

Article

Identifying Cultural Ecosystem Services and Relevant Landscape Elements Provided by Urban Green Space throughout History from an Information Communication Perspective

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Abstract: Throughout the long history of urban expansion and development, some of the natural mountains, lakes, and rivers that were once located on the outskirts of a city have gradually been encircled within it and have become nature in the urban, i.e., they are now in the heart of the city. These are not only green infrastructure for contemporary cities; they have also accumulated a rich cultural heritage and are closely related to the physical health and subjective well-being of city dwellers. The objectives of this study were: (1) to identify the no-material services that the public perceives from UGSs throughout history that contribute to subjective well-being; (2) to analyze which landscape elements are associated with the provision of such services and then to clarify the value of UGSs throughout history and provide a theoretical basis for urban managers. We returned to the original concept of cultural services (information services) to understand how UGSs throughout history, as information sources, have provided subjective well-being to specific groups of people. And we build a classification system for information services based on this understanding. Based on existing research methods on cultural services, we found that collecting information carriers such as texts, images, and interview transcripts is a more effective way to identifying the intangible services provided by a landscape than monetary methods. From understanding of the information communication process, we attempted to integrate the supply and demand indicators of information services. We validated the feasibility of the method of information service identification using Yuexiu Hill in Guangzhou, which has a construction history of 2000 years, as an example. Through the word frequency statistics of 1063 ancient poems (a type of information carrier), elements of the historical landscape of Yuexiu Hill and the information services provided in the past were identified. After that, semantic networks were constructed to analyze the association between elements and services. The results of this study show that information service identification is an effective method of analyzing the effect of the promotion of UGSs throughout history on the subjective well-being of the public. The provision of information services depends on the accumulation and dissemination of environmental information; both natural and cultural elements, especially symbolic elements, play an important role in this process.

Keywords: urban green space throughout history; cultural ecosystem services; information services; subjective well-being; nonmaterial benefits



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1. Introduction

The expansion of cities has caused some natural mountain ranges, lakes, and rivers that used to be located on the periphery of cities to be gradually wrapped up in them and become nature in the center of a city [1]. In this study, we focused on the contribution of such urban green spaces (UGSs) to subjective well-being throughout history. UGSs

throughout history have accumulated rich and nonrenewable natural and cultural heritage over the long history of urban construction and have even higher potential value in archaeological, esthetic, and ecological terms. They have provided both material and nonmaterial benefits to urban residents over a period of time [2]. Even if some UGSs throughout history have been destroyed through overdevelopment or mismanagement, these invisible urban natures still play a role in promoting the subjective well-being of the city dwellers as a shared cultural memory. Thus, it is necessary to identify the nonmaterial benefits that UGSs throughout history have provided to urban dwellers over the evolution of the cities. Notably, the role of urban green spaces in promoting public health and subjective well-being has received increasing attention in recent studies [3–5]. However, the problems of classification and quantitative evaluation have not been fully addressed in these studies [6]. An approach is needed to integrate the relationship between the natural ecological and cultural heritage values of UGSs throughout history and the landscape characteristics, so as to support the strategic urban green space planning.

Through the literature review, we have found that the identification of ecosystem cultural services can be an entry point to address the aforementioned issues. Numerous researches have analyzed some nonmaterial benefits that urban residents derive from urban nature by evaluation of cultural ecosystems services [7,8]. However, the concept and methodology of CES still needs to be constantly improved so that diversified cultural services are more fully considered into landscape planning and design. Early researches did not develop a standard method of identifying CESs. It is because that economic logic based on ES theory [9,10] and conceptual frameworks based on biophysical dimensions [11,12] are not applicable to all types of CESs. An obvious informatization tendency has been shown in relevant research methods of CES in recent years, although the concept of “information” is not directly used. In addition to the widely used interview and questionnaire methods, the document and social-media-based methods have also received increased attention [13]. Photographs [14,15] and comments [16,17] publicly published on online social media platforms, historical sources such as books and poetry [18,19], transcripts of community interviews [20,21], and even the number of occurrences of symbolic species in areas such as advertising and shop names [22] have all been used in CES identification. This is because these information carriers record both landscape characteristics and stakeholder perceptions of information services. Returning to the earlier concept of cultural services (information services) [23] and identifying them through the historical records related to environmental information is a more effective method of studying such nonmaterial services. Moreover, it can be easier to understand the nature of cultural service generation using the concept of Information services.

According to Costanza [24], the provision of ecosystem services stems from the flow of materials, energy, and information from natural capital stock, essentially. Capital stock can take intangible forms, notably information stored in computers, individual brains, species, and ecosystems [24]. This environment information including aesthetic information, spiritual and religious information, historic information, cultural and artistic inspiration, scientific information and so on [25]. That composes an information system which contribute to the maintenance of psychological health by providing opportunities for reflection, spiritual enrichment, cognitive development, and aesthetic experience [23]. Claude E. Shannon, the founder of information theory, depicted the general path of information dissemination as a linear model of communication. He believed that communication is the information transmission between two systems: a message is sent by the source, passed through the channel, and then acquired by the host, which constitutes a general communication system (as shown in Figure 1). Shannon stated that an information communication system must contain five basic elements: an information source, a transmitter, a channel, a receiver, and a destination [26]. Essentially, the creation of ecosystem cultural services is a process in which environment information communication occurs between the landscape and the public. Environmental information communication here implies that environmental information stored in the landscape and related social groups (information sources) is

received by the public (destinations). The above-mentioned exchange of environmental information occurs more frequently while the public is engaged in cultural activities. These information and activities are recorded in the form of textual or pictorial information and reflect the probability of environment information communication occurring in the landscape. Collecting, encoding, and computing the textual and pictorial information recorded by these carriers can, to some extent, help us understand the potential of UGS throughout history of providing services and public perception of cultural services.

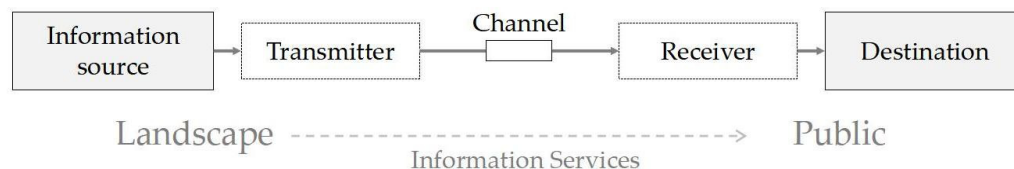


Figure 1. Schematic diagram of a general communication system [26].

As with other ecosystem services based on the delivery of landscape structure–function–value chains [27], the generation of information services requires public recognition of the value generated by the communication of the relevant information. Due to the considerations of public recognition and demand, seven indicators from the Millennium Ecosystem Assessment (MEA) that are widely recognized in existing research have been applied [28]. Two of these services have been provided due to UGSs providing places for people to communicate, including: social relations (SR) and recreation and ecotourism (RE). The other five services, including: artistic inspiration (AI), spiritual and religious (S and R), education (E), aesthetic (A), and cultural memory (CM), that have been provided due to UGSs playing the significant part as information source.

In this study, we used Yuexiu Hill in Guangzhou as an example to demonstrate the feasibility of the method of information services identification for analyzing UGSs throughout history. Through the mining of 1063 related ancient poetry texts, we identified the landscape elements of the Yuexiu Hill throughout history and the information services provided in past times. Then, we analyzed the association between them by constructing a semantic network of poetry. In the case study, we tested the following hypotheses: (1) information service is an effective way of identifying the nonmaterial benefits that the public has derived from UGSs throughout history; (2) Historic GUSs are typical examples of the information services provided by the landscape, which benefits from its diverse natural and cultural elements; (3) Evaluating the supply potential and public demand for UGS through history can be an important basis for developing strategic urban green space planning and promoting urban heritage preservation.

2. Materials and Methods

2.1. Study Area

The Yuexiu Hills are a group of natural hills trending northeast–southwest in the northern part of the ancient city of Guangzhou, China. It has a 2000-year history of construction, and the part of the preserved green space is now Yuexiu Park. As their historical boundaries could not be accurately determined, the approximate geographical extent (Figure 2) was mapped based on archaeological information and contemporary road layouts, covering an area of approximately 5110 square meters.

The gradual expansion of the city over a period of more than 2000 years was accompanied by the gradual erosion of the natural environment of Yuexiu Hill. The southern foot of the hill was incorporated into the city walls after the expansion of the city in the Ming Dynasty. The hill became the most representative symbol of the ancient city of Guangzhou during the Qing Dynasty. It has gradually become the core of the city’s cultural activities. Also known as Guangzhou’s dominant hill, which has occupied a central position in the northern part of the city. A description of the corresponding landscape changes in the different historical periods is provided in Table A1. Unlike other urban nature areas in and around the ancient city, the green spaces on Yuexiu Hill area have survived. This is

because, in addition to continuing its ecological functions, it has also been preserved as a venue for cultural activities such as festive celebrations, gatherings, and education and is rich in historical and cultural value. This has implications for the public health and subjective well-being of the city's residents.

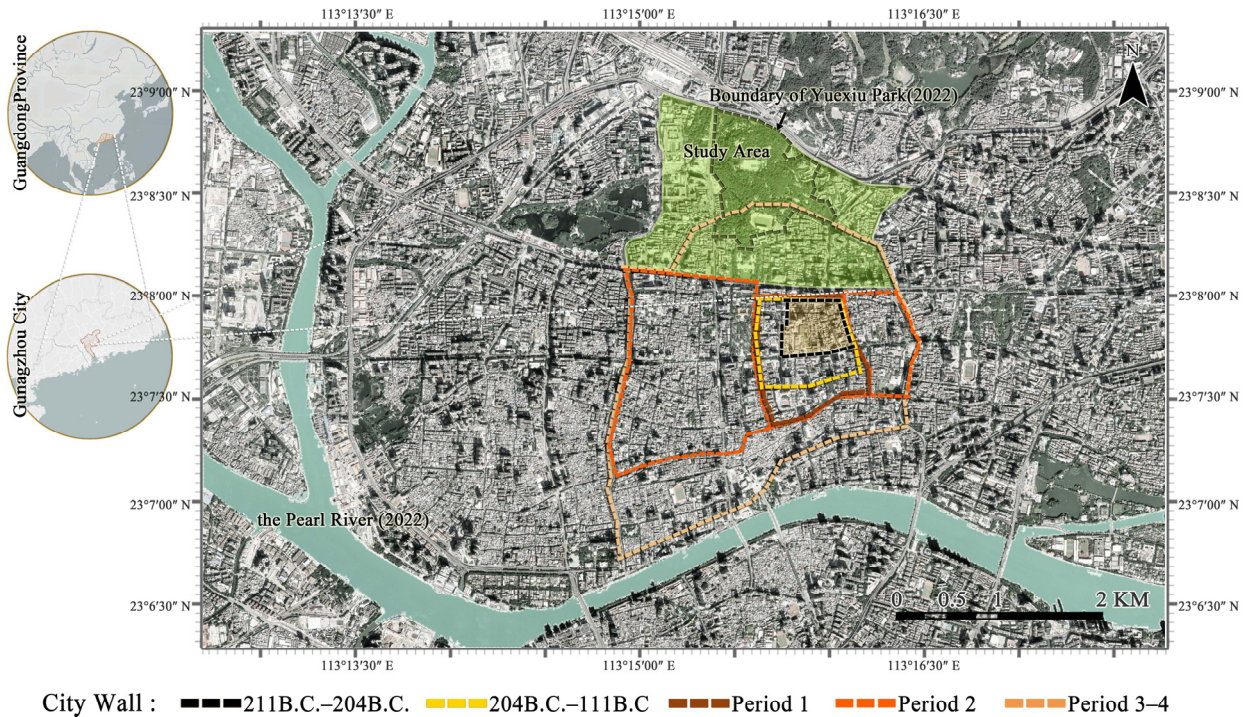


Figure 2. Map of location and changes in extent of city walls in Guangzhou.

2.2. Data Analyses

2.2.1. Database Constructing and Text Data Preprocessing of Yuexiu Hill Poetries

As a literary genre, poetry records rich historical information about cultural activities, landscape elements, and spatial locations. Online databases of poetry provide a description of the content and available data about the year in which the work was published. Conditions are created for accessing local information with a large sample size and a long-time span. Text mining technology is used to obtain valid information from unstructured textual information. The information reflects both the potential of urban green spaces to provide services and the type and extent of information services available to their users.

The poems used in this study were taken from SOU-yun.cn, an online database of 900,000 ancient Chinese poems written over a period of about 2000 years. Names of the historic sites (including their period names) were used for the poetry search. To ensure the integrity of the poem database, the retrieval covered all the names of the historic sites listed in the List of Historic Relics and Sites in the appendix of Millennium Yuexiu Hill [29], compiled by the official Yuexiu Park in Guangzhou. The search yielded 1063 poems composed between 581 and 1949 (last accessed 10 September 2022). The poems were stored in *.txt format, with each poem stored as a separate and continuous paragraph. Then the redundant information was filtered, with only the title and body of each poem stored. From the above process, a database of ancient poems from the Yuexiu Hill was constructed.

Poetry texts needed to be segmented and standardized to improve the accuracy of word frequency analysis and semantic networks. Firstly, the text was pre-segmented using the ROST Content Mining System version 6.0 (a digital humanities-assisted research platform designed and coded by Wuhan University, China). Then, the phrases with the same meaning were grouped together to obtain a standard phrase list of information services and landscape elements (e.g., Table A2 shows 36 groups of standard phrases related to information services and their corresponding original phrases). Using the bulk sub-

stitution tool in WPS, all synonyms in the original text were sequentially replaced with standard phrases to obtain a normalized text. Next, the normalized text was again used with the word segmentation tool of the ROST CM version 6.0 to more accurately segment the resulting normalized text.

2.2.2. Analyzing Public Demand: Information Services Identification throughout History of Yuexiu Hill

Poetry records the rich cultural activities of the ancient Yuexiu Hill area. The frequent occurrence of cultural activities related phrases in these poems effectively reflects the public's demand and approval of the corresponding cultural services. Using the word frequency tool of the ROST CM version 6.0, the number of occurrences of each phrase associated with the information service in the Yuexiu Hill Poetry Database was counted, under the monitoring of the Standard Phrase Table of Information Services (Table A2). From the above phrases, six categories of information services were identified. The sum of the frequency of phrases from the same category reflects the extent to which the public has historically had access to this type of information services provided in the Yuexiu Hill area (Table 1) and can be considered an indication of the demand for information services in the area.

Table 1. Identification of information services throughout history of Yuexiu Hill area.

Information Service	Standard Phrase	f	Value	Information Service	Standard Phrase	f	Value
Social relationships	Farewell	10	153	Artistic inspiration	poet	5	66
	Have a conversation	17			Compose poems	39	
	Banquet	16			Paint a picture	18	
	Drink	75			Calligraphy	4	
Recreation and ecotourism	Having tea	4	328	Education	Classical academy	13	52
	Hill-climbing	129			Academic studies	22	
	Go sightseeing	46			Gifted scholar	17	
	Go fishing	13			Nostalgia	53	
	Play music	42			Past events	77	
	Singing and dancing	98			Festival	3	
	Meditation	20			Pure Brightness	4	
Monks	23	Cold Food Day	9				
Spiritual and religious	Journey to fairyland	18	225	Cultural memory	The Double Ninth Festival	7	176
	Wonderland	68			The Lantern Festival	10	
	Fairies	71			Worship the kitchen god	2	
	Sages	14			Shangsi Festival	1	
	Worship	11			Fly kite	4	
					Dragon Boat Festival	6	

2.2.3. Analyzing Services Potential: Landscape Characteristics throughout History of Yuexiu Hill

To determine the esthetic value of an area and its tourism potential, many researchers have assessed landscape characteristics, in addition to aspects such as accessibility and the presence of tourism infrastructure [30,31]. Supply-side CES indicators, contrastingly, are focused on measuring landscape characteristics, as it is from them that CESs are generated [32]. These indicators can identify the space closely related to cultural practices [33], which can be used to indicate the potential of urban green spaces to provide information services.

Along with the construction of the ancient city of Guangzhou over more than 2000 years, the natural basis and historic sites in the Yuexiu Hill area gradually degraded and even disappeared. We have reconstructed the historical landscape characteristics of Yuexiu Hill by text-mining poems and taking historical maps of the Yuexiu Hill area as supporting evidence.

Phrases in the poems related to landscape characteristics and elements were identified and classified into three categories, including land cover, natural elements, and cultural elements, covering 2, 4, and 3 subgroups, respectively. The frequency of phrases in the subgroups in each category was separately calculated (Table A3). The results reflected the potential of providing information services in the area.

2.2.4. Connecting Supply and Demand: Constructing the Semantic Network of Poems

To analyze the associations between various information services and different landscape elements, a semantic network (SN) was constructed based on the retrieved 1063 poems. The SN approach is often used to describe how people understand things in an informative form [33] and has been widely used in studies related to urban design and planning [34,35].

An SN is a graph structure that represents knowledge using nodes and links to express semantic relationships between concepts [36]. Formally, such an object is represented as $G = (V, E)$, where V is the node set, and E is the link set [37]. Each node corresponds to a lexical group, and links between lexical groups are used to indicate the presence of semantic associations between connected nodes. In this study, each node in the semantic network represented an independent and semantically clear phrase in the poetry database. Moreover, the presence of a link between two phrases indicated that they occur in the same poem and that a semantic association exists between the cultural activities and landscape elements they represent. The higher the link weight, the more closely the two nodes are connected, that is, the stronger the association between the service or landscape elements represented by the two phrases. Links between nodes can be represented as a matrix [38].

The preprocessed *.txt file was imported into ROST CM 6.0, and we generated a co-occurrence matrix with the Semantic Network Analysis Function. The matrix was stored in a table in *.csv format. Then, a semantic network diagram (Figure 3) was drawn, and the weights of all the links in the network were derived using the complex network analysis software Gephi 0.9.2. To facilitate the comparison of the strength of the association between the six types of information services and the different landscape elements, the link weights of service phrase in the same type (i) corresponding to the element phrase in the same subgroup (j) were separately summed (W_{ij}) (Table A4) and converted to percent (PCT_{ij}) for comparison (Table 2).

$$PCT_{ij}(\text{percent}) = W_{ij} / \sum W_i * 100$$

where i is all phrases corresponding to groups of SR, RE, AI, S and R, E, and CM; j is all phrases corresponding to groups of historic sites, artificial elements, historic figures, natural meteorology, celestial objects, animal species, plant species, waterscape elements, and associated regions.

Table 2. Comparison of link weights between six types of information services and nine subgroups of landscape elements.

		Historic Sites	Artificial Elements	Historic Figures	Natural Meteorology	Celestial Objects	Animal Species	Plant Species	Waterscape Elements	Associated Regions
SR	W_{SR-j}	360	112	78	366	160	158	176	70	472
	$PCT_{SR-j}(\%)$	18.44	5.74	4	18.75	8.2	8.09	9.02	3.59	24.18
RE	W_{RE-j}	800	338	114	772	350	300	426	138	998
	$PCT_{RE-j}(\%)$	18.89	7.98	2.69	18.22	8.26	7.08	10.06	3.26	23.56
AI	W_{AI-j}	106	42	28	114	60	48	58	24	140
	$PCT_{AI-j}(\%)$	17.1	6.77	4.52	18.39	9.68	7.74	9.35	3.87	22.58
S and R	$W_{S\&R-j}$	402	148	80	494	262	154	258	116	592
	$PCT_{S\&R-j}(\%)$	16.04	5.91	3.19	19.71	10.45	6.15	10.3	4.63	23.62

Table 2. Cont.

		Historic Sites	Artificial Elements	Historic Figures	Natural Meteorology	Celestial Objects	Animal Species	Plant Species	Waterscape Elements	Associated Regions
E	W_{E-j}	54	10	8	28	14	22	24	10	58
	$PCT_{Ej} (%)$	23.68	4.39	3.51	12.28	6.14	9.65	10.53	4.39	25.44
CM	W_{CM-j}	340	110	60	344	172	138	160	44	438
	$PCT_{CMj} (%)$	18.83	6.09	3.32	19.05	9.52	7.64	8.86	2.44	24.25
	W_j	2062	760	368	2118	1018	820	1102	402	2698
	$PCT_j (%)$	18.17	6.7	3.24	18.66	8.97	7.23	9.71	3.54	23.78

W_{ij} (weight): sum of the link weights of service phrase i corresponding to element phrase j; PCT_{ij} (percent) = $W_{ij}/\sum W_i * 100$. W_j : sum of the link weights of element phrase j corresponding to all service phrases; PCT_j (percent) = $W_j/\sum W_j * 100$. (i = SR, RE, AI, S and R, E, and CM; j = historic sites, artificial elements, historic figures, natural meteorology, celestial objects, animal species, plant species, waterscape elements, and associated regions).

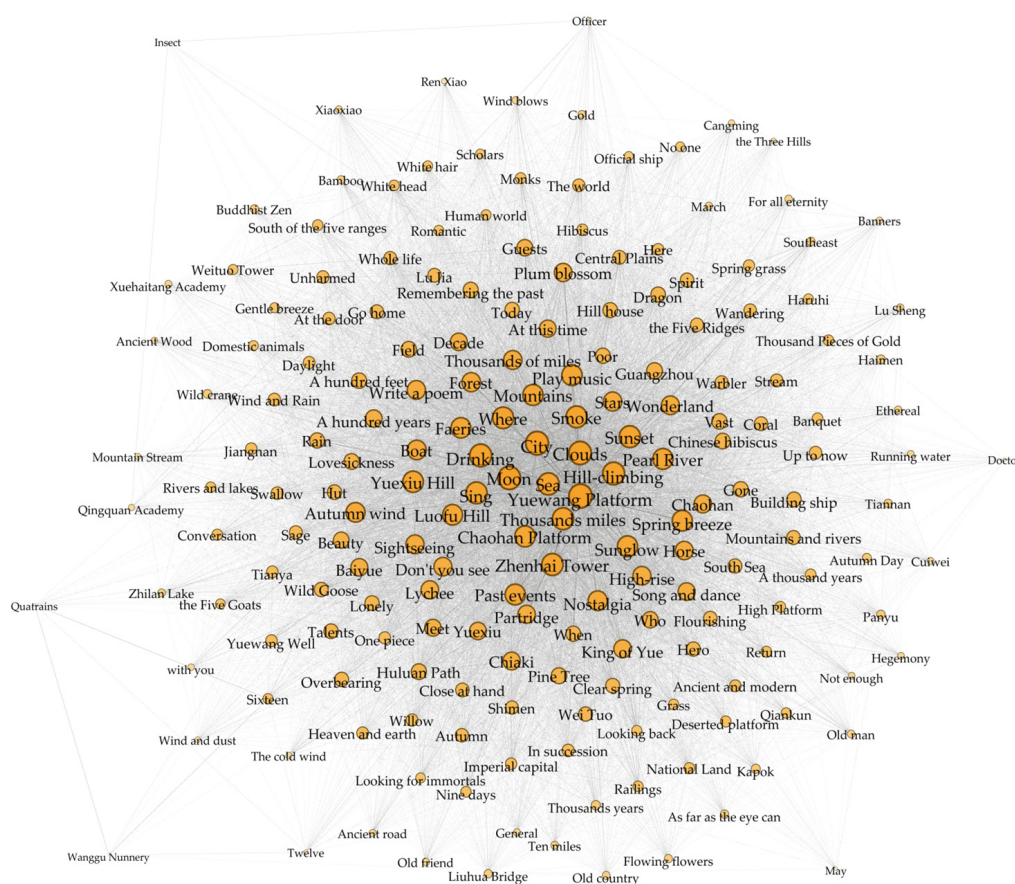


Figure 3. Semantic network diagram of Yuexiu Hill poems.

3. Results

3.1. Information Services from Yuexiu Hill Perceived by Public throughout History

By summing the frequencies of phrases related to similar information services, we found that the six categories of information services mentioned in the poetry database are not equally distributed in frequency. In descending order, they are: “recreation and eco-tourism” ($IS_{RE} = 328$), “spirituality and religion” ($IS_{S \text{ and } R} = 225$), “cultural memory” ($IS_{CM} = 176$), “social relationships” ($IS_{SR} = 153$), “artistic inspiration” ($IS_{AI} = 66$), and “education” ($IS_E = 52$) (Table 1).

The results of textual information mining reflected the historical public demand for different types of information services provided by urban green spaces. People living in urban areas needed a place for recreation and social interaction, and this was the main reason for the construction of the area over the last two millennia. The activities associ-

ated with recreation and ecotourism in the historical Yuexiu Hill area were mainly “hill-climbing” and “singing and dancing”; “banquets” were often held to promote social interaction. Additionally, the public has had opportunities for spiritual enrichment, cognitive development, and esthetic experience during their visits to the urban green spaces. The high frequency of phrases showed that “spiritual and religious” is mainly linked with “Buddhism” and the native “Taoism”; the term “cultural memory” is mainly related to the recollection of historical events that took place in the Yuexiu Hill area; “artistic inspiration” is mainly related to artistic creation activities such as “poetry” and “painting”. “Education” is related to the construction of academies at the southern foot of Yuexiu Hill and the sightseeing activities of scholars (Table 1). The specific activities involved in information services in different areas have differed [39], and the high-frequency phrases in the poems reflect the specific needs of the public for information services in the Yuexiu Hill area.

3.2. Potential of Yuexiu Hill to Provide Information Services throughout History

Three categories of phrases related to landscape characteristics reflect the potential of the historic Yuexiu Hill to provide information services (Table A3).

The first category of phrases reflects the richness of land cover types in the historical Yuexiu Hill area and includes two subgroups. We identified eight groups of phrases related to landforms and seven groups of phrases related to natural bodies of water from the poems, which together reflect the diversity of landforms and the level of public interest in each type of landform. Through calculations, we found that vegetated hills were the dominant land cover in the area, with “forest”, “ridge”, and “hill peak” being frequently mentioned, and their word frequency accounting for 19.33%, 12.00%, and 8.95% of the total word frequency in the land cover category, respectively. The words “field”, “cave”, “gully”, “cliff”, and “undulating hills” also appear in the poems. In addition, the high frequencies of “lake”, “spring”, and “stream” reflect the abundance of water in the Yuexiu Hill area, accounting for 13.53%, 11.39%, and 7.02% of the total word frequency in the land cover category, respectively. According to historical records, mountain springs, which converge from Baiyun Mountain in the north to Yuexiu Hill in the south, eventually join the Pearl River in the south, were an important source of water for the ancient city of Guangzhou. In addition to studying the topographical features of the area, the high-frequency references in the poems include the “city (Guangzhou)”, “the Pearl River”, and “the Three Hills”, which can be seen from the high point of Yuexiu Hill, as well as the names of the regions with which the poets associated when they composed their poems, such as “the imperial capital”, “the Central Plains”, and “the Five Ridges”. As seen in the ancient paintings (Figure 4), emergence of these region names reflects the relevance and integrity of Yuexiu Hill to the surrounding area, both in terms of view lines and public perception.



Figure 4. Yuexiu Hill in the ancient paintings: (a) View of Guangzhou (Canton) (part of the painting), around 1760–1770, collected by the British Library. (b) Canton harbor and the city of Canton, around 1760, collected by the British Library.

The second group of words reflects the types of natural elements in the Yuexiu Hill area and includes four subgroups: plant species, animal species, natural meteorology, and celestial objects. We found 76 plant names, such as “pine tree”, “bamboo”, “lychee”, and “kapok”. Animals also frequently appear in the poems, including ten mammals, eighteen birds, two amphibians, two fishes, and eleven insects. In addition, climatic elements such as “clouds”, “rain”, and “wind”; and celestial elements such as “sun”, “moon”, and “stars” may also be related to information services.

The third category of phrases reflects the types of human elements in the Yuexiu Hill area and includes three subgroups: historic sites, other artificial elements, and historic figures. Over the course of its long history, Yuexiu Hill has not only been a green space for city dwellers to experience nature but also an important place to perceive the city’s history and gain local identity. The 26 historic sites are mentioned several times in the text and are arranged in Table A3 according to when they were built. Among them, “Yuewang Platform”, “Chaohan Platform”, “Yuewang Well”, and “Zhenhai Tower”, which were built in the early period of its history, are more frequently mentioned. The existence of some historic sites can be confirmed in the ancient paintings that have been preserved to this day (Figure 5). In addition to these clearly named historic sites, the poetry database also contains frequent references to human-made elements such as “high buildings”, “high platforms”, “ancient roads”, and “gardens”, as well as historical and mythological figures such as the “King of Yue” and “Lu Jia”.



Figure 5. Historic sites of Yuexiu Hill in the ancient paintings: (a) Yuewang Platform, Huangbin Hong, 1930s, Collected by the National Art Museum of China. (b) The southern part of Yuexiu Hill in History of the Baiyun Mountain and the Yuexiu Hill, published in the Qing Dynasty. (c) The magnificent Zhenhai Tower, before 1696. (d) Hundred step ladders (built on the old site of Huluan Path in 1930), Huangbin Hong, 1930s, Collected by the National Art Museum of China. (e) Appreciating the moon at Xuehai Academy, Chen Pu, 1872, Collected by the Guangzhou Museum of Art.

The high frequency of the aforementioned landscape elements in ancient poems implies that there is a connection between these elements and public perception, which is a manifestation of collective consciousness. The existence of these elements brings greater potential for providing cultural services to the landscape. However, the construction of the ancient city was accompanied by the disappearance of the aforementioned landscape elements and the emergence of new ones. These changes have changed the public’s per-

ception and understanding of environmental information. In order to provide a more intuitive expression of the changes in the landscape characteristics of Yuexiu Hill, we use the 250 m \times 250 m grid cell as the basic measurement unit, and historical maps collected from different periods are plotted using a unified standard (Table A1), as shown in Figure 6. Then, mark the historic sites mentioned in the archaeological records on the maps. From Figure 5, it can be seen that the spatial connection between Guangzhou City and Yuexiu Hill is becoming increasingly close, and the construction efforts in the southern part of Yuexiu Hill continue to increase, occupying a large amount of original green space and water system space. The human element is constantly being enriched in the region, while, on the contrary, the natural element is being diminished. Of the constantly changing elements of the landscape, which are more closely related to the provision of information services? To answer this question, we further analyze the strength of correlation between landscape elements and information services in the Yuexiu Hill area by building a semantic network.

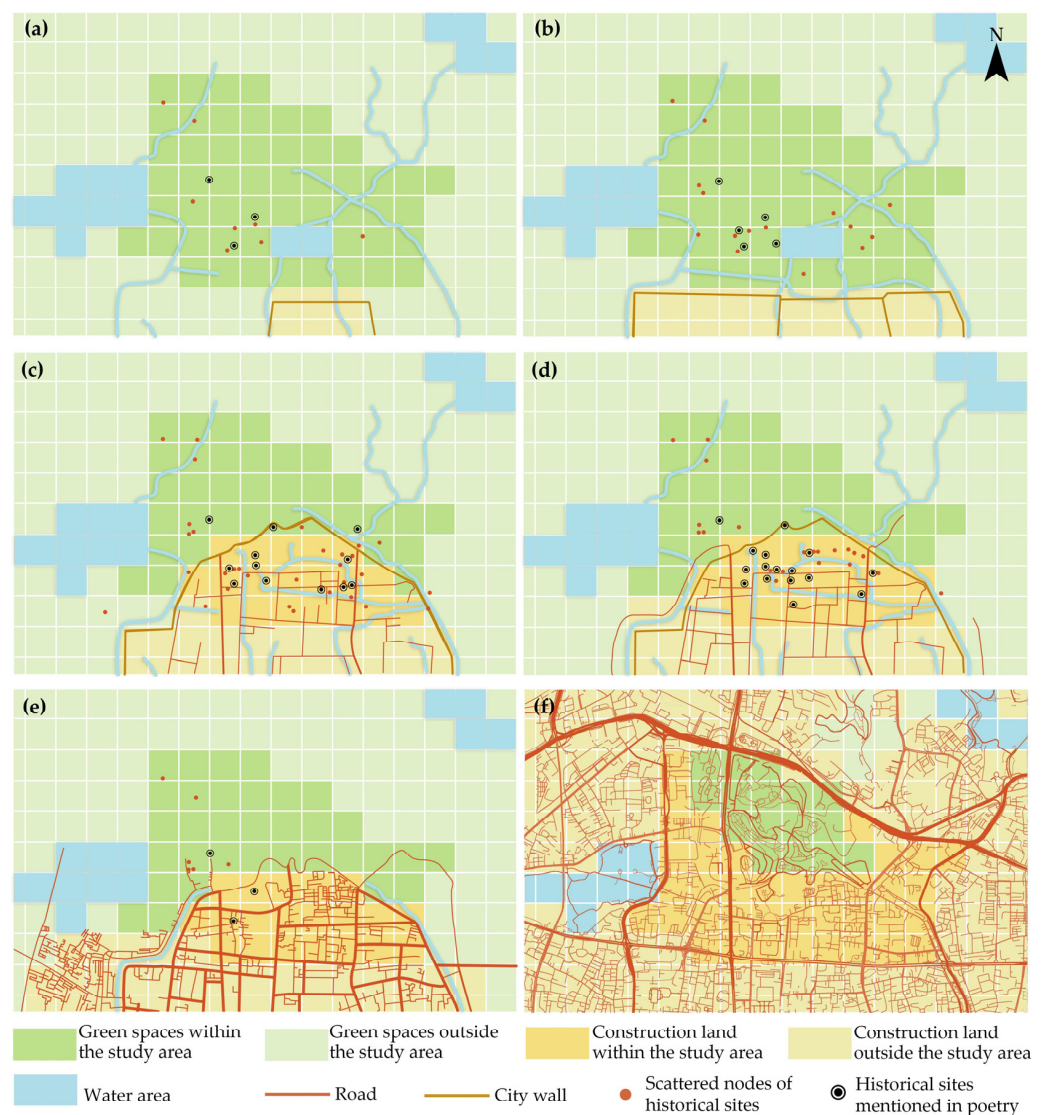


Figure 6. Historical mapping evidence for Yuexiu Hill dated (a) The Sui and Tang Dynasties: 581 A.D.–959 A.D, (b) The Song and Yuan Dynasties: 960 A.D.–1367 A.D, (c) The Ming Dynasties: 1368 A.D.–1615 A.D, (d) The Qing Dynasties: 1616 A.D.–1911 A.D, (e) The Republic of China: 1912 A.D.–1949 A.D, with (f) present situation. (Square grid: 250 m \times 250 m).

3.3. Analysis of Relevance of Information Services to Landscape Elements

Landscapes serve an important function for humans, satisfying basic emotional needs such as relaxation, a sense of identity, or a stimulating experience [39]. The correlation between landscape elements in poetry and various types of information services is further verified by the link weights between nodes in the semantic network.

Table A4 shows the link weights between each landscape element appearing in the semantic network (Figure 3) and six types of information services. A higher link weight means that the element is more closely related to the corresponding information service in the table. The statistics in Table 2 show that each type of information service provided is linked to the nine types of landscape elements. The sum of the link weights differs in the links between information services of the same type and the nine subgroups of elements but shows consistency in the links between information services of the six types and the same subgroups of elements. For example, the value of $PCT_{i\text{-association regions}}$, corresponding to the six information services and the association area, ranged from 22.58% to 25.44%; the value of $PCT_{i\text{-animal species}}$, corresponding the six information services and the animal species, ranged from 7.08% to 9.65%. The other seven elements show similar consistency. In terms of facilitating the provision of information services, the nine categories of elements are, in descending order of importance, “associated regions”, “natural meteorology”, “historic sites”, “plant species”, “celestial objects”, “animal species”, “artificial elements”, “waterscape elements”, and “historic figures”. The corresponding PCT_j in descending order are: $PCT_{\text{associated regions}} = 23.78\%$, $PCT_{\text{natural meteorology}} = 18.66\%$, $PCT_{\text{historic sites}} = 18.17\%$, $PCT_{\text{plant species}} = 9.71\%$, $PCT_{\text{celestial objects}} = 8.97\%$, $PCT_{\text{animal species}} = 7.23\%$, $PCT_{\text{artificial elements}} = 6.70\%$, $PCT_{\text{waterscape elements}} = 3.54\%$, and $PCT_{\text{historic figures}} = 3.24\%$. The sum of the link weight between each type of information services and association areas, such as “city (Guangzhou)” and “Pearl River”, is the highest. This reflects that the provision of information services came from the overall context, including the green space itself and the geographical area connected to the surrounding views or with which the public associated. In terms of landscape elements, unlike typical urban green spaces, the Yuexiu Hill area has also been built with a large number of cultural elements, which together play an important role in the provision of information services, in addition to its rich variety of natural elements. In particular, the symbolic historical and cultural landscape elements make the landscape unique. For example, the sum of the linking weights of the six service-related phrases to “Yuewang Platform” is higher than that of the other landscape elements. The names of long-established historic sites such as “Chaohan Platform”, “Huluan Path”, and “Zhenhai Tower” are also connected to a number of service phrases with a high weight (Table A4).

The results of the semantic network analysis also described the degree of correlation between the six types of cultural services identified in this study. In the semantic network, the higher the value of the link weight between two linked phrases, the more frequently they are mentioned in the same poem. We used the link weights between the phrases related to each type of cultural service and the phrases related to other types of cultural services in the form of a matrix, and we summed the weights in the blocks corresponding to the two types of services (Table 3). The six types of services show different degrees of correlation: the darker the area in Table 3, the stronger the connection between the two types of cultural services, and the more likely they are to be offered to the public together. For example, social relationships are associated with five other cultural services in descending order of strength: recreation and ecotourism, spirituality and religion, cultural memory, artistic inspiration, and education. The correlation shows that cultural services are hard to be measured by simple quantification. Therefore, we needed to clarify what simple quantification overlooks to promote an animated discussion based on objective evidence.

Table 3. Comparison of link weights between each type of information service.

		SR			RE				AI		S and R				E		CM		
		Drink	Have a conversation	Banquet	Song and dance	Go sightseeing	Song and dance	Play music	Hill-climbing	Compose poems	Fairies	Wonderland	Monks	Journey to Fairyland	Meditation	Sages	Gifted scholar	Past events	Nostalgia
SR	Drink	-																	
	Have a conversation	12	-																
	Banquet	2	-	-															
RE	Song and dance	44	8	12	-														
	Go sightseeing	30	6	4	22	-													
	Song and dance	20	-	6	16	8	-												
	Play music	44	-	8	16	16	10	-											
AI	Hill-climbing	32	10	12	38	14	24	32	-										
	Compose poems	32	4	2	20	12	12	8	20	-									
S and R	Fairies	22	14	14	12	18	20	10	28	22	-								
	Wonderland	20	8	8	12	12	16	20	22	22	30	-							
	Monks	6	-	-	10	16	4	2	10	16	4	6	-						
	Journey to Fairyland	8	-	2	10	8	6	8	10	8	10	12	-	-					
	Meditation	2	-	2	4	2	-	2	6	2	6	6	6	4	-				
E	Sages	4	4	4	4	8	-	6	6	8	32	18	4	6	-	-			
	Gifted scholar	4	6	-	8	6	4	-	4	4	2	-	-	-	-	6	-		
CM	Past events	28	4	6	18	14	24	18	8	18	16	24	16	10	6	8	16	-	
	Nostalgia	38	-	4	12	12	10	36	32	12	10	16	-	4	-	10	4	30	-

Note: The darker the color of the block, the larger the sum of the individual link weights in the block, i.e., the stronger the correlation between the corresponding cultural subtypes.

4. Discussion

4.1. Information Services Identification as an Operational Tool

The limitations of early monetary methods have caused progress in CES research to lag behind that on other types of ecosystem services [33]. For this reason, many researchers have suggested promoting increased integration between ES assessment and social science to better understand how which society interacts with ecosystems [40,41]. Some of these researchers have used informatization methods, taking a large collection of textual and pictorial information as a basis for identifying cultural services. Some of these researchers describing and revealing the quantitative characteristics and patterns of change of various services in terms of the frequency of service-related words or images [42,43], i.e., statistical analysis of information to describe and reveal the quantitative characteristics and patterns of change of information. Due to the return to the essence of information interaction between the landscape and the public, information service identification is an effective approach to assess the nonmaterial benefits derived by the public from UGSs throughout history.

This study demonstrates the feasibility of using the information services identification method, selecting the Yuexiu Hill area of Guangzhou as an example. We used 1063 poems composed between 581 and 1949 A.D. as a basis for the identification of information services, and we found that textual information such as poetry contains both descriptions of landscape characteristics and records of cultural activities and even human emotions. From the perspective of information communication, the information recorded in poetry provides data support for the study of the communication process of information from landscape entities to the public. Even from an object perspective, only those characteristics that are considered relevant to the subjective perspective were selected and described when evaluating landscape characteristics, i.e., it reflects the needs and preferences of the

people [39]. Therefore, the inaccuracies introduced by the subjective perception of the poetical creator are considered acceptable when reconstructing the characteristics of the historical landscape in this study. In this study, the data obtained from word frequency statistics visually show the intensity of information services were available to the public and the landscape elements that may have contributed to the provision of information services. The semantic network of poems shows the association of various landscape elements with information services. It reveals which types of landscape elements transmit information that plays an important role in promoting subjective well-being. Poetic textual information can be used as an effective basis for information services identification. In addition to the poems, ancient book database and historical map databases [44] can also provide a reliable basis for the identification of historical information services.

4.2. Advantages of Urban Green Spaces throughout History in Information Service Provision

UGSs throughout history have a significant advantage in providing information services compared to general green spaces. This comes from the rich and diverse symbolic landscape elements accumulated in the UGS throughout history. The landscape elements that are information sources carry deeply rooted value systems [40]. Related research suggests that signs, symbols, and written text placed in the public space make up the “discrete construction of space” [45], i.e., the construction of space through semiotic resources [46]. As a source of information, landscape elements carry a deeply rooted value system. Although there are a variety of landscape elements in poetry (Table A3), not all element names appear in the semantic network (Figure 3). In semantic network, landscape elements that are connected with information service phrases and have higher weight are usually more cultural symbolic.

Comparing the word-frequency statistics table with the landscape elements in the semantic network shows that not all the element names in the poems appear in the semantic network. More symbolic elements, including natural ecological elements and historical and cultural elements, are linked to service-related phrases with high link weights. The association of information services with these symbolic elements may stem from a general public recognition of the historical and cultural information they carry.

Natural ecological elements are the main source of information, for most urban green spaces. These elements providing multifaceted environmental information, including aesthetic information, spiritual and religious information, and historical information. The information value of natural areas was, and still is, the main reason for the creation of protected areas [25]. Through social and political development over time, plant and animal species have been integrated into human culture in many ways [47] and have a high symbolic value for a particular place [48,49]. For example, the plant most closely associated with recreation and ecotourism, the kapok, is the symbolic tree of Yuexiu Hill and Guangzhou. In ancient times, kapok was widely cultivated on Yuexiu Hill. It became a custom for the people of Guangzhou to enjoy its beauty in spring, and flourished most during the Qing Dynasty. Local painters also produced a large number of paintings depicting kapok in bloom (Figure 7). In the semantic network, links exist between animal elements and phrases corresponding to several information services: “partridge” and “wild goose” usually represent homesickness in Chinese literature. “Crane” is a symbol of the ancient imagination of the fairy world. In terms of botanical elements, “bamboo” and “pine tree” symbolize the pursuit of a noble character; local species such as “kapok” and “lychee” reflect the local identity of the Guangzhou public. In addition, meteorological elements such as “suglow” and “autumn breeze”, and the names of the celestial elements such as “moon”, “sun”, and “star” are linked to the six categories of information-service-related phrases. As with the flora and fauna elements, the message carried by these landscape elements has been agreed upon by a wide range of social groups, so that the viewer generally has a similar psychological experience when seeing them. Therefore, when managing landscapes and ecosystems, care should be taken to preserve suitable habitats for symbolic species [50] to maintain relevant information services such as cultural memory and artis-

tic inspiration. In addition, there are a large number of animal and plant elements that do not appear in the semantic network, meaning that they do not contribute significantly in conveying cultural information. These non-symbolic species remain an indispensable part of the landscape, whereas the diversity of habitats with species-diverse seminatural environments satisfies the subjective interests of different populations [51,52].



Figure 7. The kapok tree in the work of a local painter: (a) Li Jian, *The Green Mountains and Red Kapoks*, the Qing Dynasty, collection of the Guangzhou Art Museum. (b) Xie Lansheng, *The Green Mountains and Red Kapoks*, the Qing Dynasty, collection of the Guangzhou Art Museum. (c) Chen Shuren, *Spring in Lingnan*, 1929, collection of the National Art Museum of China.

For UGSs throughout history, historical and cultural elements have also been important information sources for information services, in addition to the aforementioned natural elements. Cultural landscapes have increased potential to provide cultural services than pristine natural ecosystems [33]. The semantic network diagram of Yuexiu Hill poetry (Figure 3) shows that the historic sites have played the role of cultural activity centers. For example, “Yuewang Platform”, “Zhenhai Tower”, “Chao Hantai” and “Hu Ruo”. These historic sites have a high sum of link weights with different cultural service phrases (Table A4). Among them, the Zhenhai Tower has been restored several times, and its site is preserved to this day. While in ancient paintings created during different historical periods, it is always depicted in a prominent position on the Yuexiu Hill as a symbol (Figure 8). In addition, the links between the names of historical figures such as “Wei Tuo (King of Yue)”, “Ren Xia”, and “Lu Jia” are all highly weighted (Table 2). The achievements of these historical figures and their past cultural activities in Yuexiu Hill are a common cultural memory for future generations and are part of the attraction of the area. Our findings reflect the importance of historic sites in urban green spaces, which is consistent with the findings in the literatures [53]. Agimass et al. [54] studied the impact of forest characteristics on recreation and also found that forests with characteristics such as proximity to residential areas and the presence of historic sites were more suitable for recreational use.

The uniqueness of UGS in providing information services lies in their rich cultural and heritage value. These historic sites are not only evidence of the information services that people have long-received from urban green spaces, but they have also become symbolic due to the accumulation of cultural constructions and activities throughout history. Carrying rich historical and cultural information, these symbols play an important role in promoting public access to information services the UGSs.

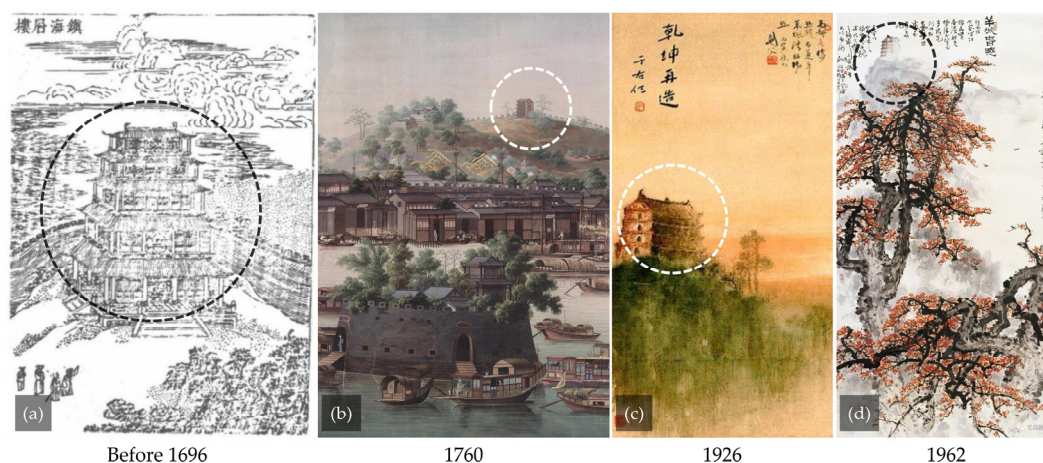


Figure 8. Zhenhai Tower in ancient paintings of different periods of history: (a) The magnificent Zhenhai Tower, Qing Dynasty. (b) Canton harbor and the city of Canton (part of the painting), collected by the British Library. (c) The Zhenhai Tower, Gao Jianfu, collected by the Hong Kong Museum of Art. (d) Spring Dawn in Guangzhou, collected by the Guangzhou Museum of Art.

4.3. Artificial Intervention of Urban Green Spaces Information Services Based on the Theory of Information Communication

Artificial intervention from viewpoint of information communication can contribute to sustainability of information services' provision in urban green spaces throughout history. Charters of the International Council on Archaeological Sites (ICOMOS) stating: "Various heritage protection behaviors are essentially communication behaviors" [55]. The information communication model revealed that the realization of information services is the communication of environmental information from the landscape to the public. The realization of this process depends on the stock of information capital (information source), the needs of the public (destination), and the readability of the information carrier or medium (channel). The transmission of information from the landscape to well-being can be achieved when the information stored in the landscape is required by the public and effectively received. This process can be optimized through human interventions such as the restoration of historical landscape characteristics and the interpretation and presentation of environmental information.

As shown in Table 1, the public demand for different types of information services in the Yuexiu Hill area has widely varied. This deviation in share is influenced by whether the information conveyed by the landscape elements can be accepted and understood by the contemporary public. More attention has been paid to the recreational and ecotourism value of urban green spaces, whereas inspirational enlightenment and educational services that require a clearer understanding of environmental information have received less attention. In addition, the deviation in share is also influenced by factors such as sociodemographic, social, and environmental values as well as the perception of the site and its characteristics by visitors [56]. Different approaches to engaging with nature should be considered in the design of urban environments and urban nature, as well as in integration programs [57].

Abundant natural and cultural information resources have been identified in the historical Yuexiu Hill area, yet the absence of historical information have hindered the transmission of historical environmental information to the public. On the one hand, urban sprawl has changed the land cover and material abundance at the foot of the mountain, which means the change of environmental information. On the other hand, time and changes in the social environment have made it difficult for the public to directly access and understand information related to historical figures and their stories from the place. In this context, interpretation and presentation facilities and activities are needed to convey information about the historical environment to the public across time and space. This will enable the public to better engage in the conservation of natural resources and cul-

tural heritage, understand the symbolic nature of natural and historical cultural elements, and the mechanisms of change. Then gain benefits such as spiritual enrichment, cognitive development and aesthetic experiences.

4.4. New Approach to Support Urban Green Space Strategic Planning for Heritage Preservation, Human Well-Being and Sustainable Development

UGSs throughout history have been witnesses of the continuous subjective well-being of urban dwellers in past dynasties based on nature, and have accumulated rich cultural information. Attitudes to managing nature in the urban environment are changing from the traditional approach of restrictive nature conservation to a balanced approach between use and conservation [58]. Therefore, in the strategic planning of urban green spaces for heritage protection, human welfare and sustainable development, it is necessary to take into account the protection of landscape element entities and related historical information, as well as the needs of the contemporary public. Information service identification based on general communication system theory is an effective way to solve the above problems.

First, the integrated identification of information services in a given area from the point of view of information communication correlates landscape elements with public perception and can provide a quantitative basis for balancing multiple service types and identifying the landscape elements associated with them. The results can guide the classification of needs and priorities for the restoration of landscape elements in historical urban green spaces. This allows for the development of targeted enhancements and the coordination of human and financial investments in strategic green space planning. Second, the method of identifying the information services integrates the joint action of natural and human forces on historic urban green spaces and is an exploration and interpretation of the dual information on natural ecology and cultural heritage. It provides a more systematic knowledge base for the revitalization and regeneration of historic urban areas, based on education about the natural and historic environment, and increases public participation in the decision-making process in the face of environmental conflicts. Third, by presenting the differences in the distribution of hotspots for various types of services, the results of evaluating information services can provide an indication to weigh the construction of green infrastructure satisfying different services. The potential to provide different information services with respect to the landscape characteristics of urban green spaces was explored to better exploit the strengths of the site and compensate for weaknesses in the whole through links with other green spaces. In the case of Yuexiu Hill, for example, which is well-stocked with historical information, the area is more than capable of providing contributions in the areas of spirituality and religion, cultural memory, and education about the historical environment. Recreational and eco-tourism related services, which are subject to conservation management policies, can be provided by other surrounding green spaces.

4.5. Limitations

The use of textual information only as our material poses two limitations for this study: First, we only identified a portion of the types of information services from textual information, for example, esthetic experiences, which are mainly visual information [59], are not represented in this study. The types of information carriers in the database need to be further enriched to more comprehensively identify information services that promote the subjective well-being of the public. Second, the historical Yuexiu Hill landscape reconstructed by semantic network analysis is actually a literary space. The next attempt in this line of research is to further match the spatial information in the historical literature with the real geographical space by combining the research methods used for describing historical landscape characteristics [60,61]. This will lead to more accurate research results in reproducing UGSs throughout history and guide contemporary planning, design, and management.

Using ancient poetry as study material, we analyzed the information services received by the public from the Yuexiu Hill area throughout history. Due to the lack of contemporary public demand identification, identifying contemporary missing historical information service hotspots from comparison with available data was difficult. Therefore, identifying contemporary information services in the Yuexiu Hill area is also the next action plan. By comparing historical and contemporary data, we will determine which historical information services have been perpetuated in contemporary times and what contemporary public needs present new challenges to the preservation and management of the Yuexiu Hill area. The methods of public participation in mapping [7,62,63] and the use of photographs or crowdsourcing of comments [14,17,64] provide a way forward for a contemporary-oriented identification of information services in Yuexiu Hill.

5. Conclusions

Cultural services do not represent a purely ecological phenomenon: they are the result of the complex and dynamic relationships between ecosystems and people [65]. In this study, we returned to an earlier concept of cultural services, “information services”, by using the “general communication system” to understand this complex relationship. Using the Yuexiu Hill area of Guangzhou as an example, we used 1063 poems as a basis to identify the information services provided by this urban green space throughout its history. As an information carrier, poetry provides a record of both landscape characteristics and the creator’s perception of the information service, providing both source and destination analysis data. In turn, text mining methods, such as word frequency statistics and semantic network analysis, provide a method to efficiently process this textual information, which can be replicated in related efforts. Our study verified that information service identification is an effective method to mining the nonmaterial benefits derived from UGSs throughout history by the public. Identifying the information services that UGSs throughout history used to provide to urban residents provides a historical basis for aspects such as cultural heritage preservation and green space management.

The results of the information service identification illustrate the nonmaterial value of historic urban green spaces from the perspective of information communication. The results showed that Yuexiu Hill, in its two thousand years of evolution from a primitive vegetation-covered hill to the urban park it is today, provided ancient city dwellers with a place for ecotourism and social interaction, as well as information services such as cultural memory, spiritual enrichment, artistic inspiration, and environmental education. The results of semantic network analysis revealed a link between information services and the conservation of natural ecological and cultural elements. Among these, symbolic elements have prominently contributed to information services. The accumulation of cultural construction and activities has given Yuexiu Hill and its landscape elements a unique symbolism that carries rich historical and cultural information. This is why this urban green space has remained an attractive and vibrant place throughout its history, playing an important role in promoting subjective well-being.

Efforts will continue to be devoted to the exploration of practical methods to artificially optimize the process of environmental information dissemination. Through planning and design, environmental information has been integrated into the public experience of UGSs throughout history, both on site and online. As such, the conservation of heritage resources should be promoted and the contemporary public demand for information services should be met.

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Appendix A

Table A1. Description of the corresponding changes in landscape of Yuexiu Hill for different historical periods.

Name of Dynasty	Number of Poems	Archaeological Maps	Description
Time Frame of the Study (581–1949 A.D)	1077		<p>The Qin dynasties (beginning in 214 BC) were the beginning of the construction of the ancient city of Guangzhou and the beginning of the construction of Yuexiu Hill by the ancient Guangzhou people. This history laid the foundation for the culture of the Yuexiu Hill: First, the earliest Yuexiu Hill was a place of worship for Nanyue monarchs and ministers; second, Yuexiu Hill was an important water source for the city during the Qin and Han dynasties. Third, Yuexiu Hill was an area for the royal tombs in the Nanyue Kingdom. Since then, Yuexiu Hill has taken on various urban functions and has gradually become an irreplaceable urban heritage composed of multiple values.</p>
Sui and Tang Dynasties–Nanhan Dynasties (581–959 A.D)	30		<p>During this period, the spatial extent of Guangzhou City did not remarkably expand, but the functions provided by Yuexiu Hill as a spatial carrier were transformed from their original basis. First, the water system that flows through Yuexiu Hill, in addition to its original function as a water source, was expanded to include navigation and recreational functions. In addition, the construction of religious sites on Yuexiu Hill gradually began during this period. Taoist temples and monasteries such as Yuegang Palaces and Yaoshi Temple were built. During the Nanhan Dynasty, the Yuexiu Hill area was further developed as a royal garden.</p>

Archaeological site map: location of Yuexiu Hill and ancient city of Nanyue.

Archaeological site map: location of Yuexiu Hill and ancient city of Tang.

Table A1. Cont.

Name of Dynasty	Number of Poems	Archaeological Maps	Description
Song and Yuan Dynasties (960–1367 A.D.)	102		<p>The city was extensively expanded to the east and west during this period, but the northern side remained at some distance from Yuexiu Hill. No major construction took place on Yuexiu Hill during this period, and only small and medium religious places of worship were built. Located at the southeastern foot of Yuexiu Hill, Lake Ju was a popular scenic spot during the Song Dynasty, and by the Yuan Dynasty, the lake had been filled in to serve as a field.</p>
Ming Dynasty (1368–1615 A.D.)	480		<p>The expansion of Guangzhou to the north during this period incorporated part of Yuexiu Hill into the city and was an important point in the development and construction of Yuexiu Hill. The number and variety of construction activities around Yuexiu Hill rapidly increased during this period. In addition to the existing wells and springs and religious sites, people began to build private gardens, academies, and military facilities at the foot of Yuexiu Hill. During this period, however, the construction of the city also blocked the Wen River, which used to flow through the city.</p>
Qing Dynasty (1616–1911 A.D.)	433		<p>During this period, Yuexiu Hill was the most famous scenic spot in Guangzhou and was known as the main hill of the city. The combination of Yuexiu Hill and Zhenhai Tower became an iconic node in the city's perception of the ancient city of Guangzhou. A number of study halls, religious buildings, and private gardens were built on the site. At the southern foot of the hill, a series of streets and lanes were built.</p>

Archaeological site map: location of Yuexiu Hill and ancient city of Song.

Map of Guangzhou Prefecture, Jiaping period of the Ming Dynasty

Map of Guangzhou Prefecture, Tongzhi period of the Qing Dynasty

Table A1. Cont.


Name of Dynasty	Number of Poems	Archaeological Maps	Description
Republic of China (1912–1949 A.D)	32	 <p>Road Map of Guangzhou in the Republic of China, 1927</p>	<p>During this period, the walls built on Yuexiu Hill were demolished and incorporated into the city; in 1925, part of Yuexiu Hill was turned into a park, and the streets at its southern foot became denser.</p>

Table A2. Standard phrases table of information-services-related phrases.

Classification of Information Services	Standard Phrase	Original Phrase
Social relations	Farewell	送别 别恨 别离 啼别
	Have a conversation	交谈 言笑 谈笑 坐谈 谈天 谈情 高谈 雄谈 谈禅 谈经 闲谈 聊偃
	Banquet	宴席 满筵 广宴 席间 溪上 座上 宾雅 集贤 人聚 叙群 贤罗 群贤 宴坐 列宴 宴列 宴集 宴会 夜宴 携宾
	Drink	饮酒 壶觞 酒器 螺杯 酌酒 酒酌 酒气 百杯 樽俎 尊罍 樽罍 杯盘 对饮 酒樽 与君醉 三百杯 衔杯 会饮 醉酒 同醉 白酒 载酒 斗酒 杜陵酒 衔杯 酒酣 小酌 清尊 酒盏 酒社 频传 罍 酣饮 对酒
Recreation and ecotourism	Having tea	品茶 茶烹 试茗 茶熟
	Hill-climbing	登高 临高 登临 登赏 登坛 登台 登楼 登城 北眺 晚眺 游眺 下瞰 登堊 凭高 吟眺 游赏 行客 旧游 吟赏 踏青 游居 嬉游 交游 卧游 同游 再游 周游 夜游 游北固
	Go sightseeing	胜游 重游 冶游 追游 邀游 漫游 来游 曾游
	Go fishing	垂钓 钓鳌 钓鱼 钓矶 钓丝 沉钓 钓著 钓竿 钓罢
	Play music	奏乐 笙歌 击节 乐声 听笙 鼓声 凤凰箫 音乐 奏乐 携琴 箜篌 丝竹 箫鼓 孤笛 听箫 笙箫 鹤笙 鼓瑟 鸣琴 教人唱 歌钟
Artistic inspiration	Song and dance	歌舞 妙舞 醉舞 狂歌 朝歌 舞锦绣 歌还舞 舞蛟 娟舞 采衣舞 清歌妙舞 朝歌暮舞
	Poet	诗人 诗仙
	Compose poems	赋诗 琼瑰 诗文笔 砚作诗 著稿 写新诗 诗盟 篇诗 词藻 寄吟 读君诗 旧诗社 觞咏 咏溪山 新诗 佳诗 为此诗 赋诗 越台词 社读 君诗 一觞一咏
Spiritual and religious	Paint a picture	作画 看画 画苑 画图 听禅图 罨画 画阁
	Calligraphy	书文 著书 敷文 琴书 读书 著稿 笔谈
	Meditation	参禅 禅关 了悟 三昧 禅味 成佛 禅灯 禅定 佛骨 佛钵 佛灯 佛光 法性 禅心 禅关 僧侣 僧少 山僧 胡僧 残僧 一个僧 高僧 野僧 为僧 比丘尼 为尼 老尼 禅师 开士 净侣
	Monks	寻仙 仙去 仙游 仙炼 仙仗 迎仙 求仙 仙迹 仙踪 仙境 仙乡 仙窟 仙室 仙都 仙已去 仙石 仙树 仙杏 蓬岛 仙岛 仙圃 仙侣 仙宅 仙家 仙城 上方 仙界 玉京 瀛洲 蓬莱
	Journey to fairyland	仙灵 仙翁 仙人 仙子 仙姑 羊石 仙踪 五仙 苏仙 歌仙 鹤仙 谪仙 神仙 仙客 五穗 仙人 三元大帝 仙羊 北斗 衔穗 仙人 五色 仙禽 郑仙
	Wonderland	圣贤 拜坡仙 鲍姑 苏子 先贤 祭拜 哭祭 祠祀 祠前
Fairies	Fairies	
	Sages	
Worship	Worship	

Table A2. Cont.

Classification of Information Services	Standard Phrase	Original Phrase
Education	Classical academy Academic studies Gifted scholar	书院 学堂 讲堂 致学 还以古籍授 绎史诵经 著书 新学 读书 学学术 论学 劝学 督学 讲学 学业 人才 群贤 大儒 群英 科名 才子
Aesthetic	-	-
Cultural memory	Nostalgia Past events Festival Pure Brightness Cold Food Day The Double Ninth Festival The Lantern Festival Worship the kitchen god Shangsi Festival Fly kite Dragon Boat Festival	怀古 吊古 凭吊 咏怀 咏史 霸业 往事 旧时 千古 当年 兴亡 前朝 回首 昔年 佳节 清明 寒食 重阳 茱萸 菊酒 花糕 莼酒 元夕 元宵节 祀灶 上巳 祓禊 修禊 纸鸢 端午 端阳 龙舟

Table A3. Phrase frequency table of landscape elements.

ID	Phrase	f	ID	Phrase	f	ID	Phrase	f	ID	Phrase	f
(I) Land Cover											
	Study area	(8)	Field	55	(16)	Range	12	(6)	South Sea	29	
(1)	Forests	190	(9)	Islet	55	(17)	Waterfall	4	(7)	Central Plains	28
(2)	Lake	133	(10)	Hole	38	Associated Regions		(8)	(8)	Five Ridges	25
(3)	Ridge	118	(11)	Gully	31	(1)	City	112	(9)	Imperial capital	22
(4)	Spring	112	(12)	Cliff	22	(2)	Pearl River	85	(10)	Panyu	17
(5)	Peak	88	(13)	Okan	22	(3)	Mountains	44	(11)	Shimen	15
(6)	Creek	69	(14)	Streams	17	(4)	Guangzhou	42	(12)	the Three Hills	13
(7)	Clear spring	56	(15)	Pond	17	(5)	Sea	31	(13)	City of Goats	12
(II) Natural Ecological Elements											
	Plant species	(34)	Huang Mei	2	(1)	Tiger	40	(32)	Crab	3	
(1)	Plum blossom	41	(35)	Orchid	2	(2)	Horse	27	(33)	Fish	3
(2)	Pine Tree	37	(36)	Brasenia schreberi	2	(3)	Domestic animals	24	(34)	Carp	1
(3)	Bamboo	35	(37)	Holly	2	(4)	Ape	10	(35)	Whitebait	9
(4)	Lychee	34	(38)	Bodhi	2	(5)	Rabbit	9	(36)	Insects	8
(5)	Kapok	29	(39)	Red bayberry	2	(6)	Leopard	5	(37)	Butterfly	8
(6)	Willow	26	(40)	Frangipani	2	(7)	Elk	3	(38)	The Cicada	6
(7)	Hibiscus	19	(41)	Sweet-scented osmanthus	2	(8)	Rat	2	(39)	Silkworm	2
(8)	Chinese hibiscus	14	(42)	Livistona chinensis	1	(9)	Wolf	2	(40)	Cricket	1
(9)	Peach blossom	11	(43)	Acacia	1	(10)	Bat	1	(41)	Snail	1
(10)	Banyan tree	10	(44)	Orange Grove	1	(11)	Birds		(42)	Dragonfly	2
(11)	Maple tree	10	(45)	Pawpaw	1	(12)	Wild Goose	57	(43)	Fireflies	1
(12)	Calamus	10	(46)	Yulan	1	(13)	Partridge	48	(44)	Spider	1
(13)	Moss	10	(47)	Apricot	1	(14)	Warbler	27	(45)	Bee	1
(14)	Chrysanthemum	9	(48)	Rattan	1	(15)	Swallow	24	(46)	Grub	1
(15)	Lotus	8	(49)	Chinese tallow tree	1	(16)	Crane	21	Natural Meteorology		
(16)	Ficus pumila	8	(50)	Elm forest	1	(17)	Crow	12	(1)	Clouds	161
(17)	Peaches and plums	7	(51)	Coconut	1	(18)	Gulls	11	(2)	Smoke	98
(18)	Jasmine	6	(52)	Apricot blossom	1	(19)	Egret	7	(3)	Rain	68
(19)	Mulan	5	(53)	Alfalfa	1	(20)	Cuckoo	9	(4)	Sunglow	67
(20)	Betelnut	5	(54)	Reed flower	1	(21)	Parrot	4	(5)	Spring breeze	56
(21)	Poplar	5	(55)	Hemerocallis	1	(22)	Petrel	3	(6)	Autumn wind	47
(22)	Nang	5	(56)	Toon tree	1	(23)	Wild duck	2	(7)	Cold wind	16
(23)	Jasmine	5	(57)	Peony	1	(24)	Magpie	2	(8)	Autumn rain	12
(24)	Rose	4	(58)	Rice	1	(25)	Goshawk	2	(9)	Spring Rain	6
(25)	Pear blossom	4	(59)	Plantain	1	(26)	Oriole	1	(10)	Thunderstorm	6
(26)	Lotus	4	(60)	Lagerstroemia indica	1	(27)	White pheasant	1	(11)	Typhoon	1
(27)	The locust tree	4	(61)	Wisteria	1	(28)	Bird of prey	1	(12)	Frost and dew	1
(28)	Rose	4	(62)	Phoenix flower	1	Amphibians		(1)	Celestial objects		
(29)	Flower of Polygonum	3	(63)	Cherry	1	(29)	Crocodile	3	(2)	Moon	118
(30)	Ficus pumila	3	(64)	Pomegranate	1	(30)	Frog	2	(3)	Sunset	91
(31)	Syzygium jambos	3	Animal species		Arthropods		(4)	Sunshine		4	
(32)	Begonia	3	Mammals		(31)	Shrimp	6	(5)	Solar eclipse		1
(33)	Red Bean	2									

Table A3. *Cont.*

ID	Phrase	f	ID	Phrase	f	ID	Phrase	f	ID	Phrase	f
(III) Cultural Elements											
	Historic sites		(18)	Taiquan Academy	1	(7)	Garden	20	(25)	Battery	1
(1)	Yuewang Platform	433	(19)	North Garden	1	(8)	Vihara	15	(26)	Bookstore	1
(2)	Chaoan Platform	101	(20)	Xuehaitang Academy	12	(9)	Academies	13	(27)	Monk's house	1
(3)	Yuewang Well	54	(21)	Zhaozhong Ancestral Hall	8	(10)	Relic	12	Historic figures		
(4)	Yuewang Tomb	1	(22)	Yingyuan Academy	5	(11)	Palace	11	(1)	King of Yue (Wei Tuo)	101
(5)	Huluan Path	26	(23)	Yixiu Garden	2	(12)	Ancient Tomb	9	(2)	Bao Gu	38
(6)	Wanggu Nunnery	17	(24)	Hongmian Temple	2	(13)	Pavilion	7	(3)	Lu Jia	24
(7)	Sanyuan Taoist Palaces	14	(25)	Ji Garden	5	(14)	Cottage	6	(4)	the Five Goats	23
(8)	Guanyin Pavilion	7	(26)	Jupo Academy	1	(15)	Battlement	5	(5)	Ren Xiao	13
(9)	Jiao Platform	4	(27)	Other Gardens	16	(16)	Stone building	5	(6)	Jingwei	5
(10)	Xizhu Temple	1	(28)	Other Academies	11	(17)	Red chamber	4	(7)	Xuan yuan	5
(11)	Zhenhai Tower	131	Artificial elements			(18)	Ancient temple	4	(8)	Emperor Wu	3
(12)	Sanjun Ancestral Hall	8	(1)	High-rise	92	(19)	Road	3	(9)	Ruan Ji	3
(13)	Weituo Tower	6	(2)	Hut	28	(20)	Red Wall	3	(10)	Han Yu	3
(14)	Xieyan Spring	2	(3)	High Platform	28	(21)	Ancient well	3	(11)	Emperor Qin	2
(15)	Banshan Pavilion	2	(4)	Hill house	24	(22)	Circular Mound	2	(12)	Jia Yi	1
(16)	Bushi Nunnery	2	(5)	Ancient road	21	(23)	Path	2	(13)	Diao Chan	1
(17)	Wanli Bridge	1	(6)	Railings	20	(24)	Meditation room	1	(14)	Emperor Yang	1

Table A4. Weight of links between service phrases and landscape element phrases.

	Historic Sites	Artificial Elements	Historic Figures	Natural Meteorology	Celestial Objects	Animal Species	Plant Species	Waterscape Elements	Associated Regions									
IS	Elements w	Elements w	Elements w	Elements w	Elements w	Elements w	Elements w	Elements w	Elements w									
Social relations	Yuewang Platform	178	High-rise	38	King of Yue	34	Clouds	86	Moon	76	Sieed	26	Plum blossom	54	Clear spring	18	City	66
	Chaoan Platform	56	Hut	32	the Five Goats	14	Smoke	80	Sunset	42	Partridge	24	Lychee	28	Clear spring	16	Sea	56
	Zhenhai Tower	48	Hill house	20	Lu Jia	14	Sunglow	44	Stars	24	Warbler	24	Willow	18	Stream	16	Pearl River	56
	Weituo Tower	28	Railings	12	Ren Xiao	10	Rain	48	Sunset	18	Dragon	20	Bamboo	18	Running water	12	Luofu Hill	30
	Yuewang Well	16	Ancient road	8	Wei Tuo	6	Spring breeze	44			Wild Goose	20	Pine Tree	16	Mountain Stream	6	Five Ridges	26

Table A4. Cont.

	Historic Sites	Artificial Elements	Historic Figures	Natural Meteorology	Celestial Objects	Animal Species	Plant Species	Waterscape Elements	Associated Regions
IS	Elements w	Elements w	Elements w	Elements w	Elements w	Elements w	Elements w	Elements w	Elements w
	Huluan Path	Deserted platform		Autumn wind		Swallow	Kapok	Running water	Imperial capital
	Taiquan Academy			Gentle breeze		Domestic animals	Chinese hibiscus		the Three Hills
	Xuehaiyang Academy			Cold wind		Crane	Hibiscus		Guangzhou
	Linhua Bridge			The wind blows		Insect			South Sea
									Central Plains
									Baiyue
									Panyu
									Shimen
W_{SR-j}	360	112	78	366	160	158	176	70	472
	Yuewang Platform	High-rise	Wei Tuo	Clouds	Moon	Partridge	Kapok	Stream	City
	Zhenhai Tower	Hut	the Five Goats	Smoke	Sunset	Horse	Lychee	Zhulan Lake	Sea
	Chaohan Platform	High-rise	Lu Jia	Sunglow	Stars	Warbler	Plum blossom	Clear spring	Pearl River
Recreation and ecotourism	346	42	32	206	152	60	74	48	170
		42	34	160	98	56	62	42	146
		74	18	108	64	44	52	32	112

Table A4. Cont.

	Historic Sites	Artificial Elements	Historic Figures	Natural Meteorology	Celestial Objects	Animal Species	Plant Species	Waterscape Elements	Associated Regions
IS	Elements w	Elements w	Elements w	Elements w	Elements w	Elements w	Elements w	Elements w	Elements w
	Huluan Path	Railings	Ren Xiao	Rain	Sunset	Wild Goose	Hibiscus	Mountain Stream	Luofu Hill
	Xuehaitang Academy	Ancient road	King of Yue	Spring breeze		Swallow	Pine Tree	Running water	Five Ridges
	Litua Bridge	Hill house		Autumn wind		Dragon	Willow		Baiyue
	Yuewang Well	Deserted platform		Gentle breeze		Domestic animals	Chinese hibiscus		Central Plains
	Weituo Tower	High Platform		Cold wind		Crane	Bamboo		Guangzhou
	Qingquan Academy	At the door		The wind blows			Pine Tree		Imperial capital
									Shimen
									Panyu
									the Three Hills
									South Sea
W_{RE-j}	800	338	114	772	350	300	426	138	998

Table A4. Cont.

	Historic Sites		Artificial Elements		Historic Figures		Natural Meteorology		Celestial Objects		Animal Species		Plant Species		Waterscape Elements		Associated Regions		
IS	Elements w		Elements w		Elements w		Elements w		Elements w		Elements w		Elements w		Elements w		Elements w		
Artistic inspiration	Yuewang Platform	54	High-rise	12	King of Yue	8	Clouds	28	Moon	32	Wild Goose	6	Lychee	12	Clear spring	6	City	20	
	Zhenhai Tower	10	Hut	6	Wei Tuo	2	Smoke	22	Stars	14	Partridge	10	Chinese hibiscus	12	Zhilian Lake	4	Pearl River	18	
	Chaohan Platform	22	Hill house	6	the Five Goats	8	Sunglow	14	Sunset	10	Dragon	6	Hibiscus	10	Stream	10	Sea	12	
	Yuewang Well	10	Ancient road	4	Liu Jia	6	Spring breeze	14	Sunset	4	Warbler	2	Pine Tree	8	Mountain Stream	4	Shimen	12	
	Huluan Path	6	Deserted platform	2	Ren Xiao	4	Autumn wind	12			Horse	8	Willow	4			Five Ridges	10	
	Xuehaitang Academy	2					Rain	16			Crane	8	Plum blossom	2			Luofu Hill	10	
	Weituo Tower	2					Gentle breeze	4			Domestic animals	4					Pearl River	10	
							The wind blows	4			Swallow	4						Baiyue	10
																		Imperial capital	6
																		South Sea	4
W_{AL-j}	106		42		28		114		60		48		58		24		140		

Table A4. Cont.

	Historic Sites	Artificial Elements	Historic Figures	Natural Meteorology	Celestial Objects	Animal Species	Plant Species	Waterscape Elements	Associated Regions	
IS	Elements w	Elements w	Elements w	Elements w	Elements w	Elements w	Elements w	Elements w	Elements w	
	Wanggu Nunnery	2	Ancient road	4	Cold wind	4	Pine Tree	6	Five Ridges	24
	Xuehaiang Academy	2			The wind blows	4	Willow	4	Guangzhou	20
	Weihuo Tower	2							Imperial capital	14
						Domestic animals			Baiyue	4
						Wild Goose			Panyu	4
									South Sea	4
W_{CM-j}	340	110	60	344	172	138	160	44		438
W_j	2062	760	368	2118	1018	820	1102	402		2698

W_{ij} (weight): sum of the weights of the links between element phrase j and service phrase i . W_j : sum of the weights of the links between element phrase j and all service phrases. (i = SR, RE, AI, S and R, E, and CM; j = historic sites, artificial elements, historic figures, natural meteorology, celestial objects, animal species, plant species, waterscape elements, and associated regions).

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