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# A digital information system for cultural landscapes: the case of Slender West Lake scenic area in Yangzhou, China

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## Abstract

The rapid development of digital technologies provides important opportunities for more effective cultural heritage conservation and management. While the concept of cultural landscape has been accepted by the academic community in the cultural heritage field for many years, the digital conservation of cultural landscapes still lacks pragmatic guidance. The aim of this article is to explore an approach for building a digital information system to support cultural landscape conservation and management. The Slender West Lake scenic area, a typical cultural landscape in China, was used as an instrumental case study. A geo-database was designed and established to integrate the information of the natural, cultural, tangible and intangible landscape features of Slender West Lake. The digital information system for cultural landscapes provides a more holistic, dynamic and specific cultural perspective on heritage for landscape conservators. The system provides comprehensive information support for heritage conservation, management and interpretation, which are not achievable with conventional tools. This article has expanded the cultural heritage theory by presenting a practical guide for the digital information management of cultural landscapes. The workflow for building a cultural landscape geo-database can be used as a reference for heritage projects in China and other countries.

**Keywords:** Digital heritage conservation, Geographical information system, Cultural landscape, Invisible landscape, Slender West Lake

## Introduction

The conservation of cultural landscapes has become a worldwide concern due to the increasing speed of landscape changes in the 21st century. Cultural landscapes represent the 'combined works of nature and man', that is, 'they are illustrative of evolution of human society and settlement over time, under the influence of physical constraints and/or opportunities presented by their natural environment and of social, economic and cultural forces' (UNESCO 2017, 19). The conservation of cultural landscapes is to reveal and sustain the great diversity of the interactions between humans and their environment in protecting living traditional cultures and the traces of those that have disappeared (Fowler 2003).

Many guidelines and technologies have been developed for the conservation of cultural landscapes since the World Heritage Convention became the first international legal instrument to protect cultural landscapes in 1992 (Han 2018). In 2009, UNESCO published *World Heritage Cultural Landscapes: A Handbook for Conservation and Management* (UNESCO 2009), which interconnected all planning and management decisions in relation to their impacts on maintaining the values and integrity of cultural landscapes. This document was followed by UNESCO's *Recommendation on the Historic Urban Landscape* in 2011 (UNESCO 2011) and the *International Council on Monuments and Sites (ICOMOS) – International Federation of Landscape Architects (IFLA) Principles Concerning Rural Landscapes as Heritage* in 2017 (ICOMOS 2017), which were released as the result of intensive global discussions over the past decade.

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We have also seen rapid progress in the application of digital technologies that acquire, store, analyse and share information about cultural heritage. The rapid increase in new technologies since UNESCO first applied a computer-assisted information management system in 1992 to support the Cambodian government's efforts to protect Angkor Wat has revolutionised cultural heritage conservation activities. Digital documents have now become the main means of communication and transmission of heritage information. The adoption of the *Charter on the Preservation of Digital Heritage* by UNESCO in 2003 formally expanded the concept of heritage to include cultural products either created digitally, or converted into digital form (UNESCO 2003). Today, the UNESCO World Heritage Centre requires nominations in an electronic format to assist in creating a uniform heritage archive that can be used for periodic monitoring (UNESCO 2017, 34). The UNESCO *Recommendation Concerning the Preservation of, Access to, Documentary Heritage in the Digital Era* was released in 2015 as a standard-setting instrument to provide a basis for the protection of the world's documentary heritage, including in digital form. In Europe, the Virtual Multimodal Museum is a coordination and support action funded under the European Union Horizon 2020 programme between 2016 and 2019 to define and support policies, decision making and technological developments related to digital cultural heritage. Founded in 2003, CyArk is one of the largest non-profit organisations to digitally record, archive and share the world's most significant cultural heritage sites and to ensure that these places continue to inspire wonder and curiosity for decades to come.

While there has been significant interest in both digital cultural heritage and cultural landscapes over the past few decades, the junction between the two remains essentially under-explored. Most digital conservation research and practices are still based on the 'conventional' concept of cultural heritage, in which buildings, archaeological sites and monuments are the main objects for the application of digital tools. While the cultural landscape, as both a cultural heritage category and a conservation framework, has been accepted by the academic community in the field of cultural heritage, the digital conservation of cultural landscapes still lacks pragmatic guidance. Compared with other types of cultural heritage, cultural landscapes have specific features in terms of their scope, scale, components, data update cycles and needed precision. Comprehensive information support is an important condition for achieving successful cultural landscape management, but it is difficult to achieve with conventional information management methods and tools. Therefore, the digital conservation of cultural landscape heritage must be explored.

China has been recognised as a major location for cultural landscapes (Fowler 2003). The value of Chinese cultural landscapes was identified by the World Heritage Centre's Cultural Landscapes program when it suggested that 'what would now be recognised as cultural landscapes, deliberately expressing a relationship between nature and humans, were created in China in the first millennium CE' (Fowler 2003, 16). However, the research in this area is still very limited today. In terms of theories, Chinese cultural landscapes have been studied mainly by cultural geography researchers. Local theories for cultural landscape conservation remain under-explored. In practice, conventional management systems cannot provide adequate information for decision-making. Chinese cultural landscapes contain extensive tangible and intangible components that cannot be presented through existing systems, which leads to the loss of heritage information during rapid development and landscape changes. With the support of contemporary digital technologies, the contextual conservation approaches for cultural landscapes must be explored and established as a matter of urgency.

The aim of this article is to explore an approach for building a digital information system as a new conservation platform for individual cultural landscape sites in China. The specific objectives were to: (1) explore a theoretical framework for building digital information systems for the cultural landscapes at individual heritage sites; (2) design a digital geo-database and test its application in the conservation and management of cultural landscape sites; and (3) identify the implications for both conservation methods and technology development.

## A theoretical framework for a digital information system for cultural landscapes

The essential concept in cultural landscape theory is to examine and interpret the generation, form and meaning of landscapes from a dynamic and specific cultural perspective to highlight the interaction between man and nature (Han 2007). The digital information system for cultural landscapes that assists in conservation and management-related decisions can be considered as a digital replica of the cultural landscape heritage. Therefore, whether this digital replica can fully record and represent the value and significance of the cultural landscape itself will be a key issue in guiding and evaluating the digital information systems. The cultural landscape theory states the following three requirements for such systems.

First, the digital information system for cultural landscapes must fully reflect the character of cultural landscapes. The character of a landscape is the most important factor in evaluating the authenticity and integrity of cultural landscape heritage (Sutcliffe et al. 2005;

Wascher 2005; UNESCO 2009). Landscape character was defined as 'a distinct, recognisable and consistent pattern of elements in the landscape that makes one landscape different from another' (Swanwick 2002, 8). It is constituted by four layers: character, characteristic, pattern, and component layers (Swanwick 2002). Therefore, the digital information system must not only have a clear record of the different layers and attributes of landscape character but should also reflect the relationships between them.

Second, the digital information system for cultural landscapes must reflect the historical aspect of the landscape to provide the necessary references for the assessment of landscape continuity. Cultural landscapes comprise a highly dynamic heritage category. What makes space become a place is that they fuse the local history to a specific location, which gives that location significance (Ryden 1993). It is necessary to simulate the historical information of the landscape as much as possible during the conservation process to ensure continuity in landscape evolution and the sustainable development of values. This requires the digital information system to not only provide a comprehensive record of the landscape's historical information but to also reflect the historical condition of the whole landscape through the integration of knowledge.

Third, the digital information system for cultural landscapes should highlight the intangible dimensions of cultural landscapes. Although they may be invisible, intangible heritage elements are very important to cultural landscapes (Relph 1976; White 1977; Ryden 1993). These intangible dimensions not only contain many historical activities and events but also contain rich spiritual and cultural meanings, which are often ignored in conservation practices because they are invisible. Spiritual meanings must be represented through various means so that they can be remembered and accumulated as the 'rich deposits' of a landscape (Tuan 1977). Therefore, using new technologies to integrate the relevant information for intangible cultural heritage is very important in protecting the integrity of the cultural heritage.

Many digital tools have been applied in the collection, analysis and dissemination of heritage information for the conservation of cultural heritage over the past few decades. The research and practices of digital cultural heritage today focus on five themes: (1) cultural heritage information integration and management based on geographical information system (GIS) technology (Li and Song 2009; Apollonio et al. 2012; Myers et al. 2012); (2) open geospatial systems and standards using network-based information platform (Gröger and Plümer 2012; Costamagna and Spanò 2013); (3) simulation of the past, present and future of cultural heritage sites based on spatial technology (Short 2007; Vanegas et al. 2010); (4) representation of cultural heritage appearances based on virtual or augmented reality tools (Guhathakurta et al. 2009; Petty et al. 2012; Norris et al. 2014); and (5) visualisation of cultural heritage using computer game technology (Mortara et al. 2014). Most technologies are designed and applied in the measurement and simulation of the physical appearance of heritage sites; thus, the methods and tools of three-dimensional mapping and modelling have been greatly developed. However, the documentation and integration of the invisible dimensions of cultural heritage have not been fully explored at both theoretical and practical levels.

Among these digital tools, GIS is the most revolutionary approach to cultural heritage documentation and conservation, especially for cultural landscapes. The contribution of GIS to cultural heritage conservation might not be achieved by other methods or tools (Wheatley and Gillings 2002; Chapman 2006). GIS is defined as information linking locations on or near the Earth's surface to the properties of these locations (Goodchild 2009). Therefore, a GIS database is designed to capture, store, manipulate, analyse, manage and present all types of geographically referenced data (Foote and Lynch 1995). Computer-based GIS integrates the data from diverse disciplines and various formats to generate useful information about a place using an appropriate scale (Easa and Chan 2000). Therefore, GIS was used in this study as a tool to design a digital information system for cultural landscapes and test its application in heritage conservation and management.

The theoretical framework for a digital information system for cultural landscapes was established based on the review of both cultural landscape theories and cultural heritage technologies (Fig. 1). The inner-circle (green) in the diagram in Fig. 1 contains the most important features and elements that must be digitally represented in the information system. According to the landscape character theory, the natural and cultural, and tangible and intangible cultural landscape features are included in the framework. The outer circle (blue) contains the digital methods and technologies involved in the conservation of cultural heritage, which covers the cultural landscape information collection, management, and sharing tools. The theoretical and technical systems are intertwined and play a role in the investigation, analysis, management and interpretation of cultural landscape heritage. The following case study and digital information system design were based on this framework.

## A case study of Slender West Lake scenic area in China

### Evolution of Slender West Lake as a cultural landscape

The Slender West Lake scenic area is located northwest of Yangzhou City, Jiangsu Province, China. The area covers 12.23 $km^2$ and was included on the World Heritage List in 2014 as a world heritage site for the

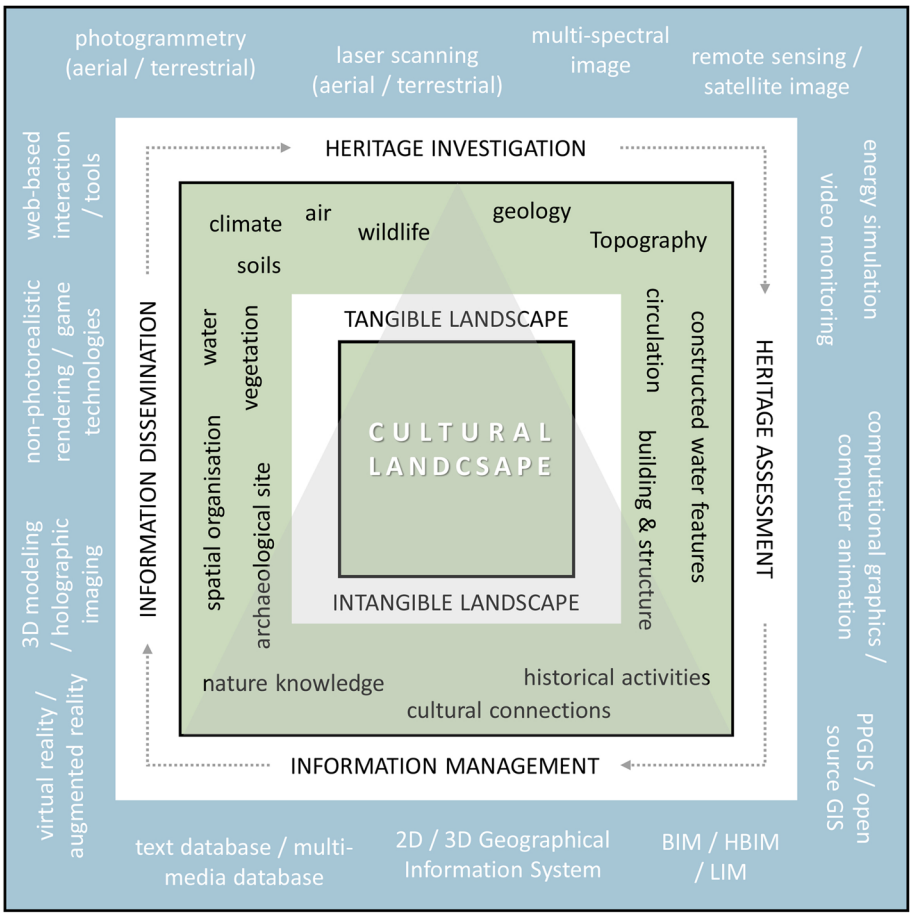


**Fig. 1** A theoretical framework for digital cultural landscape information system (Source: the authors)

Grand Canal. Slender West Lake was a garden landscape that was transformed from the military landscape formed by city moats and canals that was developed over 2500 years. In the mid-18th century, a large number of suburban villas and gardens built by salt merchants in different locations along the moats were connected and organised to welcome a southern inspection by Qianlong Emperor. This area became a beautified landscape belt alongside the lake with its garden scenery uniting the natural and human landscapes (UNESCO 2008). Slender West Lake is a typical demonstration of traditional public tourism destinations that represents the tastes and lifestyles of traditional Chinese society (Fig. 2).

The history of the Slender West Lake cultural landscape can be traced 2500 years back to the establishment of the earliest city in Yangzhou. The first city of Yangzhou, named Hancheng, was built in 486 BCE on the northern bank of the Yangtze River, which was a strategically important region between northern and southern China. A water network was then developed during the evolution of Yangzhou City because nearly every dynasty had redevelopment of the city and extended the moat system around the city (Yang et al. 2016). While these cities were built and demolished throughout the history of the area, all the moats were retained to form a military water network in northwest Yangzhou. During the Qing Dynasty (16445–1912), Yangzhou was one of the most prosperous cities in the Qing empire (Finnane 2004) and Slender West Lake was transformed from a military moat system into a recreational landscape. The local officials and salt merchants built many gardens and villas on the lakeside to please the Emperor and cater for their socio-cultural practices. Eventually, there were more than 100 gardens and public buildings built along the 3-km watercourse of Slender West Lake (Fig. 3).

The Slender West Lake scenic area is a typical Chinese cultural landscape with distinctive characteristics. As a designed landscape, Slender West Lake was the last and the largest construction of traditional Chinese gardens south of the Yangtze River during the last imperial dynasty (Han et al. 2011). As an organically evolved cultural landscape, Slender West Lake was continually developed from a military

**Fig. 2** Slender West Lake Scenic Area in summer (Source: Songsong Shen, 2009)

landscape into a recreational landscape over 2500 years. As an associative cultural landscape, Slender West Lake includes highly symbolic and metaphorical meanings and a rich, humanistic attachment to natural features. Therefore, Slender West Lake has the features of the three cultural landscape categories, which provide an important example for this study on digital heritage documentation.

### Challenges in the conservation and management of Slender West Lake scenic area

The fragmentation of heritage information is a major obstacle in the efficient conservation of Slender West Lake scenic area. As a cultural landscape heritage, the daily management of Slender West Lake requires a high degree of integration of multi-disciplinary, multi-period, and multi-sectoral information. However, the current heritage information is distributed among different institutions and in different forms and formats. Management departments, museums, libraries, archives and planning bureaus hold different sets of information about the historical and current status of Slender West Lake. However, this information lacks an integrated platform, which leads to the inability to fully consider the multi-level value of cultural heritage in making management decisions. For example, in the contemporary adaptive use and restoration of some sites in Slender West Lake, their ecological and social values may be emphasised, but its cultural and historical values may not be fully considered because of the lack of supporting information. Therefore, the establishment of an integrated digital information platform for cultural landscapes is urgently important.

There are technical challenges in incorporating the intangible cultural heritage information during the process of conservation in the Slender West Lake scenic area. The landscape itself has not only accumulated a large amount of tangible cultural relics, but also a large amount of intangible cultural heritage information during its 2500 years of evolution. Most of this information is detached from physical landscape conservation and used for heritage research as background information. Owing to the lack of an effective platform for data dissemination, the intangible cultural heritage information has not been fully incorporated into daily management. Therefore, it is difficult to understand the value of heritage and protect its integrity. Many culturally rich places have not been properly protected and interpreted; thus, the focus of this research is to explore how to systematically organise the information about the intangible heritage elements, integrate them into the heritage information management platform and support the conservators' related decisions.

The daily maintenance and restoration of the Slender West Lake scenic area lack a systematic digital recording system. In its evolving landscape heritage, the continuous maintenance, renewal, restoration and monitoring of Slender West Lake forms a management system with local characteristics. The records of site changes and interventions are important information for assessing the authenticity of landscape properties. However, there is currently no systematic registration platform and the user experience information of heritage management lacks effective transmission. Management activities mainly rely on field experience or paper materials; therefore, using a digital information system to record and monitor daily

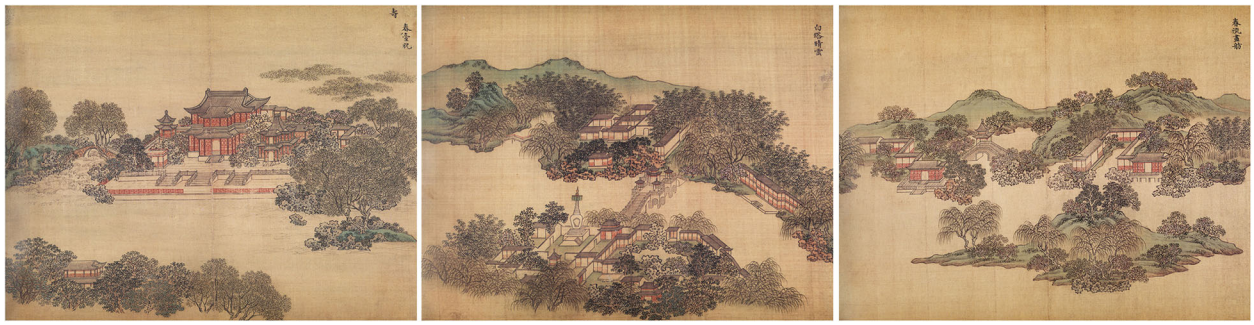

**Fig. 3** *Atlas of Great Landscape of the Gardens in the South of the Yangtze River,* 1760, landscapes in Slender West Lake (Source: Yangzhou Museum)

management work is of great significance in the sustainable development of Slender West Lake.

Like many other cultural heritage administrations, the local management team of Slender West Lake need more heritage data, technical capabilities and related technical resources. The existing national and regional heritage databases are relatively broad in scale and cannot be used for the daily management of the Slender West Lake scenic area. As a direct tool for the conservation and management of cultural landscape heritage, the data structure and functional settings of the designed digital information system should reflect the characteristics of the heritage itself and the preferences of local management teams. Therefore, it is necessary to explore a contextualised heritage information system for Slender West Lake.

### Data collection and analysis

The first step was to investigate the history, fabric, use and association of the landscape with the aim to define its cultural significance and related features. Existing conservation documents, including local chronicles, historical materials, conservation plans and professional reports, were collected from local management authorities. These documents were then analysed using a content analysis method, which provided a comprehensive understanding of the evolution of the Slender West Lake scenic area. Maps were derived from the documentary evidence as a special dataset because they are direct representations of the landscape that provide significant material for digital representation. An archaeological survey map created in 1979 and a topographic map from 2005 were combined and mainly used as a spatial reference for the following investigation and geo-database design.

Site observations were simultaneously conducted to explore Slender West Lake's physical aspects. The condition of the physical environment was recorded through sketches, notes and photographs. The connections between the tangible and intangible aspects of Slender West Lake were identified. A landscape character assessment process identified 25 landscape compartments in Slender West Lake, with distinctive landscape characteristics and certain cultural landscape values. Six types of landscape character-defining components were identified, including topography, man-made water, transportation, building, rockery and vegetation.

Based on the understanding of both the history and current condition of the landscape, semi-structured interviews were conducted with the landscape stakeholders to explore their information requirements for landscape conservation and management. Five different types of stakeholders were interviewed: a heritage conservation planner, a park manager, a local historian, an on-site tour guide and a tourism developer. Each stakeholder was asked to answer an open question: 'In your view, what information should we be collecting and using to guide the conservation and management of Slender West Lake?' The interview transcriptions were imported into NVivo 12.1 software (QSR International, Melbourne, VIC, Australia) for content analysis.

Three requirements of a digital information system for cultural landscapes were identified from the interview data. First, an inventory of tangible and intangible heritage components is required because it is an important reference for conservation and management. Information about these components must reflect their history, conservation significance, conservation guidelines and the current condition. This digital inventory must be systematically designed so that conservators find it easy to use, share and edit cultural heritage information. Second, Slender West Lake needs an integrated geo-database that can be used for on-site conservation practices. Conservation and management processes are undertaken in limited time and with limited resources. Thus, conservation managers require synthesised information to assist in their efficient decision-making. For example, the restoration work must be informed by reliable references to determine what sites and which parts of these sites can be restored. Third, tourism development was an important topic in the interviews. Both conservation managers and tourism developers wish to improve the quality of tourism in the Slender West Lake scenic area. The stakeholders described the many

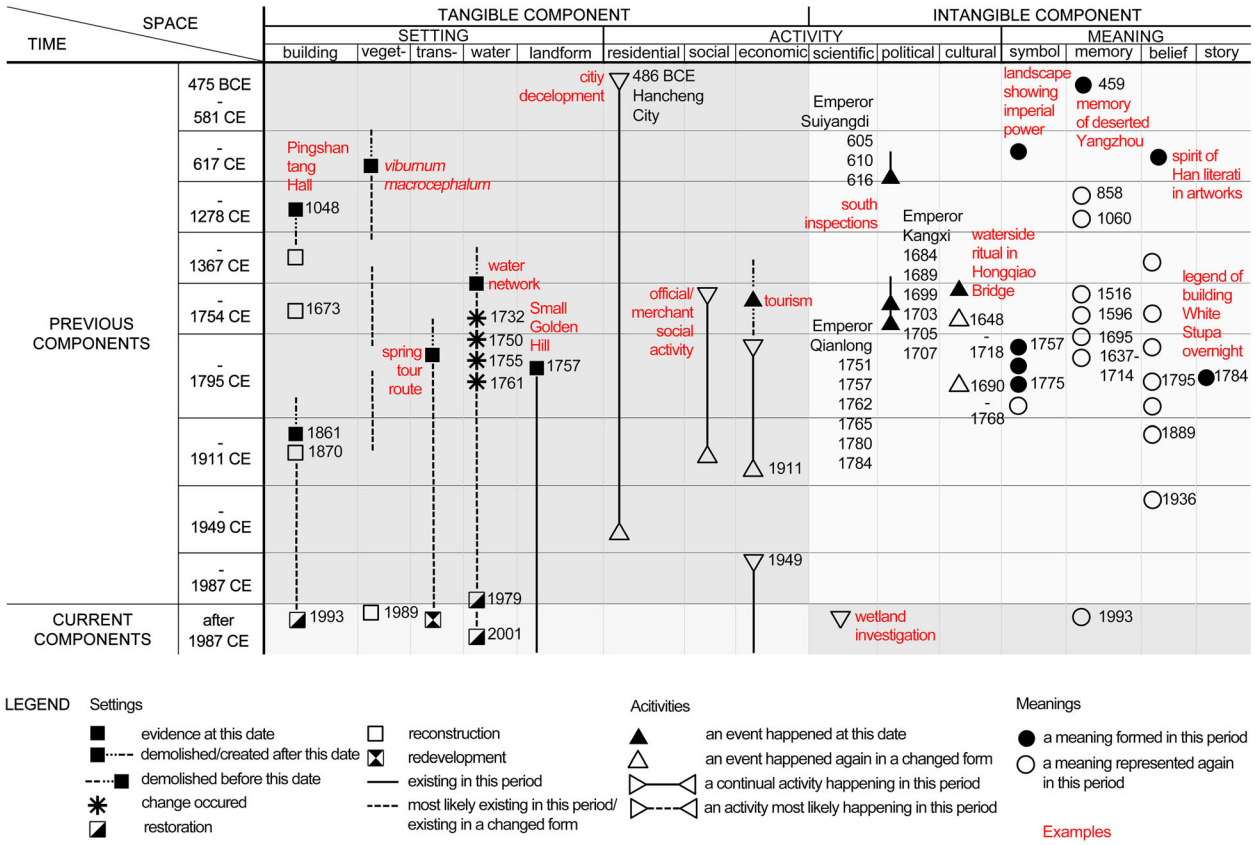


**Fig. 4** The four-dimensional model of Slender West Lake for geo-database design (Source: the authors)

intangible aspects of Slender West Lake as important resources for heritage interpretation and enhancing tourists' experiences.

## Design of a cultural landscape geo-database for Slender West Lake

Three aspects of the cultural landscape of Slender West Lake were analysed: physical environment, landscape activity and landscape meanings. The historical evolution of each aspect was further examined separately to thus form a four-dimensional model of the cultural landscape evolution of Slender West Lake (Fig. 4). The physical and non-physical components were categorised into individual features so that their characteristics could be identified. The history of Slender West Lake was divided into 10 periods and the development of the landscape and each component were identified and visualised in the model, which provided the original structure for the digital geo-database design (Fig. 4).

Accordingly, five groups of feature datasets, including 18 major feature classes, were integrated into the digital information system for cultural landscapes (Table 1). The data about the historical condition and changes for each component were attached to the landscape sites or individual features as attributes. The intangible heritage of Slender West Lake was integrated into this database through the design of a framework for feature attributes (Table 2). The digital information system was then constructed using an ESRI ArcGIS 10.1 software (Environmental System Research Institute, Redlands, CA, USA). The base map was derived from the digital survey map in DWG format provided by Yangzhou City's Planning Bureau. Most landscape components, such as buildings, water and plants, were all accurately illustrated on the map.

## Results: potential applications of the digital information system for Slender West Lake

The example geo-database of Slender West Lake was designed and built to test the application of such a system in conservation and management. The physical environment of Slender West Lake was represented using different database features: polygons were used to represent landscape compartments; buildings were represented by polylines drawn on their footprints; points were used to represent plants, rockeries and small-scale components; and polylines were selected to represent roads. The

**Table 1** The data structure of Slender West Lake geo-database

| Thematic layer | Feature dataset | Feature class | Type | Layer | Reference |
|---|---|---|---|---|---|
| Slender West Lake | – | – | Polygon | Scenic area boundary | Survey map / Aerial image |
| Landscape compartment | Landscape character type | Landscape character area | Polygon | Compartment boundary | Landscape character assessment map |
| Landscape component | Water | – | Polygon | Water border | Survey map |
| | Transportation | Road | Polyline | Road line | Survey map |
| | | Water cruise | Polyline | Cruise line | |
| | Building | – | Polygon | Building footprint | Survey map |
| | Topography | – | DEM | Elevation | Survey map |
| | Rockery | – | Point | Location | Research report |
| | Vegetation/Land cover | Arbor | Point | Location | Survey map |
| | | Shrub | Polygon | Boundary | |
| | | Herbaceous plant | Polygon | Boundary | |
| | | Historic plant | point | Location | Survey map |
| Historical period | 475 BC-581 CE; – 617 CE; – 1278; – 1367; – 1754; – 1795; –1911; 1949; – 1987; – Today | Historic map | Polygon/ polyline/ raster map | Location and shape of landscape component | Archaeological survey map 1979 |
| | | Feature attribute | Polygon/polyline/point | Boundary/location/area | Documentary evidence |

**Table 2** Feature Attribute in Slender West Lake geo-database: Intangible cultural heritage

| Intangible cultural heritage | | | Name | Time | Associated features | Description |
|---|---|---|---|---|---|---|
| Knowledge of the physical landscape | Knowledge of the physical landscape | Traditional land management technologies | Char | Short integer | Short integer | Char |
| | Traditional craftsmanship | Local techniques and tools | Char | Short integer | Short integer | Char |
| | | Traditional plants | | | | |
| | | Traditional food | | | | |
| | Oral history and tradition | Folklore | Char | Short integer | Short integer | Char |
| | | Oral history and tradition | | | | |
| | | Dialects and placenames | | | | |
| Historical activities | Social event | Historical events | Char | Short integer | Short integer | Char |
| | | Cultural events | | | | |
| | Ritual and custom | Religious events | Char | Short integer | Short integer | Char |
| | | Festival events | | | | |
| | | Folk activity | | | | |
| Spiritual connection | Spirit of place | Sensory characteristic | Char | Short integer | Short integer | Char |
| | | Cultural memories | | | | |
| | | Spiritual connections | | | | |
| | Artwork | poem | Char | Short integer | Short integer | Char |
| | | Painting | | | | |
| | | Local chronicles | | | | |
| | | Traditional music | | | | |
| | | Performing art | | | | |


**Fig. 5** The main interface of the geo-database of Slender West Lake (Source: the authors)

initial user interface for the example geo-database is a vector map of Slender West Lake (Fig. 5). This map and the layers available on the map allow conservators to access spatial layers and perform database queries. The users can zoom in and out at different scales using four levels of spatial bookmarks, which were set for different scales of Slender West Lake. The whole landscape is the primary home of the ArcMap documents, while the other two bookmarks display its compartments and components. For example, bookmark 1 in Fig. 5 shows Small Golden Hill, a compartment in Slender West Lake while bookmark 2 displays an individual building, the Hushang Caotang pavilion within this compartment. The identification tool allows the users to choose a specific feature and retrieve its related attribute data.

The database also contains rich information about intangible cultural heritage components. The intangible cultural heritage information is systematically integrated among the attribute information corresponding to each landscape compartment and component. Six different information categories were included in the database. When the user clicks on any database features, the query tool can be used to obtain the related intangible landscape information attribute table. As shown in Fig. 5, Small Golden Hill's intangible heritage information sheet contains six categories, each containing detailed text and non-text descriptions: knowledge of the physical landscape, traditional craftsmanship, oral history and traditions, social events, the spirit of place, and artworks. The data source could be expanded by using the hyperlink function to allow the attachment of multimedia data because many intangible landscape components cannot be represented by texts. For example, historical paintings and poems were digitalised and attached to specific database features using hyperlinks (Fig. 5). The artworks from Small Golden Hill in historic books, such as the *Illustrated Gazetteer of Pingshantang Hall* (1765) and *Atlas of Great Landscapes of the Gardens in the South of the Yangtze River* (1760) were all integrated as PDF files into the database. The database was also linked with other online sources, which greatly expands the database's capacity (Fig. 5).

In addition to the function of attaching multimedia information to individual features, the database can also provide a holistic picture of the available historical

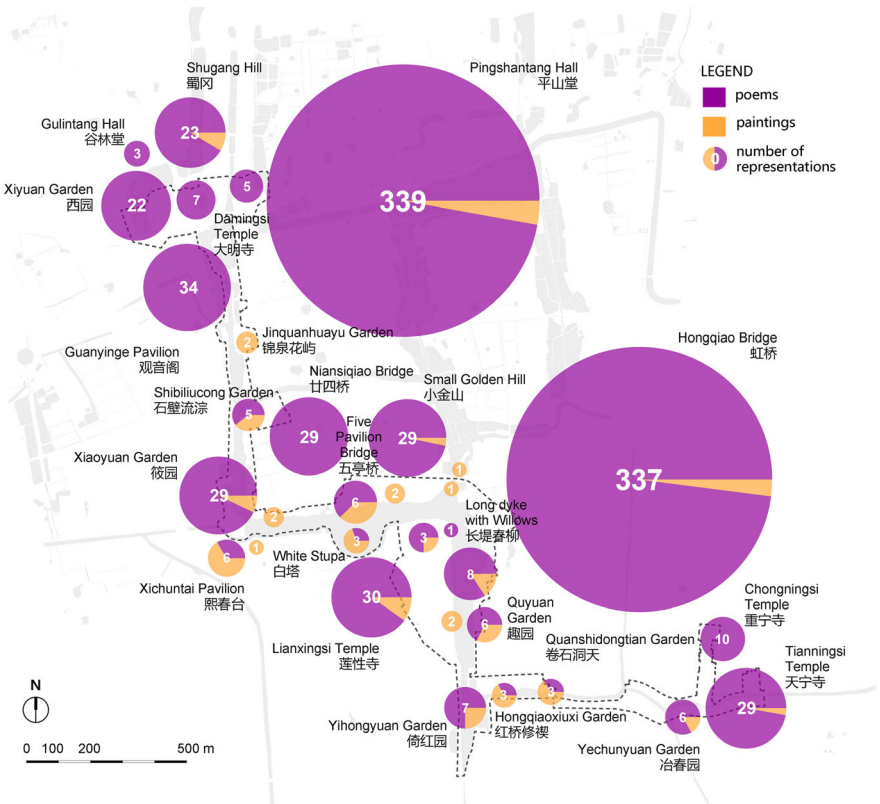


**Fig. 6** The thematic map of landscape representation analysis for Slender West Lake between 1644 and 1911 (Source: the authors)

artefacts representing the cultural landscape. Figure 6 was generated from the database to demonstrate the most represented landscape sites in Slender West Lake and indicates that two sites had many historical representations. That is, Dahongqiao Bridge and Pingshantang Hall were the most meaningful landscapes in Slender West Lake with more than 300 pieces of artworks related to each of them created between 1644 and 1911 (Fig. 6). Therefore, the artistic achievements and cultural values carried by these two sites far exceeded that for other attractions in Slender West Lake.

This database can also be a useful platform for maintaining and restoring landscape heritage at the component level. The geo-database produces information for heritage restoration at the component level by revealing the components that contribute to or are inconsistent with authenticity and the required restoration approach. For example, Pingshantang Hall is a garden located in northern Slender West Lake. Both the historical maps and the current condition of landscape components in Pingshantang Hall were integrated into the database. Thus, the difference between the historical and current conditions can be perceived directly.

First, this site contained four buildings from the Qing Dynasty as shown in the *Illustrated Gazetteer of Pingshantang Hall*; however, only one building remains today. Second, no rockeries were depicted in historical paintings, and no documentary evidence shows the rockery in Pingshantang Hall. Inconsistent with the historic evidence, however, three rockeries can be found on this site today. Third, the most significant characteristic of Pingshantang Hall is its commanding view of the surrounding terrain, including the mountains south of the Yangtze River, which were portrayed as the mountains spread out it an arc below the eaves, as if they could be grasped (Meyer-Fong 2003). The hall was named Pingshantang Hall, which means 'level mountain hall', because of its appearance. The view from the hall was deemed as an iconic feature of the site and generations of scholars visited Pingshantang Hall and inspected the broad region of the South Yangtze River as a ritual activity over thousands of years. However, this grand view is today blocked by newly planted spring palm trees in the front yard (Fig. 7). Additionally, based on the historical documents, five kinds of plants were significant in the history of Pingshantang Hall: willow, pine, plum, peach, and Chinese herbaceous peony trees, which were planted by scholars for their cultural significance and then beautifully depicted in poetry and paintings. However, only pine could be found on the digital map. Restoration guides for Pingshantang Hall were proposed based on the above comparisons of the integrated data.

## Discussion: new perspectives in cultural landscape heritage conservation

With the support of digital technologies, the concept of investigating the generation, form and meaning of landscapes from a dynamic and specific cultural perspective advocated by cultural landscape theory can be realised. The designed digital geo-database relies on a highly inclusive cultural landscape framework and landscape character assessment theory to integrate nature and culture, tangible and intangible, and historical and current information into a database platform. This holistic perspective cannot be achieved by conventional methods and tools; thus, this paper establishes an alternative approach for heritage conservation. The powerful data integration and analysis functions of GIS are very suitable for cultural landscape heritage studies. The geographical character of cultural landscapes can be used in a geo-database as an indexing framework for integrating heritage data, displaying complex information with a clear data structure and finally pointing to the monitoring and management of core heritage features.

This database provides visualisation for previously invisible historical information, which can improve our perceptions and appreciation of intangible cultural heritage components and values. The data sources for cultural landscape management can be expanded to include non-empirical evidence, such as oral history and informal archives. The physical landscape setting can still be visualised in the database using a historical map overlay function, which can better demonstrate the evolution of cultural landscapes and support the examination of the continuity of landscape characters. Many intangible landscape components, such as historical practices that promote the generation of landscapes, and artworks depicting the landscape, can be accessed through the powerful multimedia linking function of the geo-database and integrated into landscape evaluation and management processes. The database also simultaneously provides a powerful information platform for the interpretation of cultural landscape heritage. By relying on the database's collection of rich heritage information, the development of intelligent interpretation systems for cultural landscapes will be possible.

The geo-database also brings new perspectives to the monitoring and information management of cultural landscapes. Changes from the overall landscape to specific components can be recorded and inherited in the database, which greatly improves the efficiency and transparency of heritage site management. For cultural landscapes, as a continuously evolving heritage site, the records of its management methods and processes provide key data for the assessment of landscape authenticity. Meanwhile, this database provides opportunities for conservators to examine the landscape through a more

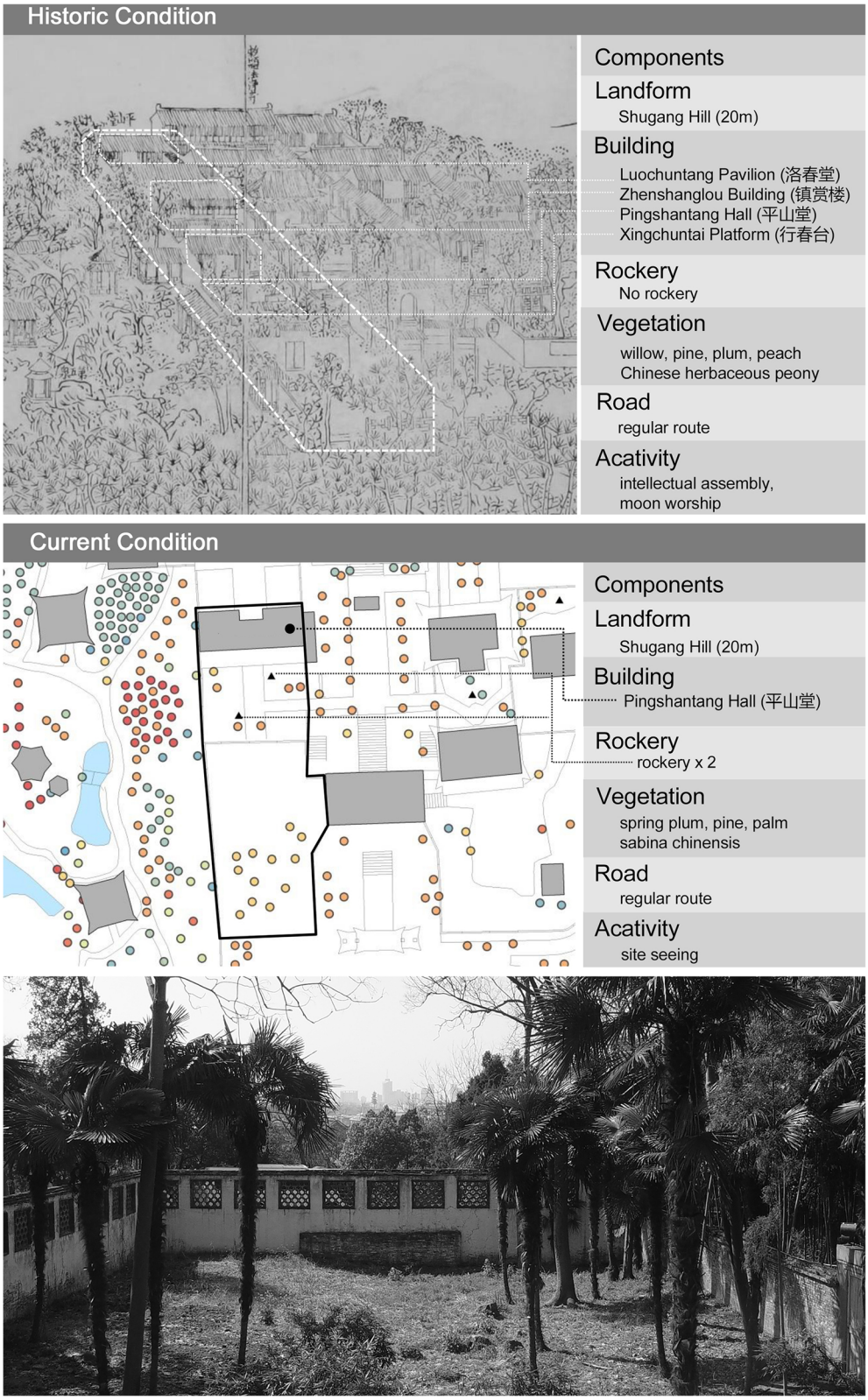


**Fig. 7** Component restoration plan for Pingshantang Hall based on the digital cultural landscape database (Source: the authors)

inclusive process. For example, professionals in charge of vegetation monitoring in Slender West Lake can more easily obtain the cultural and historical information of specific plants using this database. Conservators can now have a more comprehensive understanding of the value of the management objectives and the landscape can be conserved meaningfully.

This research also reflects the new requirements for digital technologies in cultural landscape heritage conservation. Currently, the challenges with the digital conservation of cultural landscapes are in the divisions between the humanities and the sciences. Digital tools like GIS can represent the physical components, knowledge of physical settings, and the activities occurring in these settings; however, they can hardly represent some of the invisible landscapes, especially its spiritual connections. As significant components of the authenticity and integrity of cultural landscapes in China, spiritual connections were created and delivered mainly through traditional landscape representations such as paintings and poetry. Therefore, a more straightforward way to solve this problem is to develop and expand the multimedia database functions of GIS. More powerful data compatibility, support for more data types and a more easily extensible database structure using GIS tools will provide a better platform for integrating traditional landscape representations artefacts.

However, with the rapid development of digital technologies in cultural heritage practices, the objective and accurate recording has become the primary method of landscape documentation. A more practical problem for the GIS database was that items to be included in a GIS must have longitude and latitude values, which indicate a geographic location. However, many mythical or oral stories about Chinese cultural landscapes are not necessarily linked with any spatial locations. This lack of 'physical carriers' is a significant barrier to the representation of these invisible landscapes using GIS. Therefore, objective documentation needs subjective interpretation. The information source of digital documentation should be extended to include phenomena not represented by experimental evidence. In the process of digital replica making, we need both 'descriptors' and landscape 'interpreters' with sufficient knowledge of a place. Based on a deep understanding of the place, the interpreter might be able to identify a layer, a compartment or a feature in the landscape database to 'carry' its invisible meanings.

## Conclusion

The implementation of the cultural landscape methodology and conservation approach requires strong data and information support. In China or other countries, how to establish a cultural landscape data platform and information management method with local characteristics is currently a front-line issue in the field of heritage research and practices. The integrity and accessibility of heritage information are still one of the important technical reasons hindering the effective management and sustainable development of cultural landscapes. This paper explored and demonstrated an innovative approach for building a digital information system for cultural landscapes to address these problems. First, this paper established a cultural landscape framework to guide the design of a digital information system with an emphasis on the invisible dimensions of cultural heritage. Digital technologies for different stages of cultural landscape conservation were simultaneously identified to form a technical reference. Second, the cultural landscape perspective provides a holistic vision for cultural heritage identification, which integrates the natural and cultural, visible and invisible heritage information into a digital information platform to support conservation and management. Third, in terms of technology, this paper provides pragmatic guidance for building a geo-database that can be used as a reference for other sites and projects in China and other countries. The technical challenges for digital technologies were also identified, which provide implications for developing new GIS tools in the future.

#### Acknowledgements

The case study was greatly assisted by landscape management authorities in Yangzhou China. The authors are grateful to the experts and directors in the Office of World Heritage Application of Slender West Lake and Historic Urban Area of Yangzhou.

We thank Peter Fogarty, MA English 1st Class, from Liwen Bianji, Edanz Editing China (www.liwenbianji.cn/ac), for editing the English text of a draft of this manuscript.

#### Authors' contributions

Feng Han established the cultural landscape assessment framework and identified the cultural heritage value of the case study site. Chen Yang performed the design of the geo-database, and was a major contributor in writing the manuscript. All authors read and approved the final manuscript.

#### Funding

This research was supported by the National Natural Science Foundation of China (Youth Foundation) under Grant number 51608369; the National Key R&D Program of China under Grant number 2016YFC0503308; and the Research Funds for the International Open Projects in the College of Architecture and Urban Planning (CAUP) in Tongji University under Grant number 2018040301.

#### Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

#### Competing interests

The authors declare that they have no competing interests.

Received: 16 December 2019 Accepted: 8 January 2020
Published online: 25 March 2020

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## Publisher's Note