radiating throughout China and the world, and a prosperous commercial culture.

This study revealed that the need for flood control is the main factor in the rise of Weiyuan on the Jianghan Plain in the middle reaches of the Yangtze River. The concept of flood control has always been embodied in all aspects of the construction of Weiyuan settlements on the Jianghan Plain, from the site selection of Weiyuan to the site selection of villages and towns within the Yuan, as well as the construction of residential buildings.

This study found that the agricultural heritage value of Weiyuan settlements is mainly embodied in the traditional village and town layout model centred on "Yuan," as well as the "Yuan field-fish" rice farming system formed thereby. Similar systems worldwide, such as the Ifugao rice terraces in the Philippines, have been declared GIAHS. The "Yuan field-fish" rice farming system on the Jianghan Plain in China should also receive attention and be declared a GIAHS as soon as possible.

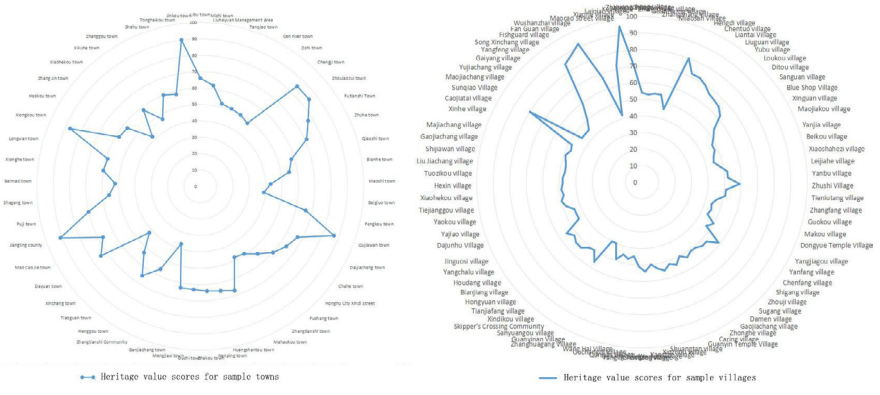


Fig. 7. Heritage value scores of Weiyuan settlement remains on the Jianghan Plain at the town and village level.

CONCLUSIONS

The conclusions of this study are as follows: The four ancient towns rated as Grade I (Excellent) are conserved due to the protection of red tourism cultural resources, with well-conserved Weiyuan remains and high heritage value. Currently, all four ancient towns have been rated as Chinese historical and cultural towns. The 20 towns rated as Grade II (Good) have relatively well-conserved Weiyuan remains and relatively high heritage value. However, they have not been rated as historical and cultural towns and lack effective protection measures. They urgently need recognition of their heritage value and protection. Among the four villages rated as Grade I (Excellent), only Yufan Village has been renovated and protected thanks to being rated as a traditional village, while the other three villages currently lack effective protection measures and are at risk of disappearing at any time during the urbanisation process. They urgently need recognition of their heritage value and protection. The six villages rated as Grade II (Good) have relatively well-conserved Weiyuan remains and relatively high heritage value, but they also lack effective protection measures and are at risk of endangerment, requiring attention and protection from cultural heritage protection author

ENDNOTES

1. They are (1) Zhoulao Zui Town, Jianli City, Jingzhou City, Hubei Province (2nd batch); (2) Chengji Town, Jianli City, Jingzhou City, Hubei Province (3rd batch); (3) Qujiawan Town, Honghu City, Jingzhou City, Hubei Province (3rd batch); and (4) Xiongkou Town, Qianjiang City, Hubei Province (5th batch).
2. Yufan Village, Zhengchang Town, Xiantao City, Hubei Province (3rd batch) and Keli Village, Laowan Hui Ethnic Township, Honghu City, Jingzhou City, Hubei Province (5th)

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DISCLOSURE STATEMENT

The authors declare no known conflict of interest.

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REFERENCES

Water conservancy terminology.2020.Weiyuan. Water Resources Construction and Management (09):4.

Zhang JM and Lu XQ.2011.Thematic Study on Human Activities and Environmental Changes in the Middle Reaches of the Yangtze River during the Historical Period.Wuhan,China:Wuhan University Press: 352-354.

Lu XQ.2013.The Making of Water Community in the Traditional China:Discussion around the Enclosed Embankment in Tianghan Plain during Ming-Qing Period.Research on Chinese Economic History (02):122-

139+172+176.

Wang DY,TangXQ,Ding HJ,Li YH and Li ZW.2023.Status,causes,and management of water environment in polders of middle-lower Yangze River.People's Yangtze River (06):19-26.

Luo D.2020.The Dikes Lead to the Country:Civil and Official Governance in Water Control system—Based on the Survey of Banbianyuan Village in Central Hubei Province.Wuhan:China:Huazhong Normal University:88- 92.

Fang Y.2016.Settlement and Dwellings Patterns in the Hydrological Environment Crisscrossed with Rivers and Lakes:Illustrated by the cases Around the River and Lake Area of Jianghan Plain during Ming and Qing Dynasties to the Republic of China.Wuhan:China:Huazhong University of Science and Technology:138-141.

Chen YH.2008.The Polder Construction and the Wetland Evolution in Jianghan plain.Wuhan:China:Huazhong University of Science and Technology:7-13.

Liu JG,Peng SJ,Tao Y,Xiang QF.2023.Prehistoric water control civilization of the Jianghan Plain. Beijing:China:China Social Science Press (8):133-135.

Chen X.2004.Study on the Economical Development of Jianghan Plain in Song and Yuan Dynasties.Wuhan,China:Wuhan University:44-51.

Zhang GX.1989.Characteristics of Yuan field in the Jianghan Plain and its Development and Evolution in the Ming and Qing Dynasties. Agricultural Archaeology (01):227-233.

Zhang GX.1989.Characteristics of Yuan field in the Jianghan Plain and its development in the Ming and Qing Dynasties (continued). Agricultural Archaeology (02):238-248.

Li S.2019.Study on the reconstruction of Yuan field and river network and related problems in the Jianghan Plain in the 1920s.Xian,China:Shaanxi Normal University:19-23.

Zhao Y,Wu YJ,Du Y.2000.Impact of human activities on the environmental evolution of the Jianghan Lake Group. Journal of Huazhong Agricultural University (Social Science Edition) (01):31-33+37.

Zhang Y,Zeng Q,Chen YH,Deng HB,Jin BX.2009.Reclamation of lakes in the 1950s and 1970s and the evolution of lakes and wetlands in the Jianghan Plain. Wetland Science and Management (02):52-55.

Circular of the General Office of the State Council transmitting the report of the State Planning Commission on the progress of the construction of towns by immigrants in Hubei, Hunan, Jiangxi, and Anhui Provinces on the return of fields and lakes from the Weiyuan. Bulletin of the State Council of the People's Republic of China, 1999, (27):1164-1168.

Yang YP,Zhang MJ,Sun ZH and Han JQ.2018.The relationship between water level change and river channel geometry adjustment in the downstream of the Three Gorges Dam.Journal of Geographical Sciences (12):1975- 1993.

Ma Q,Yao Y,Chang D.2019.Study on the work of returning Weiyuan (field and fishery) to the lake in Hubei Province. Water Resources Development and Management (05):60-63.

Kang CC,Huang XY and Xia YF.2023.Construction and empirical evidence of graded and classified evaluation system of traditional village cultural heritage value:a case of national traditional villages in Shaanxi province.Journal of Shaanxi Normal University (Natural Science Edition)Vol.51:No.1-13.

Hubei Provincial People's Government.2012.Hubei Province Releases Strategic Plan for Urbanization and Town Development (2012-2030).Report,Hubei Provincial People's Government,China,September 28,2012.

Chen T.2018.Research on self-established residence in villages of Jianghan Plain since 1978.Changsha,China:Hunan University:28-35.

Tu L,Zhang CR.2018.Theoretical framework construction of traditional village heritage value evaluation//Sharing and quality:Proceedings of 2018 China Urban Planning Annual Conference (09 Urban Cultural Heritage Protection):1080-1089.

Shao Y,Fu JJ.2012.Research on comprehensive evaluation of historical and cultural villages and towns based on value. Urban Planning36 (2):82-88.

Tan H,Liu Y.2022.Value evaluation and categorization protection of traditional villages in Yunnan based on cultural heritage objectives. West Journal of South Forestry University (Social Science Edition)6 (4):92-100.

Sun H.2020.An Introduction to Cultural Heritage (above): Types and Values of Cultural Heritage. Research on Natural and Cultural Heritage Research,5 (1):8-17.

Wang Y,Zhou X,Li GB.2019.Evaluation and characterization of ruralness of different types of traditional villages in Southern Jiangsu: a survey based on 12 traditional villages in Suzhou. Geography Research, 38 (6):1311-1321.

Zhou TJ,Huang YT,Wang XS.2011.Research on the Evaluation System of Historical and Cultural Villages and Towns Protection in Southwest China. Journal of Urban Planning, (6):109-116.

Huang JP,Xiao DW,He DD.2011.Research on Basic Data Indicator System of Historical and Cultural Villages and Towns Protection Planning. Journal of Urban Planning (6):104-108.

Mark E.1994.Japanese Studies on the History of Water Control in China:A Selected Bibliography.The Institute of Advanced Studies,Australian National University.

Ebert D.2004.Applications of archaeological GIS.Canadian Journal of Archaeology28:319-341.

Martyn J.2005.The application of a geographical information system to the creation of a cultural heritage digital resource.Literary& Linguistic Computing20 (1):71-90.

Diofantos H,Athos A and Dimitrios A.2013.Exploring natural and anthropogenic risk for cultural heritage in Cyprus using remote sensing and GIS.International Journal of Digital Earth 6 (2):115-142.

Robinson M,Alexander C,Jackson C et al. (2010) Threatened Archaeologi cal,historic,and cultural resources of the georgia coast:Identifica tion,prioritization and management using GIS technology.Geoar chaeology25 (3):312-326.

Yin L and Luo DY.2010.The role of agricultural factors in the formation of traditional villages.Southern Architecture (6):28-31.

Hein,Carola. 2011.*Port Cities: Dynamic Landscape and Global Networks*. New York: Routledge.

IMAGE SOURCES

Figure 1 Base map from: Department of Zoning and Geographical Names, Ministry of Civil Affairs, compiled by China Map Publishing House: National Platform for Querying Information on Administrative Districts, at http://xzqh.mca.gov.cn.
Figure 2 Created by the authors
Table 1 National Library of China - National Digital Library of China. https://www.nlc.cn/web/index.shtml
Figure 3 Created by the authors
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