RESEARCH

Spatial distribution of toponyms and formation mechanism in traditional villages in Western Hunan, China

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Abstract

Traditional village toponyms contain rich vernacular geographical information, profound cultural connotations, and social group memories. Studying the meanings and spatial distribution characteristics of traditional village toponyms and their formation mechanism is significant for the sustainable development and protection of the intangible culture of traditional villages. However, previous studies mainly focused on qualitative description combined with geospatial analysis techniques to explore their spatial distribution and influencing factors, but there has yet to be an in-depth study on why such a pattern is formed. Thus, this study employs statistics, a GIS kernel density estimation method, a geodetector, and historical data to examine the spatial distribution, influence factors, and formation mechanisms of various toponyms in traditional villages in western Hunan, China. The results show that (1) the toponyms in traditional villages in western Hunan can be categorized into natural and cultural landscape toponyms. Natural landscape toponyms predominate in the northwest, whereas cultural landscape toponyms are more concentrated in the southeast, with Huayuan, Longshan, and Dong Autonomous Counties as the primary focal points; (2)Natural toponyms are shaped by terrain, river proximity, and vegetation, whereas cultural toponyms cluster due to natural features and historic trail influence, mirroring the historical migration and settlement patterns in the development of western Hunan; (3)Multiple influencing factors, regulatory powers, and curing processes reveal the formation mechanism of the spatial patterns of toponyms. This study offers a novel lens for recognizing and understanding the characteristics of human settlement environments and culture in traditional villages. Moreover, the results of this study can provide scientific guidance for the cultural protection of traditional villages on a cross-regional scale.

Keywords Traditional village, Toponym, Spatial distribution, Formation mechanism

Introduction
Background
Traditional Chinese villages were formed before 1912 A.D. and are well preserved, with high historical, cultural, scientific, artistic, social, and economic value [1]. A toponym is a name given to a particular place [2]. Toponyms as intangible cultural heritage contain a wealth of regional, geographical, civilizational, historical, and cultural information [3]. Traditional village toponyms record the development of human society and contain rich local geographic and folklore information, which is the cohesion of deep historical and cultural landscape connotations with social group memories [4]. The excavation and protection of cultural heritage sites with toponyms have received international attention [5]. Several countries, such as America, Sweden, United Kingdom, Spain, Italy, and China, established organizations for the study of toponyms to protect and study their cultural heritage [6–9].

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Liu *et al. Heritage Science*   (2024) 12:171

Page 2 of 28

Although toponyms carry essential cultural values, many villages and towns in China have merged due to rapid urbanization, and some original toponyms have gradually been renewed and replaced by modern naming methods. In 2015, Hunan Province implemented a township zoning adjustment and reform plan, merging more than 500 townships and 16,000 villages. As of 2020, 3000–4000 traditional toponyms had disappeared from Hunan Province [10]. In addition, modern values have influenced some traditional village toponyms, and some toponyms with deep historical and cultural significance have been arbitrarily changed and gradually disappeared [11], causing significant damage to the intangible cultural heritage of traditional villages.

The protection and development of traditional villages involve not only repairing old buildings but also focusing on the excavation and inheritance of traditional culture [12, 13]. The historical and cultural connotations and processes transmitted by traditional village toponyms must be investigated. Current research on toponyms involves the origin of toponyms [14], semantic meanings [15], word structures [16], and classification of toponyms [17], as well as how toponyms contribute to our understanding of historical change, geographic evolution, and the development of local cultural landscapes. In order to deeply analyze the characteristics of the spatial distribution of different types of toponyms and identify the strength of influencing factors on a regional scale, some scholars have applied geospatial analysis techniques such as kernel density analysis, standard deviation ellipse, imbalance indices, and geographic concentration indices [18–20] to explore the spatial distribution and influencing factors of different types of toponyms. These methods have shed light on the influence of geographic environment characteristics on toponym distribution but fail to explain the diachronic influence of cultural processes on toponym distribution. Therefore, there still needs to be a more comprehensive exploration at the regional scale, integrating both natural and humanistic factors, to systematically investigate the spatial distribution characteristics of toponyms and their formation reasons across various temporal and spatial contexts.

The formation of toponyms and their spatial patterns is subject to historical, natural, cultural, and economic factors. Integrating historical data with geospatial analysis techniques to delve into the semantics, spatial distribution characteristics, and formation mechanisms of traditional village toponyms plays an essential role in uncovering the historical trajectory, the uniqueness of geographical features, and the evolution of the cultural landscape of the area. It can not only offer a comprehensive perspective on the interplay between regional history and geography but also provide support for preserving and continuing these distinctive intangible cultural heritages. Therefore, this study aimed to.

1) Based on toponymic cultural landscape characteristics, compile and categorize the semantic meanings of toponyms in traditional villages,
2) By using GIS, parameter-optimized geodetectors, in conjunction with historical economy, population, and war information from the Qin dynasty to the Qing dynasty, analyze the diachronic spatial distribution characteristics of different types of toponyms and elucidate factors that influence the emergence of toponyms and the intrinsic formation principles of their geographical distribution of toponyms, and
3) From the perspective of toponymic cultural landscape resources, propose preservation strategies for both traditional toponyms and broader cultural heritage in these villages.

This study contributes to a deeper understanding of the cultural dimensions of traditional villages in western Hunan. It lays the groundwork for protecting and inheriting toponym cultural landscapes and intangible cultural diversity. Firstly, Studying the connotative characteristics of toponyms can help understand local cultural imprints and enhance the sense of cultural belonging in traditional villages. Secondly, the formation of toponyms is subject to historical, natural, cultural, and economic factors. An in-depth study of diachronic spatial distribution patterns of toponyms and formation mechanisms can reveal the characteristics of the geospatial environment and uncover ancestors' sense of locality and perceptions of place. Thirdly, by examining the historical changes in the spatial distribution of toponyms, the study goes beyond static analyses to consider the dynamic changes over time. The diachronic perspective is essential for understanding the historical processes that have shaped the toponym culture landscape. All of these would provide an innovative perspective on the identification, protection, and sustainable development of the regional characteristics of the intangible culture of traditional villages.

Literature reviews
Toponymy
Toponyms are a product of the times and are relatively stable, retaining numerous historical traces in politics, economy, military, and culture. The record of toponyms in China began as early as the Pre-Qin Period (221BC) when research focused on the etymological analysis of toponyms and the exploration of naming patterns. For instance, the Classic of Mountains and Seas systematically recorded ancient toponyms [21]. The Book of Lüshi Chunqiu and the Guan Di Ren Chapter discussed the

Liu *et al. Heritage Science*   (2024) 12:171

Page 3 of 28

division of territories, the use of characters for toponyms, naming principles of toponyms, and meanings and origins of toponyms[22]. The Wamyoruijusho, a book compiled by Minamoto no Shitagau between 931 and 938 in Japan, documented the names of prefectures and towns during that era [23].

The study of place naming, or toponymy, has been an independent discipline since the end of the nineteenth century, concerning the origin, structure, and significance of toponyms and historical change, geographical evolution, and cultural development [2]. Toponymy has been an important field of study for a long time in historical linguistics and etymology. The earliest toponymy studies were focused on the records and origins of place names and used linguistic methods to discuss the nature and etymology of toponyms [24].

Toponyms are composed of morphemes. Taylor, Egli, and Nagl et al. analyzed the toponym morphemically from the perspectives of lexicography, etymology, semantics, and onomastics and studied the toponym's etymology, phonology, meaning, the shape of the word, and evolution [25–27]. Perono Cacciafoco proposes an etymological method to reconstruct the place names system of multiple language families, including Indo-European languages, Semitic languages, Austronesian languages, Papuan languages, and Sino-Tibetan languages, from the perspective of historical linguistics [28, 29]. This method effectively constructs the major events and activities of prehistoric humans.

Toponymic classification system

Toponymic classification is crucial to the study of toponyms, as it is the basis and prerequisite for our understanding and analysis. Depending on their etymology, toponyms can be categorized into dialect words, ethnonyms, and exonyms toponyms. As historical and social phenomena, toponyms can be categorized into contemporary and historical toponyms. Some scholars believe that toponyms are proper nouns in language, which can be categorized into simple toponyms and compound toponyms according to word formation. According to grammatical structure, toponyms can be summarized into a sequence of specific and generic elements [30]. A toponym's generic element reflects the geographical entity's category, and depending on the generic element, it can be divided into natural geographical entity toponyms and humanistic geographical entity toponyms. The former includes plains, deserts, mountains, rivers, et al. The latter includes man-made features, settlements, administrative divisions, etc. The formation of specific elements is related to people's initial understanding and knowledge of the territory. It is a unified manifestation of the combination of the objective existence of geography and the

subjective cognition of human beings. Compared with generic elements, specific elements are more open, flexible, subjective, and humanistic, embodying a variety of naming methods which is often referred to as the origin of the name of the toponym [31].

Stewart claims that all place names arise from a single motivation, which is the desire to distinguish a particular place from places in general, and then proposed ten categories of toponyms: descriptive, associative, incident, possessive, commemorative, commendatory, folk etymologies, manufactured, mistake, shift names [32, 33]. To distinguish between 'place' as a human settlement and 'feature' as a natural element, Rennick proposed eight categories of toponyms: personal names, names taken from other places or features, local or descriptive names, historical names, subjective names, mistake names, names from more than one source, underived names based on "the names themselves rather than the purposes for the naming" [34]. Rudnyćkyj proposed toponymic principles: historical(H), linguistic(L), and onomastic(O) to categorize Canadian and North American place names and then proposed that each place name can be explained according to the formula: PN=O/H, L [35]. Tent and Blair proposed a system for classifying placenames according to how the toponym expresses the naming intention [36]. Toponyms can be categorized into seven types: descriptive, associative, evaluative, occurrent, copied, eponymous, and innovative names. This system has been employed by ANPS as well as by several other researchers around the world [37–39]. At the same time, he suggested that the classification of toponyms needed to be adapted to different geographical and cultural contexts.

The Chinese scholar Li proposed a similar system of naming methods [31]. He believes that the naming methods of Chinese toponyms can be categorized into three main groups: descriptive toponyms, narrative toponyms, and allegorical toponyms. Descriptive toponyms mainly reflect natural geographic features (indicating geographical location, describing natural landscapes, illustrating natural resources). Narrative toponyms mainly reflect humanistic geographic features (descriptions of humanistic landscapes, records of people or ethnic groups, surnames, historical facts, and legends). Allegorical toponyms mainly reflect the intention of the namer, and are usually used by the ruling class to glorify themselves. Wang et al., in research related to toponymic landscapes, categorized specific elements into natural and humanistic landscapes based on their cultural semantic connotations [40]. It is further subdivided into toponyms relevant to mountains, terrain, blessings, surnames, hydrological features, orientation, ancient relics, and minority languages according to the different cultural characteristics

Liu *et al. Heritage Science*   (2024) 12:171

Page 4 of 28

of the study area. Based on the cultural landscape connotations of specific elements, Hu et al. divided the naming characteristics of toponyms in Shaanxi Province into eleven types: for mountains, for water, for both mountains and water, for terrain, for orientation, for plants, and scenic spots et al. [41].

Our research object is traditional village toponyms in western Hunan, China. Most traditional village toponyms in western Hunan were formed in the Ming and Qing dynasties and are stable [42]. By analyzing the grammatical structure of traditional village toponyms in western Hunan, it is concluded that the generic element of traditional village toponyms in this region is defined as "village", and the differences in the cultural landscape of the toponyms are mainly reflected in the naming of specific elements. Descriptive toponyms mainly reflect natural geographical features, while narrative toponyms mainly reflect humanistic ones. Therefore, combining the characteristics of toponyms in the study area and the previous research, we divided the cultural landscape of toponyms' specific elements based on the Chinese toponyms' naming method and the cultural semantic contents. We divided the 370 toponyms in western Hunan into natural landscape toponyms and humanistic landscape toponyms. Natural landscape toponyms include toponyms related to terrain, hydrological features, and plants. Humanistic toponyms include toponyms related to surnames, implied meanings, orientation, transportation, architecture, and economy.

Toponym spatial distribution

Since the twentieth century, the study of toponyms worldwide has gone through a process from linguistic interpretation to geographic spatial analysis and from the interpretation of individual toponyms to the analysis of regional toponymic systems. 1900–1912, Gilliéron compiled and drew the Atlas Linguistique de La France from the perspective of linguistic geography, which contributed to the development of toponymic studies from traditional etymology to geography [43]. In 1926, Dauzat proposed using cultural geography to explore the chronological sequence of toponyms and the chronological stratification of toponyms [44].

Geographers proposed the term "toponym landscape" to refer to the origin, evolution, etymology, typology, and groups of toponyms and the natural and socio-cultural phenomena reflected in them [45]. Dauzat analyzed the influence of national migration, economic development, war, and other factors on toponyms from a cultural geography perspective [46].

Some geography scholars focus on the spatial distribution, temporal and spatial evolution of the cultural landscapes formed by toponyms and the cultural meanings they reflect, as well as their interrelationships with the natural and cultural environments. Its essence is to explain the relationship between people and land as reflected in toponyms in the spatial and temporal dimensions [47]. History's discipline reflects a particular period's unique history and culture by exploring toponyms. Sociology mainly studies the relationship between the development of human society and the formation and change of toponym culture. Ethnology studies the spatial distribution of different ethnic groups, historical migration paths, and national languages through the cultural and semantic features of toponyms [15].

In terms of research scale, studies of spatial patterns of toponyms include administrative units, such as provinces [48, 49], cities [50], and towns [51]; and natural features, such as mountain ranges [52], wetlands [53], canyons [54], and islands [55]. In terms of research content, the main focus has been on culture [56–58], spatial distribution characteristics and influencing factors [59–62], and spatiotemporal evolution characteristics [63]. Some studies have focused on critical toponyms, analyzing the political, cultural, and economic motives behind toponyms and interpreting toponym changes [64–66]. Rose-Redwood et al. linked street naming to memory and symbolic capital by examining two critical moments in the history of New York City [67]. Simeu-Kamdem examined the role of colonial rule in toponym naming in several Central African cities [68]. Young et al. explored the current problems in urban toponym commodification and proposed several directions for future toponym commodification [69, 70]. Furthermore, studies have examined the extraction of toponym information. Hu et al. proposed a computational framework to obtain local toponyms from geotagged house advertisements, which often go unrecorded due to regional dialects but play an essential role in the lives of local people [71].

Since the beginning of the twenty-first century, GIS has been widely used for the classification and spatial visualization of toponyms. GIS helps visualize the geographical and cultural information contained in toponyms. Capra [3] and Kerfoot [72] synthesized GIS to reveal that toponyms are products of interactions between the natural environment and human activities. Some scholars have used GIS to explore the spatial distribution of toponyms, such as naming types related to mountains and plains according to geographical location. According to cultural characteristics, toponyms are categorized into naming types related to surnames, architecture, and so on [73]. Studies have used GIS to examine the spatial distribution and their influencing factors of toponyms. The spatial distribution of toponyms sheds light on the characteristics of geographic environments, history, culture, and society [60, 74, 75]. Some scholars have focused on the

Liu *et al. Heritage Science*   (2024) 12:171

Page 5 of 28

evolution and cultural connotations of the spatial pattern of toponyms [40, 61, 73]. Zhong et al. analyzed the spatial pattern of toponyms as "living heritage" using GIS to reveal the region's past geographic and cultural information [76–78].

Geodetectors were used in toponym research to detect spatial divergence and reveal its driving forces. Yuan et al. used a geodetector to analyze the expansion of villages and land development from the Yuan to Qing dynasties due to migration data during China's middle and late imperial periods, which will assist us in understanding the migration patterns of ethnic groups and the distribution of settlements in the Hunan region throughout historical data [79]. Li addressed the spatial distribution characteristics of traditional villages in the northern hilly and gully areas and used GIS and a geodetector to find that the socio-economic factors had the strongest impact on the distribution of traditional villages, while the geographical factors' influence was relatively weak [80]. Li et al. examined the spatial autocorrelation and heterogeneity in 75 traditional villages using kernel density analysis and Moran's I index and revealed the spatial distribution of traditional village hamlets [81]. They explored 12 influencing factors to construct a GWR model and geodetector to analyze the main driving forces and interaction mechanisms. Geodetectors are effective in identifying and measuring factors that influence spatial differentiation. However, due to the various methods of discretization of influencing factors, geodetector results differ, and conclusions may not reflect the real influencing factors. Therefore, this study used the optimal geodetector, which can automatically calculate the optimal method and classification using an algorithm, and has a convenient and fast function for quickly optimizing data for analysis. Using a geodetector based on optimal discretization parameters could scientifically identify the main factors affecting the spatial distribution of traditional village toponyms.

Thus, previous studies on traditional village toponyms mainly used qualitative descriptions and spatial analysis techniques to explore their spatial distribution and influencing factors rooted in the natural geographic environment [82, 83]. However, the historical and cultural processes that have shaped the current spatial distribution of these toponyms remain largely unexplored. In addition, most research mainly focused on describing the spatial pattern, but there has been no in-depth study on why such a pattern is formed. Studying the spatial distribution of toponyms and formation mechanism is the premise of better cognition, protection, and inheritance of toponym landscapes and cultural heritage in traditional villages.

The geographic conditions of western Hunan are complex and diverse and include plains, hills, mountains, and other terrain. Many traditional villages have been preserved as typical gathering locations for ethnic minorities. During long-term development, the interactive integration of multi-ethnic cultures and economies resulted in many traditional village toponyms with unique geographic and humanistic features [84]. Therefore, this study chose traditional village toponyms in Western Hunan, China as the research object. Statistics and GIS kernel density analysis were used to sort toponym types and spatial patterns and reveal the spatial distribution characteristics of traditional village toponyms. Moreover, using the optimal geographic detector, we quantitatively analyzed the relationship between toponyms and geographic elements and combined them with historical data to reveal the characteristics and formation mechanisms of the spatial patterns of traditional village toponyms in western Hunan. Finally, we propose specific strategies for protecting and inheriting traditional village toponyms to expand their connotations and develop protection methods for the intangible culture of traditional village toponyms.

Study area and data processing
Study area overview
Western Hunan includes Huaihua and Zhangjiajie cities and the Xiangxi Tujia-Miao Autonomous Region (Fig. 1). It is a vast area surrounded by two major mountain ranges, Wuling and Xuefeng, and the Yunnan-Guizhou Plateau. The middle and upper reaches of the Yuanjiang and Lishui Rivers and their tributaries converge. With an area of approximately 78,700 square kilometers, western Hunan includes the first to fifth batches of traditional Chinese villages, totaling 370 villages. Western Hunan is a typical multiethnic production and living area. It includes many ethnic groups, such as the Tujia, Miao, Yao, Dong, and Hui. Consequently, many traditional villages of ethnic minorities have formed, among which the traditional villages of Miao and Tujia are the most numerous (Fig. 2). According to the related literature, footprints of settled people exist in western Hunan as early as the Neolithic period, and some traditional villages were established in the Qin and Han Dynasties (Fig. 3).

Research framework and data source
As shown in Fig. 4, the research framework includes four parts: data preprocessing, spatial pattern analysis, formation mechanism, and strategies for protecting. The first part is data preprocessing. As shown in Table 1, the data included toponyms of traditional villages in western Hunan, historical information, and
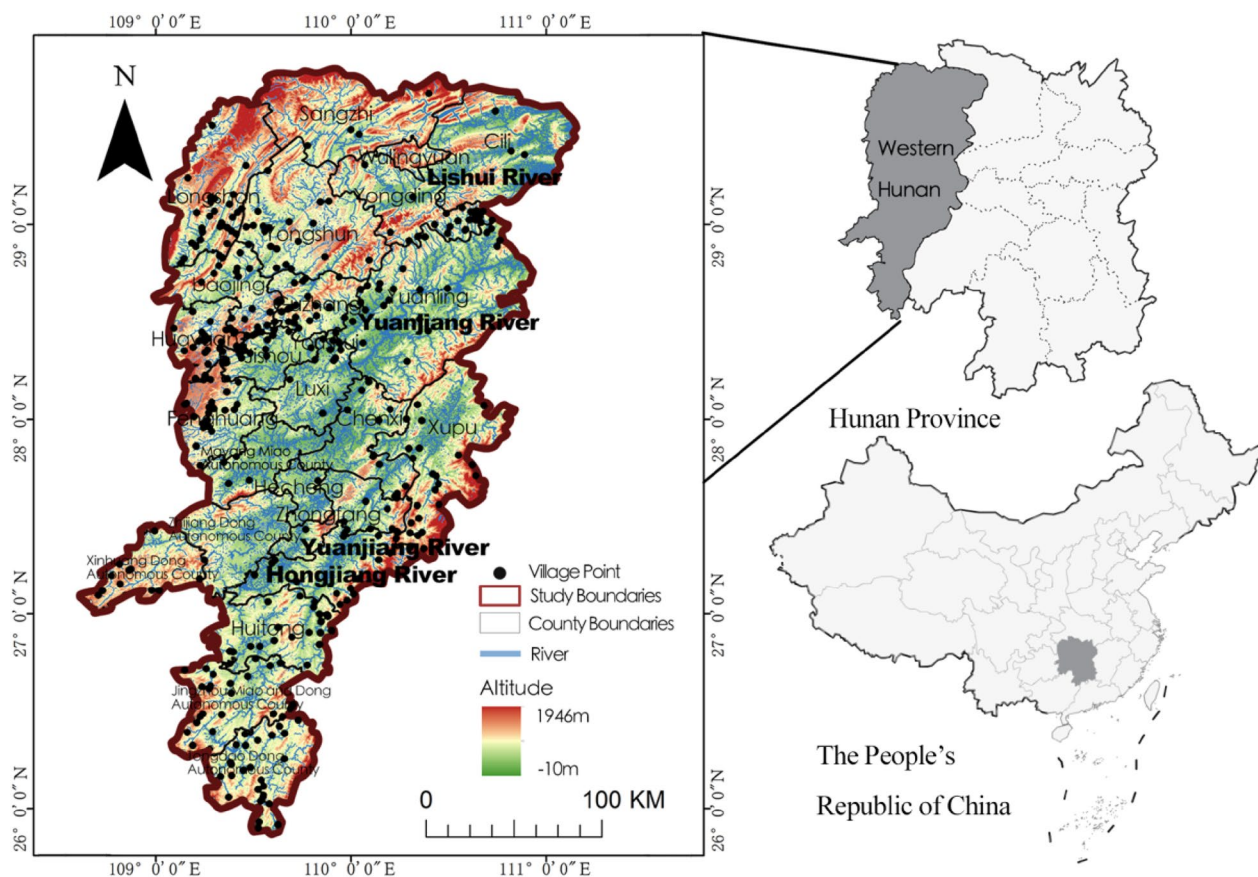
Fig. 1 Study area

geographic information were collected. The study spans the period from the Qin to the Qing Dynasty.

The second step is spatial pattern analysis. Initially, based on the cultural landscape characteristics reflected by the semantics of the place names, we categorized traditional village toponyms into distinct types related to terrain, hydrological features, plants, surnames, implied meanings, orientation, transportation, architecture, and economy. Then, from the spatial and historical dimensions, Kernel density analysis and the standardized ellipses were used to identify the diachronic spatial distribution and the trend of changes in various toponym types. Finally, we adopt a dual approach to examine the spatial distribution of toponyms. On the one hand, we employ parameter-optimized geodetectors to analyze the determinants affecting the spatial distribution of toponyms that reflect natural landscapes. On the other hand, we integrate historical information to dissect the spatial distribution of toponyms representing humanistic landscapes, considering three pivotal aspects: ancestral ideas, folk beliefs, and mode of production and lifestyle. This comprehensive methodology deeply explains the complex interplay between place names and their socio-natural context.

The third part is the formation mechanism. The formation of spatial patterns of toponym landscapes is a complex process involving the interaction and influence of multiple aspects, such as the natural geographic environment, human activities, history and culture, and socio-economics. The formation mechanism of toponym spatial patterns is explored through three aspects: influencing factors of the shift in the spatial gravity center, regulatory power, and curing access. Firstly, in the context of nature, historical migrations, wars, population, and economy, the factors influencing the shift in the gravity center of natural and humanistic toponyms landscape were discussed. Secondly, the regulatory power of toponym spatial pattern formation is investigated through environmental orientation, immigrant integration, behavioral activities, and inherited changes. Thirdly, the curing process of toponym spatial pattern formation is examined through topophilia, localization, and livedization.

The last part is strategies for protecting. From the perspective of toponymic cultural landscape resources, legislative protection, establishing a toponym database,
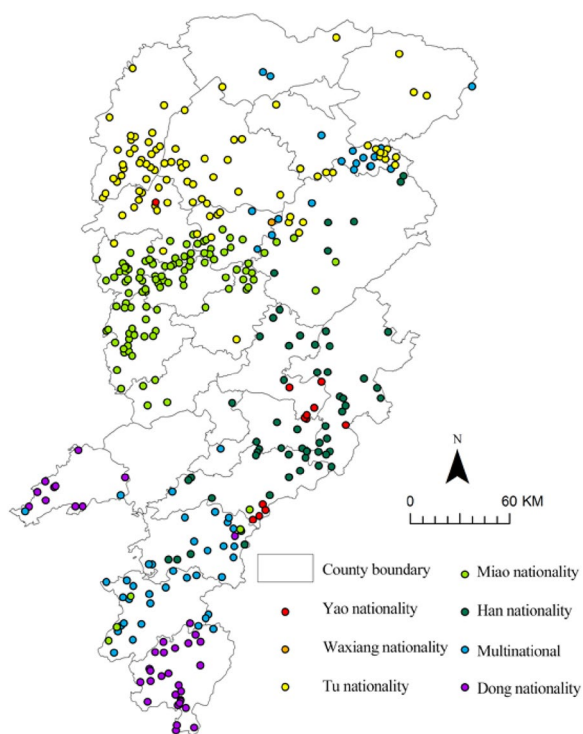
Liu *et al. Heritage Science* (2024) 12:171

Page 7 of 28

Fig. 2 Distribution of ethnic groups in traditional villages in western Hunan
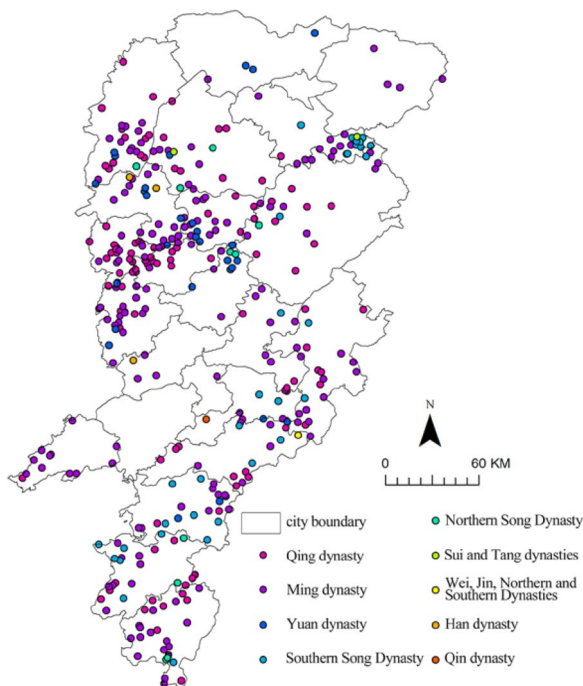

Fig. 3 Spatial distribution of geographical names from different historical periods

regional protection of toponym culture, create toponym cultural landscape tourism routes are proposed as cultural preservation and sustainable development strategies.

Methods

Kernel density analysis

The basic principle of kernel density analysis [90] is to use a regular moving sample to calculate the density contribution of spatial point elements. Kernel density analysis can visualize spatial density changes in traditional village toponyms and accurately express their spatial distributions. The following formula was used:

$$f(a) = \frac{3}{mh^2\pi}\sum\nolimits_{i=0}^{n}\left[\frac{(a-a_i)^2 - (b-b_i)^2}{h^2}\right] \quad (1)$$

where f (a) is the kernel estimate of the two-dimensional probability density; h is the bandwidth; m is the number of toponym points falling within a search radius with bandwidth h; (*a, b*) are the coordinates of the sample center point; and (ai, bi) are the coordinates of sample point i. The bandwidth in Eq. 1 is determined by the degree of discretization and scale of analysis. Closer distance to the center point indicates greater weight and density contribution, which is consistent with the distance-decay law. The kernel density analysis function in ArcGIS was used to calculate the density distribution of toponyms, which showed high-density areas.

Standard deviation ellipse

The standard deviation ellipse method is a classical algorithm for analyzing the direction and distribution of points. The standard deviation ellipse distribution range was the main range of the spatial distribution of toponyms. The mean center of the ellipse is the center of gravity of the spatial distribution of toponyms, and the azimuthal angle indicates the direction of the primary trend of its distribution. A more significant the gap (flatness) between the long and short semi-axes indicated a more pronounced direction of toponyms. In contrast, toponyms have no distributional characteristics when the short semi-axis is equal to the long semi-axis.

Parameter-optimized geodetectors

The Geodetector method was proposed by Jinfeng et al. [91]. This method can be used to analyze and detect the spatial dissimilarity of toponyms and reveal the driving factors. The core idea is that if dependent variable Y is primarily influenced by independent variable X, then the spatial distributions of X and Y should be similar. The q-value measures the strength of the factor explanation in the geodetector; higher
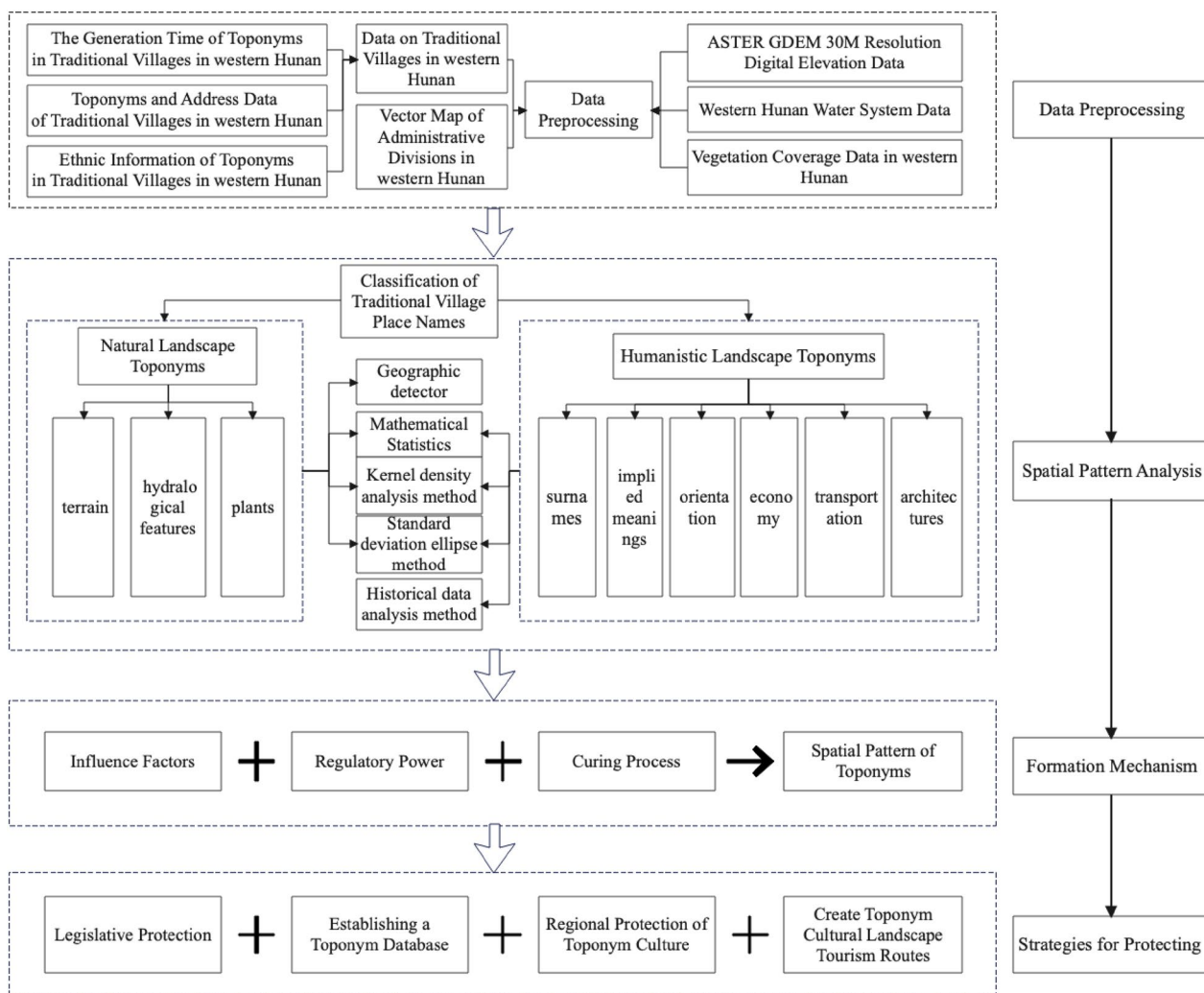
Liu *et al. Heritage Science*   (2024) 12:171

Page 8 of 28

Fig. 4 Research framework

Table 1 Data source

Data	Data source
Five batches of traditional village toponyms in western Hunan	https://www.mohurd.gov.cn
Vector map of administrative divisions in Western Hunan	http://www.gscloud.cn/
ASTER GDEM 30M resolution digital elevation data	http://www.resdc.cn/
Western Hunan water system data	http://www.gscloud.cn/
The generation time of traditional village toponyms in western Hunan	Dictionary of Ancient and Modern Geographical Names of Hunan [85], History of Political Regions in Hunan [86], Chronicle of Hunan Geographical Names [87], and Record of Geographical Names of Hunan [88]
Ethnic information of traditional village toponyms in western Hunan	Dictionary of Ancient and Modern Geographical Names of Hunan [85], History of Political Regions in Hunan [86], Chronicle of Hunan Geographical Names [87], and Record of Geographical Names of Hunan [88]
History economy data of western Hunan	Jiaqing Hunan chorography volume36-39 Land tax [89]
History population data of western Hunan	Jiaqing Hunan chorography volume34-35 household registration [89]

q-values indicate better effects. However, a traditional geodetector must be set artificially to identified continuous variables, and poor discretization may occur. Therefore, this study adopted a parameter-optimized geodetector [92] to analyze the spatial differentiation drivers of the toponyms of traditional villages in western Hunan. This study used the G.D. package in R language with equal, natural, quantile, geometric, and standard deviation breaks. The number of classification levels was set to 3–6 categories, from which the spatial scale with the largest q-value was selected as the parameter for geodetector analysis. Using the optimal parameters and geodetector factor detection, we revealed the driving force of the spatial distribution characteristics of toponyms, as follows:

$$q = 1 - \left(\sum_{k=1}^{L} N_k \sigma_k^2 \right) / \left(N \sigma^2 \right) \tag{2}$$

where k=1, …, L represents the stratification of the dependent variable or influencing factor, that is, classification or partitioning; N_k and σ_k^2 are the number of units and variance of stratum k, respectively; and N and σ^2 are the number of units and variance of the study area, respectively. The q-value was calculated using Eq. 2 to determine the explanatory power of the factors influencing the spatial differentiation of traditional village toponyms. Larger q-values indicated stronger corresponding X-variable, which explained the formation of traditional village toponyms.

The interaction detector judges the interaction characteristics between bivariate variables by comparing the q-value of a single factor with that of a two-factor interaction. Driver interaction identifies whether the joint action between the drivers increases or decreases the explanatory power of the analyzed variables by detecting the q(Xh ∩ Xi) value of the results.

Results

Types and numbers of traditional village toponyms in western Hunan

Toponyms are closely related to geospatial environments. The formation, development, and evolution of toponyms are influenced by the geographical environment. Toponyms reflect the characteristics of a local geographical environment. Some villages have toponyms associated with mountains because they are located in the mountains. Other villages may have water-related toponyms because they are located near the water. Therefore, the toponym represents a culture of mountains and water. Other factors in natural geographic environments include topography and vegetation. In addition, toponyms related to historical buildings, commercial economy, ethnic groups, surnames, and clans are influenced by the social environment and present rich socio-cultural characteristics. In western Hunan, 372 different Chinese characters were included in the 370 toponyms of traditional villages. These 370 toponyms could be categorized into natural and humanistic landscape toponyms. The natural landscape toponyms reflected local natural landscape features and were categorized into naming types related to terrain, hydrological features, and plants. The toponyms of the humanistic landscape reflected the characteristics of the local human landscape, which could be categorized into naming types related to surnames, orientation, economy, transportation, architecture, and implied meanings.

Statistics and classification of toponyms in the natural landscape category

As shown in Table 2, categorizing the semantic meanings revealed 205 toponyms in the natural landscape category, accounting for 55.41% of all the toponyms. Among these, the toponyms related to terrain were the most prevalent (107, 28.92%). The main terms used in the naming included plain, mountain, cave, ridge, and

Table 2 Traditional village toponyms in western Hunan by character classification

Type	Subtype	Main words	Quantity	Percentage of subtypes	Percentage of types
Natural landscape	Related to terrain	Plain, mountain, cave, ridge, slope, etc	107	28.92	55.41
	Related to hydrological features	Stream, pond, bay, river, spring, etc	66	17.84	
	Related to plants	Tree, pine, wood, etc	32	8.65	
Humanistic landscape	Related to surnames	Zhang, Song, Deng, Gong, etc	29	7.84	44.59
	Related to orientation	East, south, west, north, up, down, etc	22	5.95	
	Related to economy	Market, field, iron, copper, etc	13	3.51	
	Related to transportation	Bridge, road, car, boat, etc	12	3.24	
	Related to architecture	Stockade, building, city, camp, etc	25	6.76	
	Related to implied meanings	Peaceful, dragon, lucky, bright, light, etc	64	17.30	

slope. For instance, Laodong Village was named after a mysterious, primitive cave adjacent to the village. The number of toponyms related to hydrological features ranked second (66, 17.84%). The main naming characteristics were streams, ponds, bays, rivers, and springs. For instance, Huangxi Village was named after the Huangxi River, which runs straight to the village in the northwest corner. The third was a toponym related to plants (32, 8.65%). The main words used were tree, pine, and wood. For instance, the name of Ginkgo Tree village comes from having the oldest surviving ginkgo trees in Asia. The above toponyms fully reflected the natural geographic features of western Hunan and showed the results of people's perceptions of natural geographic features, such as terrain, hydrological features, and plants.

Statistics and classification of toponyms in the humanistic landscape category

In addition to the natural environment, humanistic factors significantly affect toponym formation. As shown in Table 1, 165 toponyms were identified in the humanistic landscape category, which accounted for 55.41% of all the toponyms. Among them, 64 (17.30%) toponyms were related to the implied meaning, accounting for. The main characters used were peaceful, dragon, fortunate, bright, and light. For instance, Peaceful Year Village refers to peace and tranquility every year in the future. The second type were toponyms related to surnames (29, 7.84%).

The main characters used were Zhang, Song, Deng, and Gong. For instance, Zhangjiaping Village, as the name suggests, was comprised of members of the Zhang clan. The number of toponyms related to architecture ranked third (25, 6.76%). The main characters used in the naming were stockades, buildings, cities, and camps. For instance, Liao City Village and Liao Yan were named as such because they were built during the Song dynasty. The number of toponyms related to orientation ranked fourth (22, 5.95%). The main characters used were east, south, west, north, up, and down. For instance, West Lou Village had a Diaojiao house on the west side of the mountain, where the village is located, contributing to the name. Toponyms related to economy account for 3.51%. The main naming characters were market, field, iron, and copper. Transportation toponyms account for 3.24%. The main characters were bridge, road, car, and boat. These findings reveal the humanistic flavor of western Hunan during this historical period, reproduce historical life scenes, and reflect people's visions of a better life.

Spatial distribution of toponyms
Natural landscape toponyms

The distribution of toponyms in the natural landscape category was strongly associated with local natural landscape features. These toponyms are relatively stable and generally do not change [93]. Western Hunan is located on the northeast side of the Yunnan-Guizhou Plateau and southwest Exi Mountains. Wuling Mountains runs diagonally across the territory, and the terrain slopes from northwest to southeast. The high-value kernel density of natural landscape categories is mainly concentrated in the northwest mountain area, and the spatial distribution of different types of toponyms varies significantly and is characterized by non-equilibrium.

The toponyms related to terrain formed a high-density core area, mainly in the west-central and southeastern parts of western Hunan, with an overall distribution coinciding with topographic direction. The largest group was linearly distributed along Wuling Mountains, followed by a linear distribution along the Xuefeng Mountain Range and other scattered sporadic distributions with prominent spatial aggregation characteristics (Fig. 5a). Most toponyms were distributed in areas with a degree of undulation of 30–75 m, accounting for 63.55% of the total. They were concentrated in areas with elevations of less than 500 m, accounting for 54.21% of the total (Tables 3 and 4). As shown in Fig. 5a, the distribution of toponyms in the geomorphology category had a weak centripetal force (agglomeration) and clear directionality, with the primary distribution direction being approximately 5.3° north by east.

Western Hunan is rich in water resources, with a well-developed water system and a dense river network. The spatial distribution of toponyms related to hydrological features was balanced, and most were linearly distributed along the rivers (Fig. 5b). A total of 69.70% of the toponyms related to hydrological features were located less than 500 m from the rivers (Table 5). This indicated that the formation of a toponym in this category was closely associated with the water system. As shown in Fig. 5b, the distribution of toponyms related to hydrological features was more centripetal (aggregated) than that of toponyms related to terrain. In contrast, the direction of distribution was weaker, with the main trend being approximately 10° east of the north.

With lush and evergreen vegetation in all seasons, western Hunan is a subtropical broadleaved forest area. Toponyms related to plants were mainly distributed in places rich in plant resources (Fig. 5c). As shown in Fig. 5c, the distribution of toponyms related to plants had the most vital centripetal force and directionality, with the primary trend direction of distribution being approximately 14.2° north by east.
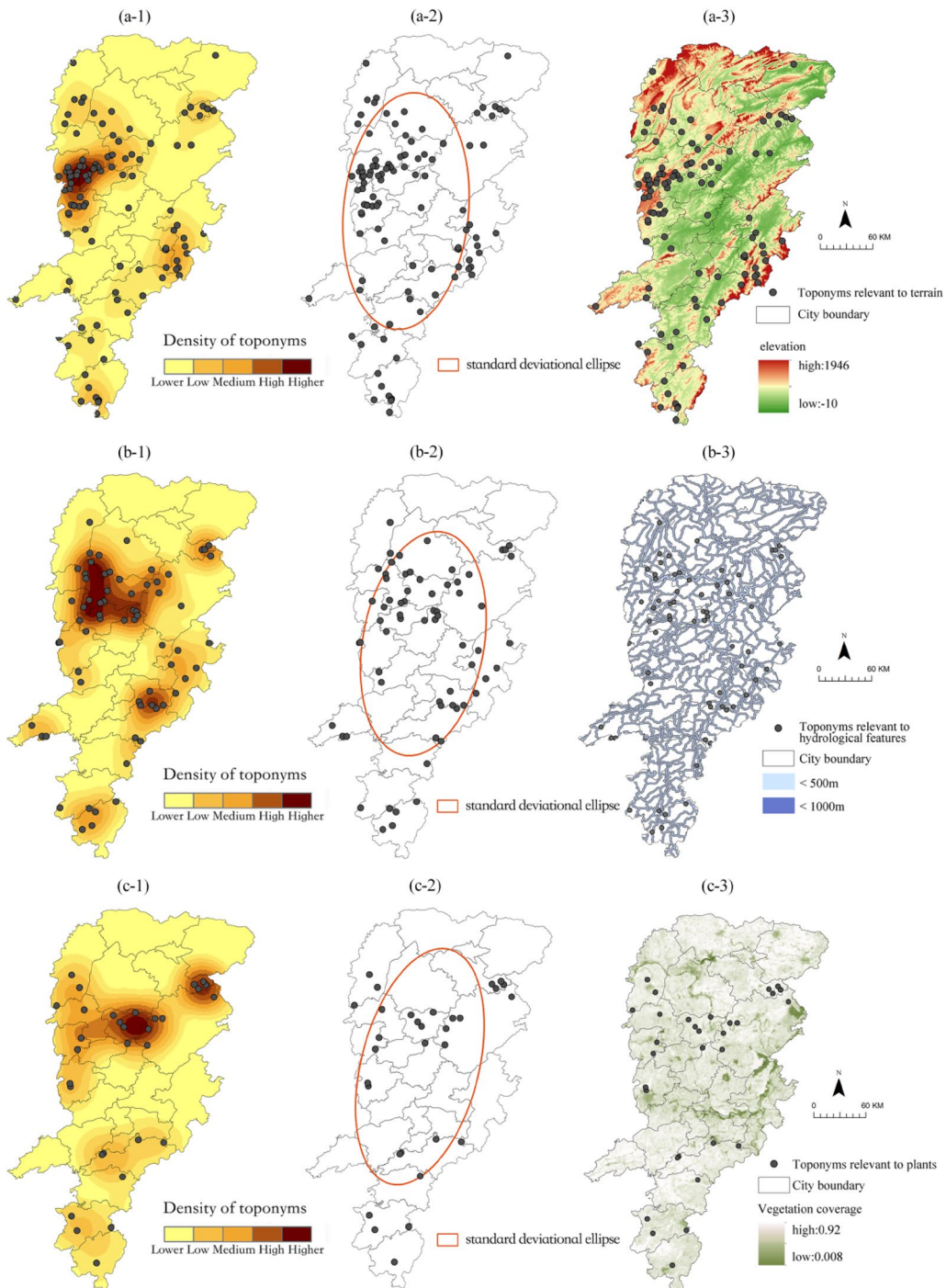
Fig. 5 Spatial distribution of natural landscape toponyms in western Hunan. (**a-1**) Kernel density distribution of toponyms related to terrain; (**a-2**) Directional distribution map of toponyms related to terrain; (**a-3**) Elevation and toponyms related to terrain; (**b-1**) Kernel density distribution of toponyms related to hydrological features; (**b-2**) Directional distribution map of toponyms related to hydrological features; (**b-3**) Hydrological buffer zones and toponyms related to hydrological features; (**c-1**) Kernel density distribution of toponyms related to plants; (**c-2**) Directional distribution map of toponyms related to plants; (**c-3**) NDVI and toponyms related to plants

Liu *et al. Heritage Science*   (2024) 12:171

Page 12 of 28

Table 3 Distribution elevation of toponyms related to terrain

Altitude (m)	Number	Percentage (%)
< 500	58	54.21
500–1000	46	42.99
> 1000	3	2.80

Table 4 Distribution fluctuation of toponyms related to terrain

Relief amplitude (m)	Number	Percentage (%)
< 30	10	9.35
30–75	68	63.55
> 75	29	27.10

Table 5 Distance between toponyms related to hydrological features and rivers

Distance from river (m)	Number	Percentage(%)
< 500	46	69.70
500–1000	14	21.21
> 1000	6	9.09

humanistic landscape toponyms

Toponyms of the humanistic landscape reflected the regional culture of western Hunan [94]. Areas with high kernel density in the humanistic landscape category were mainly concentrated in southeastern low-mountainous and hilly areas, including Tongdao Dong, Jingzhou Miao, and Dong Autonomous Counties. However, the value of the kernel density was much smaller than that of the northwestern mountainous areas.

As shown in Fig. 6a, toponyms related to surnames were mainly concentrated in the central part of western Hunan, with Guzhang County having the highest Kernel density. Of the toponyms related to surnames, 60% were generated in the Ming and Qing Dynasties when an immigration rush from Jiangxi to Hubei and Hunan occurred in southern China, causing a large-scale influx of people into ethnic minority areas. People of the same clan often move together and the gathering place develops into a village. At that time, most used their surnames as village toponyms. Therefore, as a prominent form of the clan concept, toponyms related to surnames may reflect population migration and settlement during the historical development of western Hunan. As shown in Fig. 7a, the distribution of toponyms related to surnames had a weak centripetal force (aggregation) and an unclear direction, with the primary trend direction of the distribution being approximately 15.2° north by east.

As shown in Fig. 6b, toponyms related to implied meanings formed a significant cluster in the northwest. Areas with the highest kernel densities were in Longshan and Baojing Counties. Among the toponyms, 82.81% were created in the Ming and Qing Dynasties. Western Hunan is a multi-ethnic area with diverse languages. Some toponyms are related to dialectal meanings; therefore, the distribution of toponyms is related to the distribution of ethnic minorities. When toponyms first appeared, the ability of people to defend themselves against natural disasters was poor. During social development, humans experience social changes and wars. Regardless of the historical stage, people refer to their wishes daily. Consequently, traditional village toponyms often reflect residents' aspirations and longing for a better life. As shown in Fig. 7b, the distribution of toponyms in the allegorical category had a weak centripetal force (agglomeration) and unpronounced directionality, with the primary trend direction of the distribution being approximately 2° east of the north.

The toponyms related to the orientation were diverse and formed an area of high kernel density in the southern part of the region. The highest kernel density values were found in the remnants of the Miao Ridge in Guizhou, southwest of Tongdao Dong Autonomous County (Fig. 6c). Toponyms related to orientation were primarily concentrated in areas with high topographic relief, with a tendency to appear according to the direction of the mountains, such as the remnants of Miaoling Mountains in southern Guizhou. Toponyms related to the orientation were characterized by directional solid pointing, particularly when representative terrain and buildings were in the surrounding area. Using measurements and orientation for toponym naming provides people with an intuitive and concrete feeling. As shown in Fig. 7c, the distribution of toponyms related to the orientation had a solid centripetal force (agglomeration) and clear directionality, with the primary trend direction of the distribution being approximately 6.9° east of north.

As shown in Fig. 6d, toponyms related to economy were mainly distributed around the central-western and southeastern regions, and most (92.9%) were formed during the Ming and Qing Dynasties. Some of these toponyms were closely related to local economic activities, such as Shitian Village in Huitong County and Huaihua City. In addition, some toponyms were named after developed local industries, such as Changtian Village in Huaihua City in Huitong County and Titian Village in Huaihua City in Chenxi County. Some of these villages were located near historical trails during the Ming and Qing Dynasties, and the formation of toponyms may have been related to them. As shown in Fig. 7d, the centripetal force (agglomeration) of the distribution of economic
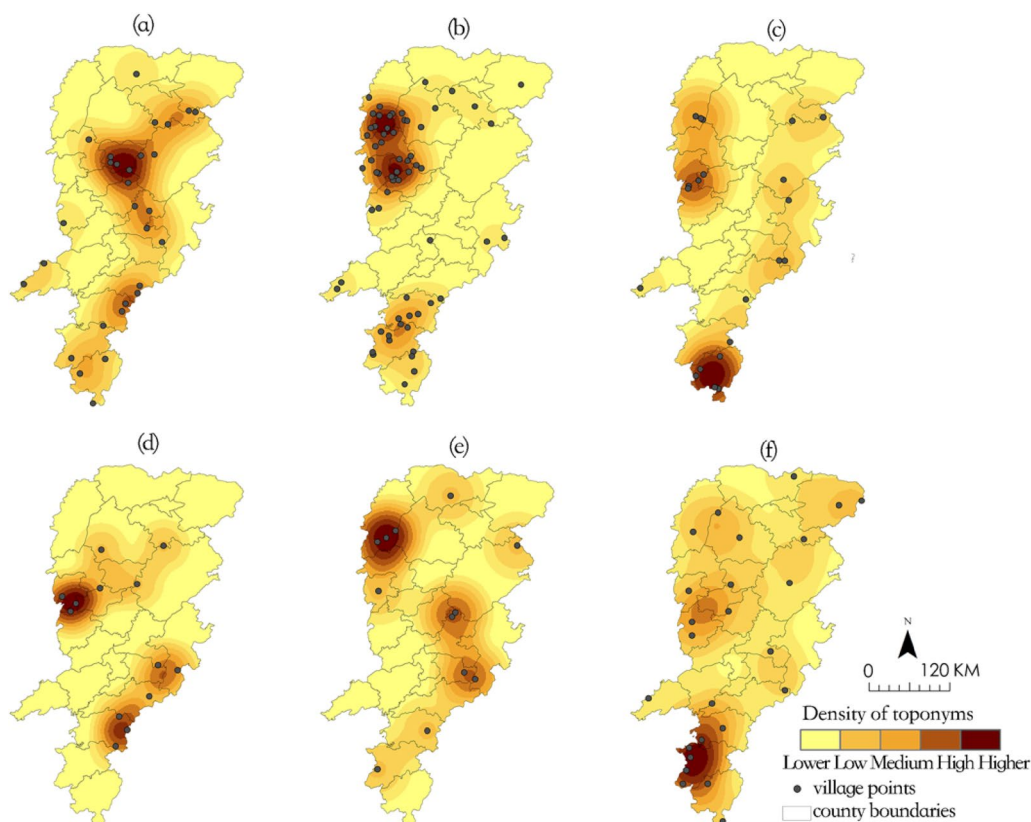
Liu *et al. Heritage Science*   (2024) 12:171

Page 13 of 28

Fig. 6 Kernel density distribution of humanistic landscape toponyms in western Hunan. **a** Related to surnames; **b** Related to implied meanings; **c** Related to orientation; **d** Related to economy; **e** Related to transportation; **f** Related to architectures

toponyms was weak, directionality was unnoticeable, and the direction of the primary trend of the distribution was approximately 10.4° north by west.

The spatial imbalance of toponyms related to architecture was the highest in the Jingzhou Miao and Dong Autonomous Counties (Fig. 6f). Half of the toponyms related to architecture were generated during the Ming Dynasty. During the Ming Dynasty, Jingzhou Miao and Dong Autonomous Counties were central commercial towns along the borders of Hunan, Guizhou, and Guangxi. Due to their unique geographic location, Jingzhou Miao and Dong Autonomous Counties were important nodes for merchants and travelers to rest and trade goods on the ancient Guizhou–Guangxi Road. Consequently, they gradually prospered, with inns, hotels, and other businesses thriving. As architecture is closely linked to the production and lives of residents, this period saw the most significant number of toponyms related to architecture. As seen in Fig. 7f, the distribution of toponyms related to architecture had a solid centripetal force (agglomeration) and clear directionality, with the primary distribution trend in the direction of approximately 19.3° north by east.

As shown in Fig. 6e, the distribution of toponyms related to transportation was higher from the northeast to the southwest, and 75% were generated during the Ming and Qing Dynasties. As shown in Fig. 7e, the distribution of toponyms related to transportation had a solid centripetal force (agglomeration). However, the direction was less noticeable, and the main trend direction of the distribution was approximately 0.7° east of north. As shown in Fig. 8, toponyms related to transportation often appeared near historical trails. For instance, Chuanxi Stage village was crossed by a historical trial and had a stage, which was an essential node in the Qing Dynasty.

Historical distribution of toponyms
Historical changes in the spatial distribution of natural landscape toponyms
This study further extracted center-of-gravity points to explore historical changes in the spatial distribution of natural landscape toponyms from different dynasties. The results showed that the coordinates of the center-of-gravity points of traditional standard deviation ellipses of villages from the Song and Qing Dynasties shifted from (28.48N, 110.17E) to (28.01N, 109.83E). The east–west
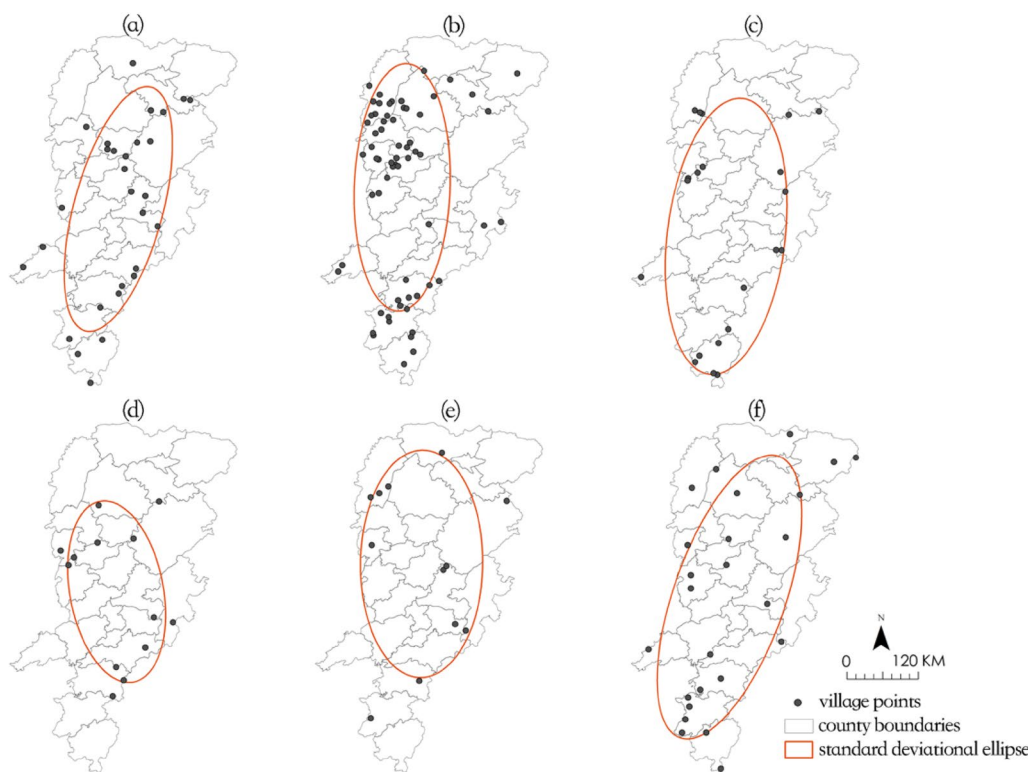
Fig. 7 Directional distribution map of humanistic landscape toponyms in western Hunan. **a** Related to surnames; **b** Related to implied meanings; **c** Related to orientation; **d** Related to economy; **e** Related to transportation; **f** Related to architectures
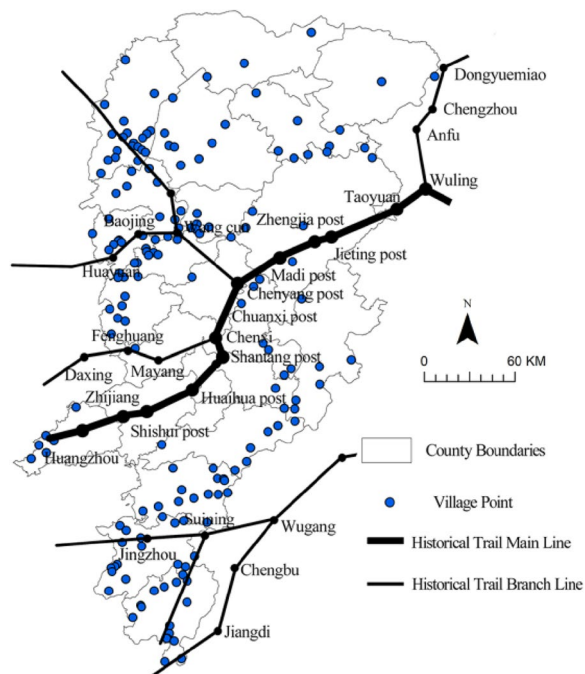

Fig. 8 Historical trails of the Ming and Qing Dynasties

and north–south spans were approximately 0.34° and 0.47°, respectively. The center tended to move from the northeast to the southwest and from Yuanling County to Luxi County (Fig. 9). The short semi-axis of the standard deviation ellipse indicated the extent of the data distribution. A shorter semi-axis indicated a more pronounced centripetal force of the data. The short half-axis of the standard deviation ellipse shortened from 0.69 during the Song Dynasty to 0.63 during the Qing Dynasty, and the long half-axis shortened from 1.43 to 1.18. This indicated that the distribution of traditional villages tended to concentrate in the main direction over time; however, the degree of concentration was small. Regarding the azimuth angle, the rotation angle before the Song Dynasty was 17.13°, and that before the Qing Dynasty was 8.17°. This indicated that the center of gravity of natural landscape toponyms with respect to discrete features gradually became less evident in the northeast–southwest direction.

Historical changes in the spatial distribution of humanistic landscape toponyms

The results demonstrated that the coordinates of the center-of-gravity points of standard deviation ellipses of traditional villages before the Song and Qing
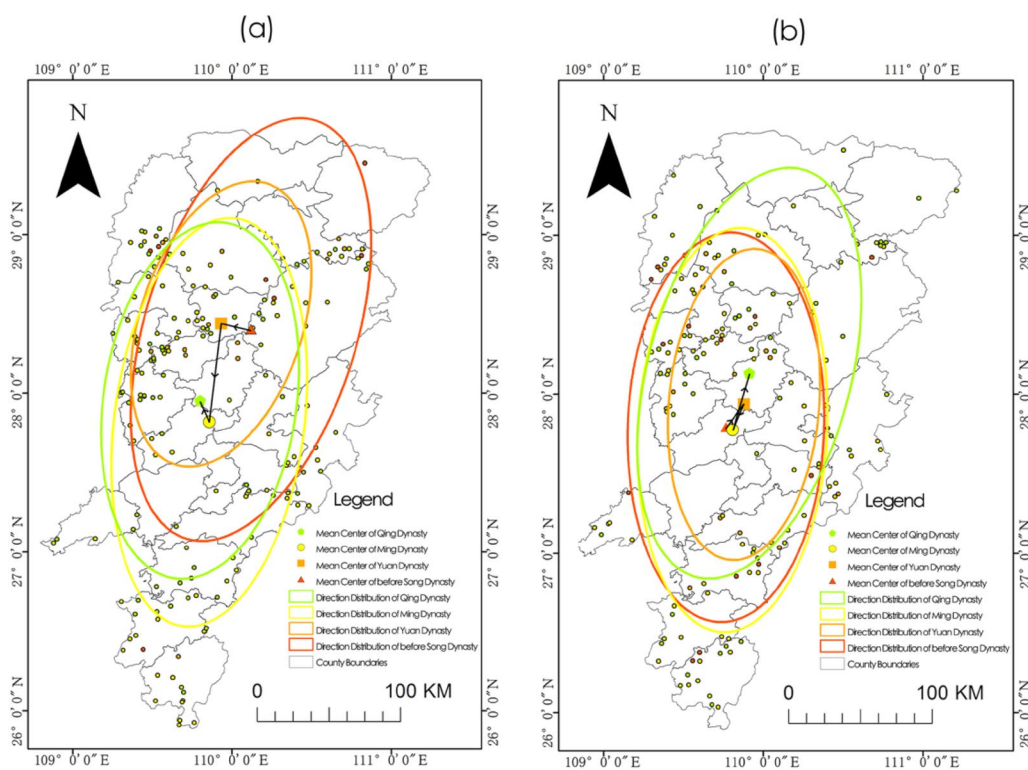
Liu *et al. Heritage Science*   (2024) 12:171

Page 15 of 28

Fig. 9 Gravity center and direction of traditional village toponyms. **a** Gravity center and direction of natural landscape toponyms; **b** Gravity center and direction of humanistic landscape toponyms

Dynasties shifted from (28.85N, 109.80E) to (28.20N, 109.95E). It moved from the southwest to the northeast but remained within the boundaries of Mayang Miao and Luxi Autonomous Counties (Fig. 9). The short semi-axis of the standard deviation ellipse indicated the range of data distribution. A shorter semi-axis indicated more pronounced centripetal force of the data. The length of the short half-axis of the standard deviation ellipse grew from 0.64 during the Song Dynasty to 0.66 during the Qing Dynasty, and the long half-axis grew from 1.28 to 1.38. This indicated that the distribution of traditional villages and hamlets tended to concentrate in the main direction over time; however, the degree of concentration could be improved. Regarding the azimuth angle, the rotation angle before and during the Song Dynasty was 1.89°, and that during the Qing Dynasty was 14.55°. This showed that the center of gravity of toponyms of humanistic landscapes was discrete in the northeast–southwest direction, with gradually noticeable features.

Factors influencing the spatial patterns of toponyms
Natural landscape toponyms
We further analyzed the influence of natural factors on the spatial patterns of toponyms based on the spatial differentiation characteristics of natural landscape

toponyms and principles of data accessibility and quantification. The kernel density value of traditional village toponym sites was selected as the Y variable. A geodetector was used to explore the NDVI (X1), undulation (X2), slope direction (X3), slope gradient (X4), elevation (X5), and shortest river distance (X6) on the distribution of natural landscape toponyms, such as those related to terrain, hydrological features, and plants. Interpretations of the influencing factors are presented in Table 6, and the detection results are presented in Table 7 and Figs. 10, 11, 12, 13, 14, 15.

Table 6 Index system of impact factors of natural landscape toponyms

Designator	Indicator
NDVI (X1)	Normalized Difference Vegetation Index
Undulation (X2)	Terrain undulation of traditional villages
Slope direction (X3)	Terrain slope direction of traditional villages
Slope gradient (X4)	Terrain slope gradient of traditional villages
Elevation (X5)	Elevation of traditional villages
Shortest river distance (X6)	The shortest distance between traditional villages and rivers

Table 7 Factor detection results

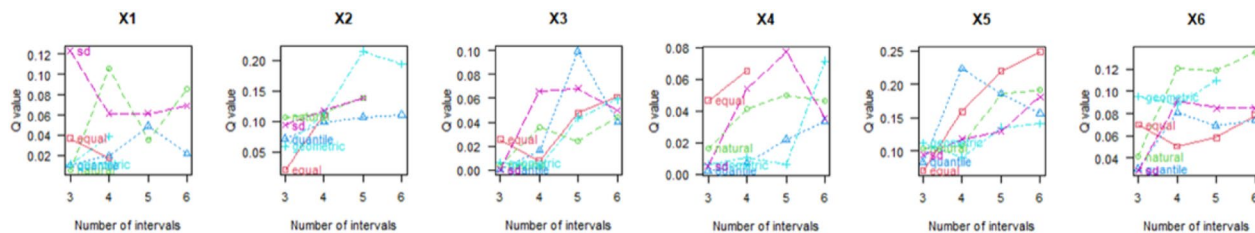| Influencing factor	X1	X2	X3	X4	X5	X6
q (related to terrain)	0.1231*	0.2150*	0.0995*	0.0771	0.2487*	0.1455*
q (related to hydrological features)	0.1283	0.1035	0.0617	0.1120	0.1100	0.1542*
q (related to plants)	0.5714*	0.5604	0.2735	0.4621*	0.2424	0.1712

* $p < 0.05$

Fig. 10 Statistics of classification methods and number of subdivisions of toponyms related to terrain q-values
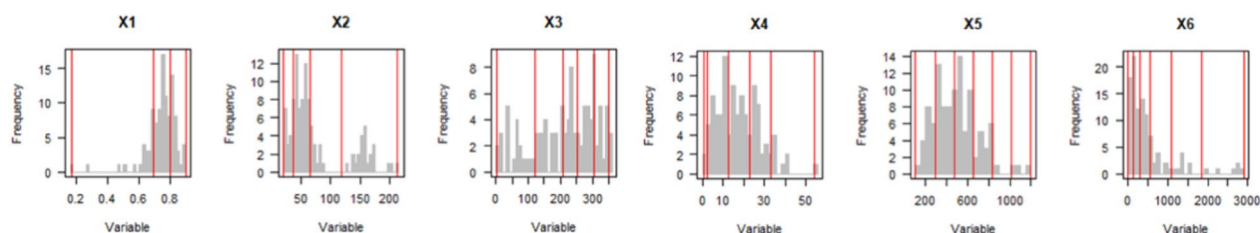

Fig. 11 Discretized best classification of toponyms related to terrain
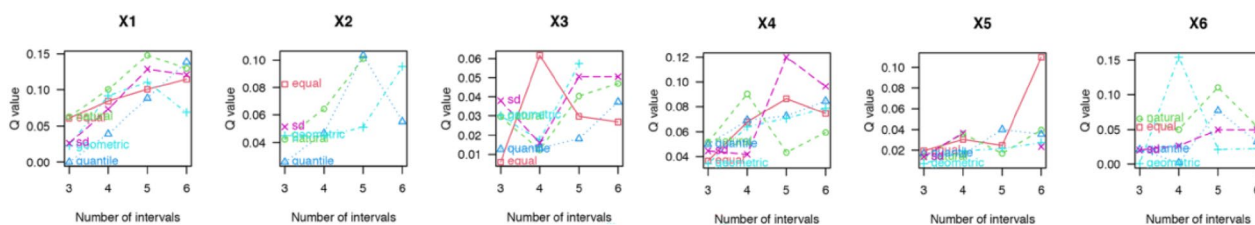

Fig. 12 Statistics of classification methods and number of subdivisions of toponyms related to hydrological features q-values
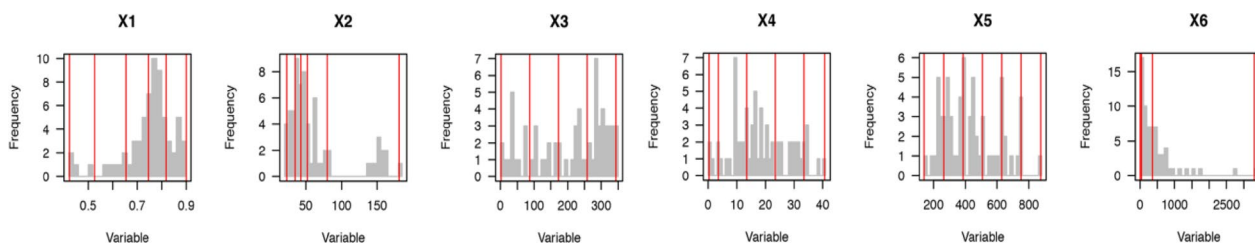

Fig. 13 Discretized best classification of toponyms related to hydrological features

As shown in Table 7, the results of factor detection indicated that the factors influencing the spatial pattern of toponyms in the geomorphology category were, in order of significance ($p < 0.05$), elevation > degree of undulation > shortest river distance > NDVI > slope direction. Elevation was a decisive factor in the spatial patterns of the toponyms. The elevation distribution of traditional village toponyms in western Hunan revealed that toponyms related to terrain were concentrated in areas with an elevation of less than 500 m, accounting for 54.21% of the total. This indicated that transportation became inconvenient for human production and life as the elevation increased. Therefore, villages were distributed in areas with lower elevations. The vast majority of geomorphology toponyms were distributed in an area with 30–75 m degrees of undulation, accounting for 63.55% of the total. In a higher-elevation environment and slightly undulating terrain, it causes inconvenience to transportation and is less affected by external factors. This reduced the influence of the outside world on traditional villages and provided an essential foundation for their formation and development. However, the terrain may have been treacherous, making it difficult for people to live and produce here. Traditional villages could develop unique characteristics, such as customs and cultures with local characteristics, and become preserved throughout history.

Factor interaction detection was performed on terrain toponyms based on single-factor detection. The detection results are shown in Table 8. The magnitudes of interactions driving this effect are shown in Fig. 16. The driving effects of factors influencing the spatial patterns of toponyms related to terrain were not independent but showed nonlinear or two-factor enhancement effects. This indicated that the interaction of any two of the six driving factors in this study had a significant driving effect on the spatial patterns of the terrain toponyms.

As shown in Fig. 16, X3∩X5 was the dominant driving factors. The q-value was 0.4716, and the combined effect of elevation and slope direction was a significant underlying condition for the distribution of toponyms related to the terrain. Moreover, the q-values of X2∩X3, X2∩X5,
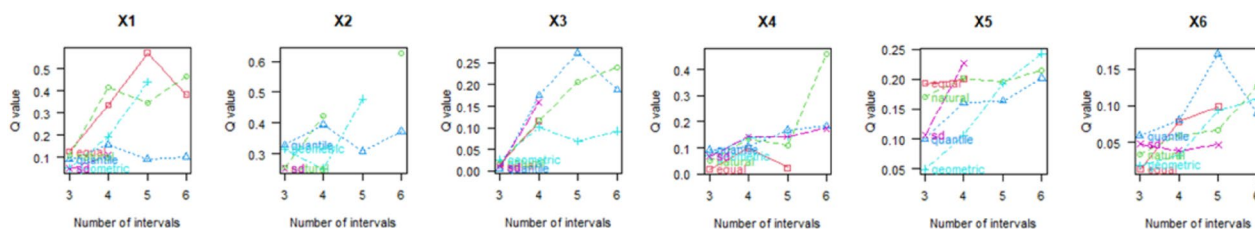

Fig. 14 Statistics of classification methods and number of subdivisions of toponyms related to plants q-values
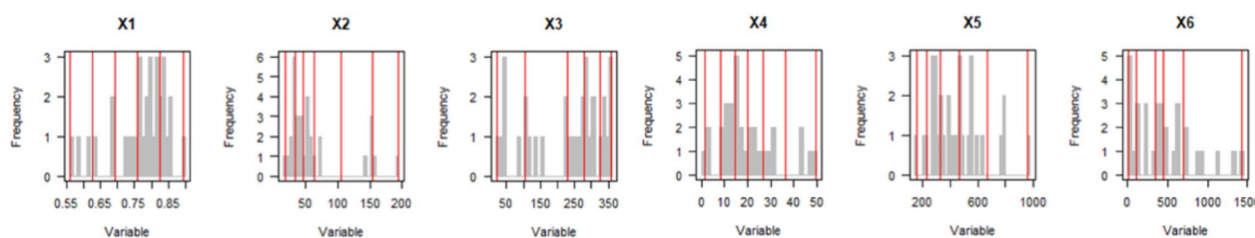

Fig. 15 Discretized best classification of toponyms related to plants

Table 8 Interactive detection of geomorphologic influencing factors

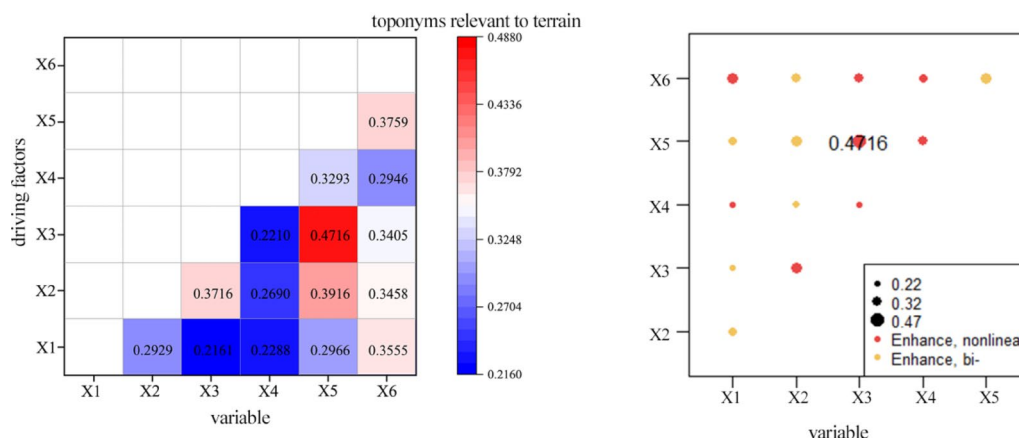|	X1	X2	X3	X4	X5	X6
X1	NA	NA	NA	NA	NA	NA
X2	0.2929	NA	NA	NA	NA	NA
X3	0.2161	0.3761	NA	NA	NA	NA
X4	0.2288	0.2590	0.2210	NA	NA	NA
X5	0.2966	0.3916	0.4716	0.3293	NA	NA
X6	0.3555	0.3458	0.3405	0.2946	0.3759	NA

Fig. 16 Interaction detection of influencing factors for toponyms related to terrain

X5∩X6, and X1∩X6 were similar to those of the most influential factors. Thus, the spatial distribution of toponyms related to terrain was affected by a combination of factors.

The spatial distribution of toponyms related to the hydrological features (Table 7, Figs. 12, 13) revealed that the shortest river distance was the main influencing factor. Lakes and rivers affect the advantages of agricultural production conditions and convenience of production and living facilities. This was the dominant factor influencing the location distribution of toponyms related to hydrological features.

As shown in Table 7 and Figs. 14, 15, the factors influencing the spatial pattern of toponyms related to plants were in the following order: NDVI > slope direction. Western Hunan has luxuriant evergreen vegetation throughout all seasons. It is a subtropical evergreen broad-leaved forest area with high vegetation coverage, and places with rich plant resources were hotspots for toponym distribution. In addition, plants could not easily survive in areas with significant topography, and toponyms related to plants were distributed in areas with gentle topography.

Humanistic landscape toponyms

1. Ancestral idea

   Confucianism has influenced China since ancient times, and the idea of the clan bloodline has occupied a critical position in people's lives, leading to the formation of unique toponyms related to surnames. In the conflict between immigrant and local cultures, immigrant families live in clusters to unite the entire family and perpetuate their family line. With the village as the outside and the clan as the inside, the

village name is often based on the family surname, reflecting the historical origin of the village culture.

For instance, Gongjiawan Village was built between the late Ming and early Qing Dynasties and was initially inhabited by the Yao people. During the Ming Dynasty, the ancestors of the Gong Clan moved from Jiangjiaping in Yuanling County and settled there; consequently, the name was changed to Gongjiawan. Another example is Zhangjialiu Village, which was built in the early Qing Dynasty. This village, initially called Tangdiping, was on the western bank of the Yuanjiang River. Subsequently, the Zhang family moved there and then grew and prospered; therefore, the name was changed to Zhangjialiu.

2. Folk beliefs

   Western Hunan is inhabited by many ethnic groups and possesses diverse languages and cultures. They intertwine to form a unique western Hunan culture. Among them, the Tujia and Miao ethnic groups had the greatest number of people. Thus, the toponyms of traditional villages in western Hunan are profoundly influenced by the Tujia and Miao languages. Moral toponyms consist of two categories: good wishes and dialectal meanings. For instance, in the name of Hangji Village, Hang means canyon, and Ji refers to tea. The village's name means a canyon filled with tea, reflecting the area's primary industry. Moreover, in the name of Liangdeng Village, Liangdeng means where the eagles landed in the Miao language, indicating that its terrain is dangerous and isolated.

3. Mode of production and lifestyle

The trade of surplus production goods, that is, commodity trade, emerged in the late primitive period. Since the Song Dynasty, China's commodity economy has developed rapidly. A grass market appeared in many areas, including the commodity trading distribution center. Therefore, if a toponym can be reproduced during commercial distribution, its value should not be ignored. Agricultural production is the basis for human survival and provides people with their daily needs. Toponyms may reveal information about agricultural production in ancient times. In the Ming and Qing Dynasties, rice cultivation was the primary industry, and most of the economic toponyms that appeared were terraces and fields. Many handicraft industries, such as rice milling, were developed, and toponyms such as rice and mill appeared. During the Ming and Qing Dynasties, Hunan's smelting and casting industries developed rapidly, resulting in the emergence of mineral and metal toponyms, such as iron and copper. The toponyms of different periods reflect the production methods and activities of different stages of development in western Hunan. The toponyms of production and life landscape were evenly distributed in the spatial center of each county, reflecting the central effect of economic development in western Hunan. In addition, toponyms related to economy and transportation were clustered near historical trails in the Ming and Qing Dynasties. These areas had convenient transportation and an active economy, affecting the formation of toponyms.

Discussion
Research value of traditional village toponyms
Many studies have been done on the spatial distribution [1, 80], architectural art, and history [12] of traditional villages in China, but there is a lack of research on toponyms, which include essential heritage information, such as regional characteristics and historical memories. Our study analyzed the distribution and causes of toponyms of traditional villages in western Hunan from two dimensions of time and space and traced the interaction between ancestors and the natural environment, social change, ethnic migration, economy, lifestyle, and belief in the formation of toponyms in traditional villages. Thus, the toponym as intangible cultural heritage is of great importance to the historical and cultural value, which is consistent with the findings of other scholars [13, 49].

Formation mechanism of the spatial patterns of toponyms
Factors influencing the shift of spatial gravity center of toponyms
Toponym spatial patterns are often driven by the shared aspirations of a group of people in a particular geographic area and at a particular time. The naming of places is a reaction to people's perception of their surroundings [31]. The people of various ethnic groups who lived in ancient western Hunan for generations created tens of thousands of toponyms. These toponyms are sketches of the natural environment, traces of the social history, carriers of cultural information, living fossils of history and culture engraved on the ground of western Hunan [40], and valuable cultural treasures left by the ancestors of various ethnic groups. Behind the spatial pattern of toponyms lies a real historical memory closely related to historical population and migration, economy, and natural environment. Migration movements and wars during the historical period have considerably impacted the spatial pattern of traditional villages within western Hunan. Then, ancient people living in diverse areas developed distinct perceptions of their environment. Consequently, naming place names by communities rooted in varied social and environmental contexts has given rise to discernible spatial patterns.

(1) The shift of spatial gravity center of natural landscape toponyms

During the Qin and Han Dynasties, the government set up counties extensively to strengthen its control over western Hunan, creating conditions for the migration of people from the north during the Wei, Jin, and North–South Dynasties. There was a constant stream of people from the central plains migrating southward. During theSui and Tang dynasties, Hunan had fewer wars most of the time and was more socially stable. Hence, the population from the north continued to move southward, and most of the population from the central plains moved into western Hunan along the valleys of the Lishui and Yuanshui watersheds. The Ming and Qing dynasties were the prime period of immigration in western Hunan, with a large number of immigrants pouring into the region. Due to the overflowing population capacity of the plain and the influence of the policy of Change of Making Native Official into a Uniform Official System, many Han Chinese immigrants poured into the mountainous areas of western Hunan, which was sparsely populated before [79].

In the mountainous region of western Hunan during the Qing Dynasty, the number of people proliferated, as did the number of traditional villages. As seen in Fig. 9, from the Qin to the Qing dynasty, the gravity center of

natural landscape toponyms tends to move toward the mountainous areas of western Hunan. This region is characterized by complex terrain and relative inaccessibility, and as can be seen in Fig. 17, it is significantly backward in terms of population and economy. This has resulted in a region where people's lives and production are closely linked to the natural environment and where people need to adapt to the natural environment. With low productivity levels and the threat of natural disasters, there is a greater dependence on natural resources and, therefore, a more excellent worship and reverence for nature. This reliance on nature is also reflected in toponyms by having mountains, rivers, grasses, and trees in the natural environment. The gravity center of toponyms in the natural landscape category has shifted toward mountainous areas (Fig. 9).

(2) The shift of spatial gravity center of humanistic landscape toponyms

Humanistic factors provided a stable background for generating the spatial characteristics of traditional villages in western Hunan. Since ancient times, western Hunan has been rich in diverse ethnic cultures and religious beliefs. It has nurtured people of various ethnic groups, mainly the Miao and Tujia. Therefore, the formation and development of 44.59% of the toponyms of traditional villages in western Hunan were influenced by religious beliefs, customs, lifestyles, and methods of production of various ethnic groups.

The spatial pattern of humanistic landscape toponyms has changed due to economy, population, migration, and war factors, which do not act independently but synergistically influence the spatial pattern of toponyms. From the Qin and Han Dynasties to the Ming Dynasties, western Hunan has been a place of military competition for generations, not only guarding troops at land and water transportation hubs but also building military forts. These military forts were the earliest prototypes of towns in western Hunan, bringing in many immigrants and advanced production techniques and rapidly promoting the economic development of the regions. It can be seen from the toponyms relevant to architecture that a considerable part of them originated from military buildings. Toponyms relevant to architectures formed in Huaihua during the Ming Dynasty were one of the reasons why the gravity center of humanistic landscape toponyms moved toward the south. From the Ming to Qing dynasty, the gravity center of humanistic landscape toponyms shifted toward Yuanling in the northeast, which is strongly
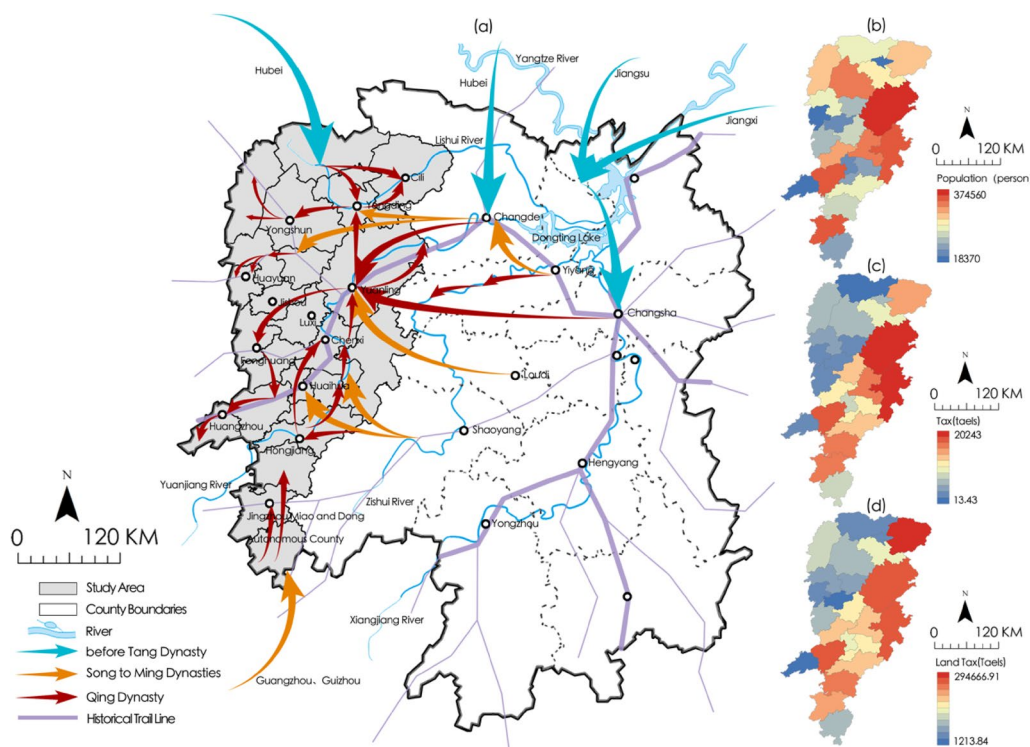

Fig. 17 Western Hunan historical population migration and tax, population distribution. **a** Population migration in western Hunan; **b** Population statistics for the Jiaqing period of the Qing Dynasty; **c** Tax statistics for the Jiaqing period of the Qing Dynasty; **d** Land tax statistics for the Jiaqing period of the Qing Dynasty

Liu *et al. Heritage Science*   (2024) 12:171

Page 21 of 28

related to economic development. In economically developed areas, commercial and industrial activities are more active, and traces of human activities are often reflected in the toponyms formed. The economic development within western Hunan was highly unbalanced. During the Qing Dynasty, the middle and lower reaches of the Yuanshui River basin were places of settlement for foreign commercial immigrants due to the convenient water transportation. Among them, the Yuanling area on the mainstream of the Yuanshui River was one of the leading destinations for Jiangxi immigrants to Hunan, where the economy was the most developed and one of the highest taxed regions(Fig. 17), which may explain why the gravity center of the humanistic toponyms shifted in the direction of Yuanling(Fig. 9).

Regulatory power of spatial patterns of toponyms

(1) Environmental orientation

During the period of underdeveloped natural science and productivity, people continuously adapted to nature to survive, forming the concept of unity between nature and humans. The natural environment formed the basis for site selection and construction of traditional villages. This affected the naming of traditional villages. Natural elements, such as mountains, rivers, flowers, and plants, were figuratively presented in traditional village toponyms, reflecting the critical role of the environment in forming traditional village toponyms.

(2) Immigrant integration

The intermingling of ethnic groups in localization is an essential basis for forming traditional village names, with surnames and ethnic groups as symbols. For instance, the toponyms with implied meanings contained deep cultural connotations. They reflected the characteristics of a nation and recorded the local economy, political activities, folklore, religious beliefs, and other humanistic characteristics. Toponyms' origin, development, and demise were closely related to local natural environments, historical changes, development, and construction.

The unique natural environment and historical development of western Hunan have led to a unique toponym system in the settlement areas of minorities. Systematic excavation and research are of great significance for understanding the natural environment, history, and cultural evolution of the minority areas in western Hunan, the inheritance of an excellent ethnic culture, and the development of ethnic areas.

(3) Behavioral activities

People's behaviors and activities were reflected in toponyms in various ways during different historical periods. Behaviors include labor, business, building houses, and commemoration. People in western Hunan recorded the process of building traditional villages, including building houses, repairing roads, and comducting rituals. In addition, they recorded the routes of village expansion and development through business and farming. Both internal and external interactions promoted village formation and development. In the spatial construction and clan reproduction of traditional villages in western Hunan, participating in activities was a critical regulating power for the spatial distribution of toponyms.

(4) Inherited changes

Village toponyms are inherited as a reflection of the will of the village community. Village toponyms changed in both folk and official ways. Folkloric toponyms were often used to beautify village toponyms. Consequently, toponyms related to implied meanings were created. This type of toponym often reflects people's aspirations and pursuit of a better life. People in different periods yearn for different things; thus, toponyms related to implied meanings reflected changes over time. Chinese people attach significance to blessing words because in ancient times when productivity was low, people could not explain many phenomena and were in awe of them. For instance, language was a mystery. People believed that words would come true and that good words and phrases would bring good luck. Therefore, they used words with good wishes as toponyms to pursuit a better life and achieve their wishes.

Curing process of spatial patterns of toponyms

(1) Topophilia

People revered nature and were deeply attached to the natural environment in which they lived. In site selection and construction of villages, they conducted a full investigation of the human environment, measuring the conditions for survival, safety and security, space for development, and aesthetic taste. Topophilia caused natural factors, such as terrain, hydrological features, and plants, to influence the formation of traditional village toponyms in western Hunan. Therefore, village toponyms related to terrain, hydrological features, and plants gradually solidified in topophilia, forming a stable spatial distribution.

Liu *et al. Heritage Science*   (2024) 12:171

Page 22 of 28

(2) Localization

Localization was a vital basis for village toponyms related to surnames and nationalities as symbols. It recorded the origin and development of the toponym culture of traditional villages in western Hunan. Moreover, it portrayed local customs. As reflected in many ancient poems, the hometown complex has always been essential to Chinese cultural values. Toponyms also reflected homesickness, serving as not only the hometown name but also nostalgia for the hometown of relatives. Toponyms related to surnames aroused people's sense of belonging to their hometown. A strong sense of homeland helped the stable development of the region and was the key to maintaining regional unity. Cohesion was a prerequisite for maintaining clan integrity. Villages named based on surnames could bind clans. This identification was beneficial for the continued development of a clan and a powerful motivator for a group. Toponyms influenced people's sense of belonging to a clan.

Western Hunan has had many immigrants since the Song Dynasty. The immigrants faced mutual exclusion and conflict with the local culture. Moreover, they had to cope with the problems of xenophobia and their incompatibility with the local environment. Immigrant families lived in clusters to unite the family and perpetuate their family lines. With the village as the outside and the clan as the inside, the village name was often accompanied by the family surname, indicating the village residents' kinship and reflecting the village's historical origin. As the village population grew, its carrying capacity tended to saturate, resulting in further migration. During the historical development of traditional villages in western Hunan, the localization process led to unique toponym systems and distribution characteristics.

(3) Lifestyles

Transportation, buildings, and economic orientation embody social culture, lifestyles, and production methods. Activities have complex relationships. The behaviors embodied in village toponyms are generated in everyday life, including labor, business, building, and commemoration. Participation in behavioral activities was an essential foundation for western Hunan's traditional village toponym culture. The ancestors used activities such as building houses and roads to recount the process of building the material spaces of traditional villages. Traditional village development was recorded through business and farming activities. Internal and external interactions contributed to cultural nurturing and diffusion.

Formation process and characteristics of toponym spatial patterns

Toponyms depend on space, are highly compatible with the geographic environment, and firmly connect to humanistic activities. Through an analysis of the influencing factors, regulatory power, and curing process of the spatial distribution of toponyms in traditional villages in western Hunan, the specific formation mechanism of the spatial pattern of toponyms in these villages was summarized and categorized (Fig. 18).

Multiple influencing factors formed the current toponym system and spatial patterns of traditional village toponyms in western Hunan over the course of different regulatory powers and long-lasting curing processes. Western Hunan is divided into two spatial patterns of toponyms: naturally dominated northwest and humanistically dominated southeast.

(1) Naturally dominated northwest

The northwestern mountainous region is in the Wuling Mountains. Relatively treacherous terrain is formed at high altitudes and in undulating terrains. This reduced the influence of the outside world on traditional villages. This provided an essential foundation for forming and developing traditional villages and played a prominent role in their names. Natural elements, such as terrain, hydrological features, and plants, are presented figuratively in traditional village toponyms. This reflects the environment's critical role in forming traditional village toponyms [63]. The ancient ancestors revered nature and had a deep attachment to the natural environment in which they lived. Natural factors, such as terrain, hydrological features, and plants, were essential for forming traditional village toponyms in western Hunan, gradually forming a stable spatial distribution.

(2) Humanistically dominated southeast

The humanistically dominated spatial pattern of toponyms in the southeast concerns the low-mountainous and hilly areas in the southeastern part of western Hunan. This spatial pattern of toponyms formed due to the influence of humanistic factors, such as transportation and the economy.

The southeastern part of western Hunan experienced frequent migration, including large-scale influxes of people into ethnic minority areas. They first lived in the plains and areas with convenient transportation; however, as they became saturated with people, they had to move elsewhere. Although these areas are hilly and unsuitable for farming, migrants settled along the southern and central Hunan Rivers. The complexity and dispersion of the
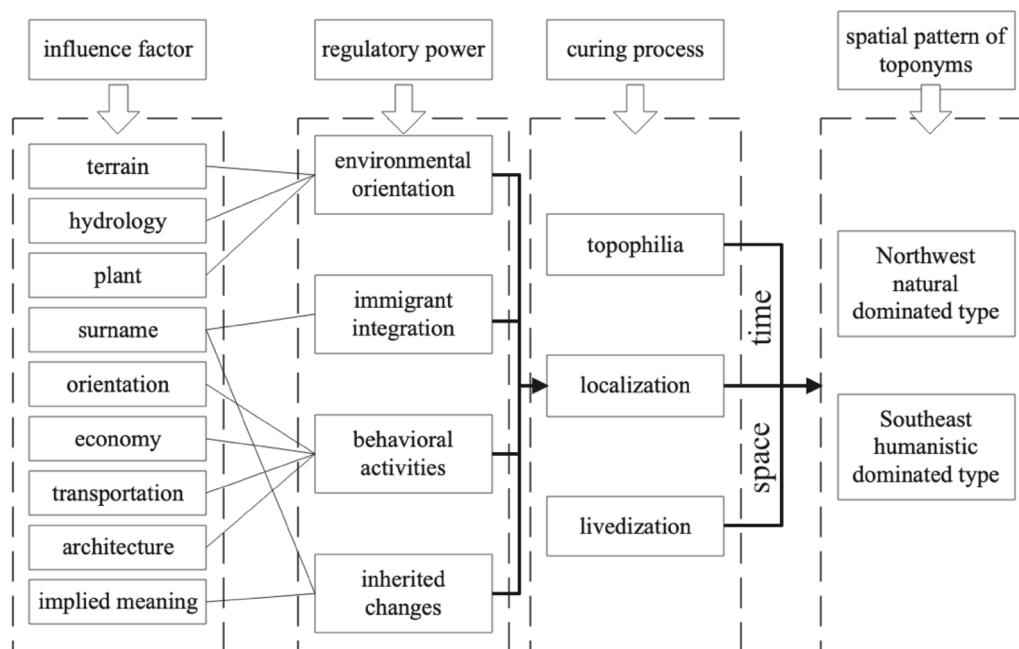
Liu *et al. Heritage Science*   (2024) 12:171

Page 23 of 28

Fig. 18 Formation mechanism of spatial patterns of toponyms

migrants' origins contributed to the diversity of toponyms related to surnames in western Hunan.

The unique distribution characteristics of toponyms formed during surname localization. This reflects the population migration and settlement during the historical development of western Hunan and promotes the formation of a spatial pattern of toponyms dominated by culture in the southeast.

The southeastern part of western Hunan was economically and politically important. During the Ming and Qing Dynasties, the region was one of the main sites of the activities of the insurgent army of the famous general Zhang Xianzhong. Moreover, historical trails from the Ming and Qing Dynasties passed through this region. It was an essential node for conducting economic transactions and other activities and recounting the process of building the physical space of traditional villages with activities such as building houses and roads. It recorded the development of traditional villages through business and farming activities. This further promoted the formation of a toponym spatial pattern dominated by culture in the southeast.

The southeastern part of western Hunan has a long history. The toponyms of villages were inherited as an embodiment of the will of village settlements, along with changes in human cognition and social backgrounds. Village toponyms were altered through inherited changes. The formation of village toponyms has a long history. The origin, development, and demise of traditional village toponyms reflect the local natural environment, political and religious beliefs, economy, construction, folklore, and other humanistic characteristics during different periods [64].

Thus, the spatial pattern of humanistically dominant toponyms in southeastern Hunan formed due to the combined effects of these factors. Historical evolution, geographic environment, ethnic aggregation, population migration, cultural inheritance, political factors, and economic development significantly impacted these patterns [60].

Protections of toponym culture
Legislative protection
The protection of toponym culture requires a legal basis. In 1987, the Hunan Provincial People's Government introduced local regulations, such as Measures for the Administration of Toponyms in Hunan Province. However, these measures address only the management of toponyms, such as the delineation of departmental responsibilities and procedures relating to the renaming and naming of geographical names while ignoring the protection of toponym culture. The absence of relevant laws and regulations has prevented the adequate protection of toponym culture. Given that toponyms are included in the intangible cultural heritage and the international attaches great importance to protecting cultural heritage, the corresponding legal basis should be formulated to protect toponyms in western Hunan.

Establishing a toponym database

Currently, most of the existing village name identification systems only mark the village's name but do not mention the relative information, such as the name's origin, meaning, and connotation. As a result, the current identification system can only reflect a village's geographical location but not its cultural connotation. Therefore, it is necessary to establish the toponym database for western Hunan, strengthen the information construction, improve the toponym identification system, and fully reflect the geographical characteristics and cultural connotation. For representative historical toponyms, explanatory texts must be added. In addition, establishing the toponym database can provide the public with accurate toponym search functions and realize information sharing. Thus, toponyms with historical stories would be brought to the public's attention, significantly enhancing and strengthening public protection awareness.

Regional protection of toponym culture

Different toponyms exhibit certain geographical aggregations. It is possible to rely on toponym regional characteristics to carry out the protective planning of toponym cultural space, to form a toponym network with an orderly layout of a toponym block structure, evident toponym characteristics, and rich cultural connotations, and to achieve the hierarchical, serialized, and standardized management and adequate protection of various types of toponyms of traditional villages in western Hunan. Furthermore, traditional villages have developed across regions. At the same time, relying on geographical and cultural circles to develop the cross-regional protection mode of traditional villages is conducive to the deep mining and protection of the cultural characteristics of geographical names in traditional villages. For instance, the region dominated by natural toponyms in northwestern Hunan should emphasize the protection of natural landforms and the ecological environment in developing villages according to environmental needs and avoid overexploitation of the natural environment. In the region dominated by cultural toponyms in the southeast of western Hunan, the development of villages should reflect the characteristics of the historical trajectory of humanistic activities.

Create toponym cultural landscape tourism routes

Nowadays, tourism is an essential means for developing traditional villages. The traditional village characteristic tourism development mode of "traditional village toponym + tourism" can be launched, centered on distinctive toponym zoning. On the one hand, in tourism planning, events, folk customs, food, and other elements related to toponyms can be deeply explored, and high-quality tourism routes with cultural experiences such as research, health care, and sightseeing can be carried out. On the other hand, toponym cultural resources can be used to carry out immersive experience activities. By creating characteristic scenes of toponym culture experience, combining rural public space, characteristic villages, and folk culture, tourists can experience the connotation of geographical name culture. These can turn tourism into a boost for the cultural excavation and preservation of toponyms. For instance, the Toponym Cultural Tourism Route relies on rich Tujia folklore and profound historical and cultural resources in western Hunan. Taking Longshanliye Ancient City, Wulong Mountain Grand Canyon, Luotaxiang, Rebala Village, and Shoubadong Village et al. as the points, and taking the National Highway, Provincial Highway, and Youshui River and Mengdong River as the axes to form a tourist route focusing on the experience of Tujia ethnic minority customs, the cultural charm of Tujia toponyms will be experienced during the tour (Fig. 19).

Limitations

This study examined the spatial pattern and formation mechanisms of toponyms in traditional villages in western Hunan, providing a new research method for investigating village toponyms in other regions. However, this study had some limitations. First, due to the limited number of traditional villages in western Hunan, all subcategories of toponyms could not be sufficiently

Fig. 19 Cultural tourism route of the Tujia exploration line toponym

Liu *et al. Heritage Science*   (2024) 12:171

Page 25 of 28

analyzed. Second, the influence of humanistic factors was analyzed qualitatively, which could quantitatively express the magnitude of influence. Quantitative research methods should be used in the future to determine the influence of humanistic factors.

Conclusions

As essential geographical and cultural landscape carriers, village toponyms contain natural, historical, cultural, social, and geographical information. However, the natural and humanistic factors are synthesized at regional scales to systematically explore spatial distribution characteristics and formation causes of toponyms in different time and spatial conditions, which still need to be improved. This study analyzed the cultural characteristics, spatial distribution, and formation mechanism of traditional village toponyms in western Hunan by collecting and organizing the geographical and historical economy, population, and war information of traditional village toponyms and adopting mathematical statistics combined with GIS kernel density analysis, the standard deviation ellipse method, and a parameter-optimized geodetector to elucidate factors that influence the emergence of toponyms and the intrinsic formation principles of their geographical distribution of toponyms.

This study revealed 370 traditional village toponyms in western Hunan. Village toponyms were divided into two major categories: natural landscape toponyms and humanistic landscape toponyms. The natural landscape category included terrain, hydrological features, and plants. The humanistic landscape category included six subcategories: surname, orientation, economy, transportation, architecture, and implied meaning.

Moreover, the distribution of village toponyms varied significantly in different regions of western Hunan due to the different geographic environments, history, culture, and economic conditions. Among the toponyms in the natural landscape category, toponyms related to terrain had a strong geographic aggregation, tended to be distributed along mountainous terrain, and were mainly distributed around mountains. Toponyms related to hydrological features were frequently found in developed water systems. They were distributed along the water system of western Hunan, with the confluence of tributaries as the main distribution range and spread outward along the two sides of the river. Plant-related toponyms were primarily distributed in areas rich in plant resources. The spatial differentiation of humanistic toponyms was apparent. The spatial distribution pattern was dense in the southeast and sparse in the northwest. Among them, toponyms related to surnames were mainly concentrated in the central and southwestern regions, reflecting population migration

and settlement processes during the historical development of western Hunan. The southeastern region, relying on superior natural conditions and radiation driven by historical trails, became a dense area of toponyms related to economy, architecture, and transportation. Toponyms related to implied meanings became popular in the northwestern part of the country.

Furthermore, we summarized the specific paths of spatial pattern formation. The influencing factors included terrain, hydrological features, plants, surnames, orientation, economy, transportation, architecture, and implied meanings. Regulatory power was divided into four types: environmental orientation, immigrant integration, behavioral activities, and inherited changes. The curing process was divided into topophilia, localization, and lifestyles. Multiple influencing factors in the different regulation dynamics and long-lasting curing processes form the current toponym system of traditional villages in western Hunan, and the spatial pattern of toponyms was dominated by the natural class in the northwest and the humanistic class in the southeast.

As local cultural heritage, toponyms urgently require preservation and inheritance. The protection of traditional village toponyms requires legislation, assistance of social organizations, public participation, and creation of toponym cultural tourism routes.

Many traditional toponyms have disappeared in the context of rapid urbanization. In contrast, some toponyms with deep historical and cultural significance have arbitrarily changed due to the influence of modern values. Protecting traditional village toponyms includes not only names but also traditional history and culture. This study on the characteristics and spatial patterns of toponyms provides a new method for excavating the formation and development of traditional village toponym culture and a scientific basis for the recognition, protection, and inheritance of traditional village toponym culture.

Liu *et al. Heritage Science*   (2024) 12:171

Page 26 of 28

Code availability
Not applicable.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

References

1. Ma HD, Tong YQ. Spatial differentiation of traditional villages using ArcGIS and GeoDa: a case study of Southwest China. Ecol Inform. 2022;68:101416. https://doi.org/10.1016/j.ecoinf.2021.101416.
2. Perono Cacciafoco F, Cavallaro F. Place names: approaches and perspectives in toponymy and toponomastics. Cambridge: Cambridge University Press; 2023.
3. Capra GF, Ganga A, Filzmoser P, Gaviano C, Vacca S. Combining place names and scientific knowledge on soil resources through an integrated ethnopedological approach. CATENA. 2016;142:89–101. https://doi.org/10.1016/j.catena.2016.03.003.
4. Nash J. Folk toponymy and offshore fishing ground names on the Dudley Peninsula, Kangaroo Island, South Australia. Isl Stud J. 2010;5(1):43–60. https://doi.org/10.1016/j.ijintrel.2009.11.001.
5. Škofic J. Microtoponyms as an important part of Slovenian cultural heritage. Acta Geogr Slov. 2017;57(1):141–52. https://doi.org/10.3986/AGS.4670.
6. Gannett H. The origin of certain place names in the United State. USA: Washington government printing office; 1905.
7. Stewart GR. Names on the land: a historical account of place-naming in the United States. Boston, MA: Houghton Mifflin; 1945.
8. Fagundez J, Izco J. Spatial analysis of heath toponymy in relation to present-day heathland distribution. Int J Geogr Inf Sci. 2016;30(1–2):51–60. https://doi.org/10.1080/13658816.2015.1017729.
9. Perono Cacciafoco F, Nanetti A. Linguistic contact in prehistoric Italy: at the origins of the placename imola. Names. 2015;63(3):158–70. https://doi.org/10.1179/0027773815Z.000000000111.
10. Xiao F, Wang H. A study on the impact of new rural construction on toponyms of administrative villages in Hunan and its countermeasures for toponymic culture protection. China Econ. 2021;04:131–2.
11. Madden DJ. Pushed off the map: toponymy and the politics of place in New York City. Urban Stud. 2018;55(8):1599–614. https://doi.org/10.1177/0042098017700588.
12. Zhang L, Lu P, Yan LJ, Li X, Wang X. Unique traditional villages on the loess plateau of China: historic evolution and challenges to sustainable development of silo-caves. Herit Sci. 2021;9:1–19. https://doi.org/10.21203/rs.3.rs-415252/v1.
13. Zhao F, Fu Y, Luan GZ, Zhang SJ, Xie ZQ. Spatial-temporal characteristic analysis of ethnic toponyms based on spatial information entropy at the rural level in northeast China. Entropy. 2020;22(4):393. https://doi.org/10.3390/e22040393.
14. Buza M. On the origins and historical evolution of toponymy on the territory of Romania. Rom Journ Geogr. 2011;55(1):23–36.
15. Qian SW, Kang MJ, Weng M. Toponym mapping: a case for distribution of ethnic groups and landscape features in Guangdong, China. J Maps. 2016. https://doi.org/10.1080/17445647.2016.1201017.
16. Deepadung S. Toponyms in the western region of Thailand. Manusya: J Humanit. 2003;6(2):31–65.
17. Abdikhalikovna KF. Principles of toponyms (place names) classifications. Int J Multicult Multireligious Underst. 2020;7(6):73–9. https://doi.org/10.18415/ijmmu.v7i6.1738.
18. Kang L, Yang ZP, Han F. Spatial distribution of intangible cultural heritage in Xinjiang and its influencing factors. Desert China. 2022;42(01):158–66. https://doi.org/10.7522/j.issn.1000-694X.2021.00146.
19. Tian L, Shi BX, Sun FZ, Zhang SX, Wang BB. Spatial correlation between traditional villages and intangible cultural heritage in the Yellow River Basin and its influencing factors. Arid Zone Resour Environ. 2023;37(03):186–94.
20. Yang Y, Hu J, Li YJ, Chen Y, Jiang L. Research on the spatial structure and influencing factors of forest countryside in China based on GIS. Arid Zone Resour Environ. 2021;35(06):182–91. https://doi.org/10.13448/j.cnki.jalre.2021.175.
21. Thomas M. Book-review shan hai ching; or, the classic of mountains and seas. J Relig. 2001;81(4):678–80.
22. Sellmann JD. Timing and rulership in Master Lu's Spring and Autumn Annals (Lüshi Chunqiu). Albany: State University of New York Press; 2002.
23. Miller RA. Old Japanese phonology and the Korean-Japanese relationship. Language. 1967;43(1):278–302. https://doi.org/10.2307/411398.
24. Ren JL, Gong P. A brief analysis of place name's regionalism. World Reg Stud. 2011;20(03):163–70.
25. Taylor I. Words and places: or, etymological illustrations of history, ethnology, and geography. New York: Macmillan; 1873.
26. Egli JJ. Nomina geographica: sprach-und sacherklärung von 42000 geographischen namen aller erdräume. F. Brandstetter; 1893.
27. Nagl JW. Geographische namenkunde: methodische anwendung der namenkundlichen grundsätze auf das allgemeiner zugängliche topographische namenmaterial. F. Deuticke; 1903.
28. Perono CF. Beyond etymology: historical reconstruction and diachronic toponomastics through the lens of a new convergence theory. Acta Linguistica, J Theor Linguistics. 2014;8(3):79–98.
29. Perono Cacciafoco F, Binte Adzman N, Binte Sharin NS. Mythical place names: naming process and oral tradition in Indonesian toponymy. Rev Hist Geogr Toponomastics. 2014;12(23–24):25–35.
30. Tent J, Blair D. A clash of names: the terminological morass of a toponym class. Names. 2019;67(2):65–77.
31. Li RL. Chinese dialectology. Shanghai: Shanghai Educational Publishing House; 1998.
32. Stewart GR. A classification of place names. Names. 1954;2:1–13.
33. Stewart GR. Names on the globe. Oxford: Oxford University Press; 1975.
34. Rennick R. How to study placenames. Names. 2005;53(4):291–308.
35. Tent J, Blair D. Motivations for naming: the development of a toponymic typology for Australian placenames. Names. 2011;59(2):67–89.
36. Blair D, Tent J. A revised typology of place-naming. Names. 2021;69(4):30–47.
37. Barteaux J. Urban planning as colonial marketing strategy for the swan river settlement, western Australia. Australas Hist Archaeol. 2016;34:22–31.
38. Laaboudi D, Marouane M. Ait and oulad toponyms: geographical distribution and linguistic implications. J Appl Lang Cult Stud. 2018;1:107–31.
39. Newton J. Rural autochthony? The rejection of an aboriginal placename in Ballarat, Victoria, Australia. Cult Stud Rev. 2016;22(2):114–31.
40. Wang YY, Ge DZ, Zhang TY, Wang YJ. The sustainable development of choronymic cultural landscapes in China based on geo-informatic tupu. Sustainability. 2019;11(16):1–23. https://doi.org/10.3390/su11164302.
41. Hu HN, Zhang LR. Cultural landscapes of toponyms of administrative regions in Shaanxi province. Areal Res Dev. 2013;32(1):170–4.
42. Sun ML, Zeng PF, Zhang HP, Chang Y. Analysis on the spatial distribution characteristics and causes of cultural landscapes of village place names in Jinan. J Geomat Sci Technol. 2020;37(3):319–24. https://doi.org/10.3969/j.issn.1673-6338.2020.03.017.
43. Gilliéron J. Atlas linguistique de la France. Italy: Forni; 1912.
44. Dauzat A. Les noms de lieux: origine et evolution. France: Delagrave; 1926.
45. Li JH, Mi WB, Feng CY, Yang XM. An analysis on toponym cultural landscape based on GIS application in Zhongwei county, Ningxia municipality. Human Geogr. 2011;26(1):100–4. https://doi.org/10.13959/j.issn.1003-2398.2011.01.027.
46. Shi YY. Etymology type and regional distribution difference of place names in Hubei province. Xi'An: Shanxi Normal University; 2016.

Liu *et al. Heritage Science*   (2024) 12:171

Page 27 of 28

47. Chloupek BR. A GIS approach to cultural and historical toponymic research in Nebraska. J Cult Geogr. 2018;35(1):23–43.

48. Chen XX, Hu T, Ren F, Chen D, Li L. Landscape analysis of geographical names in Hubei province, China. Entropy. 2014;16(12):6313–37. https://doi.org/10.3390/e16126313.

49. Wang FH, Zhang L, Zhang GP, Zhang H. Mapping and spatial analysis of multiethnic toponyms in Yunnan, China. Cartogr Geogr Inf Sci. 2014;41(1):86–99. https://doi.org/10.1080/15230406.2013.831529.

50. Tucci M, Ronza RW, Giordano A. Fragments from many pasts: layering the toponymic tapestry of Milan. J Hist Geogr. 2011;37(3):370–84. https://doi.org/10.1016/j.jhg.2011.02.001.

51. Membrado-Tena JC. Interpreting protohistoric societies through place names of landscape features: a case study in València, Spain. Landscape Res. 2021;46(2):1–17. https://doi.org/10.1080/01426397.2021.1914567.

52. Boillat S, Serrano E, Rist S, Berkes F. The importance of place names in the search for ecosystem-like concepts in indigenous societies: an example from the Bolivian Andes. Environ Manage. 2013;51(3):663–78. https://doi.org/10.1007/s00267-012-9969-4.

53. Sousa A, García-Murillo P, Sahin S, Morales J, García-Barrón L. Wetland place names as indicators of manifestations of recent climate change in SW Spain (Doñana Natural Park). Clim Change. 2010;100(s3–4):525–57. https://doi.org/10.1007/s10584-009-9794-9.

54. Jett SC. Place-naming, environment, and perception among the canyon de chelly navajo of arizona. Prof Geogr. 1997;49(4):481–93. https://doi.org/10.1111/0033-0124.00094.

55. Nash J. Do island toponymies exist? Isl Stud J. 2016;11(2):339–42.

56. Cogos S, Roué M, Roturier S. Sami place names and maps: transmitting knowledge of a cultural landscape in contemporary contexts. Arct Antarct Alp Res. 2017;49(1):43–51. https://doi.org/10.1657/AAAR0016-042.

57. Pohl HD. Ortsnamen in einer historisch gewachsenen Kulturlandschaft unter besonderer Berücksichtigung Kärntens und Osttirols. Europäisches J für Minderheitenfragen. 2009;2(2):72–88. https://doi.org/10.1007/s12241-009-0047-y.

58. Conedera M, Vassere S, Neff C, Meurer M, Krebs P. Using toponymy to reconstruct past land use: a case study of "bruesada" (burn) in southern Switzerland. J Hist Geogr. 2007;33(4):729–48. https://doi.org/10.1016/j.jhg.2006.11.002.

59. Caturia ML. Places of power: examining French toponymic spatial patterns in the mississippi river basin. Denver: University of Colorado at Denver; 2018.

60. Luo W, Hartmann JF, Wang FH. Terrain characteristics and Tai toponyms: a GIS analysis of Muang, Chiang and Viang. GeoJournal. 2010;75(1):93–104. https://doi.org/10.1007/s10708-009-9291-8.

61. Zhu ZH, Zhang HY, Zhao JJ, Guo XY, Zhang ZX, Ding YL, Xiong T. Using toponyms to analyze the endangered manchu language in northeast China. Sustainability. 2018;10(2):563. https://doi.org/10.3390/su10020563.

62. Fagúndez J, Izco J. Diversity patterns of plant place names reveal connections with environmental and social factors. Appl Geogr. 2016;74:23–9. https://doi.org/10.1016/j.apgeog.2016.06.012.

63. Gill G. Changing symbols: the renovation of Moscow place names. Russ Rev. 2005. https://doi.org/10.1111/j.1467-9434.2005.00371.x.

64. Herman RDK. The aloha state: place names and the anti-conquest of Hawai'i. Ann Assoc Am Geogr. 1999;89(1):76–102. https://doi.org/10.1111/j.1467-9434.2005.00371.x.

65. Rose-Redwood R, Alderman D, Azaryahu M. Geographies of toponymic inscription: new directions in critical place-name studies. Prog Hum Geogr. 2010;34(4):453–70. https://doi.org/10.1177/0309132509351042.

66. Yeoh BSA. Street-naming and nation-building: toponymic inscriptions of nationhood in Singapore. Area. 1996;28(3):298–307.

67. Rose-Redwood R, Reuben S. From number to name: symbolic capital, places of memory and the politics of street renaming in New York City. Soc Cult Geogr. 2008;9(4):431–52. https://doi.org/10.1080/14649360802032702.

68. Simeu-Kamdem M, Koulbout D. Some features of urban place names in central Africa. Open Access Librar J. 2016;03(8):1–7. https://doi.org/10.4236/oalib.1102914.

69. Light D, Young C. Toponymy as commodity: exploring the economic dimensions of urban place names. Int J Urban Reg Res. 2015;39(3):435–50. https://doi.org/10.1111/1468-2427.12153.

70. Rose-Redwood R, Vuolteenaho J, Young C, Light D. Naming rights, place branding, and the tumultuous cultural landscapes of neoliberal urbanism. Urban Geogr. 2019;40(6):747–61. https://doi.org/10.1080/02723638.2019.1621125.

71. Hu Y, Mao H, Mckenzie G. A natural language processing and geospatial clustering framework for harvesting local place names from geotagged housing advertisements. Int J Geogr Inf Sci. 2018;33(4):714–38. https://doi.org/10.1080/13658816.2018.1458986.

72. Kerfoot H. Geographical names: some current issues in the context of the united nations. Cartogr J. 2004;41(2):89–94. https://doi.org/10.1179/000870404X12536.

73. Wang YY, Wang YJ, Fang L, Ge DZ. Spatial-temporal characteristics and causes of changes to the county-level administrative toponyms cultural landscape in the eastern plains of China. PLoS ONE. 2019;14(5):e0217381. https://doi.org/10.1371/journal.pone.0217381.

74. Bazazo I, Jawabreh OA, Alsarayreh M, Abdelraza H. Towards sustainable documentation of geographical names of touristic and heritage sites in occupied jerusalem using geographical information system (GIS). J Tour Hosp Sport. 2018;35(2):13–22.

75. Fuchs S. An integrated approach to germanic place names in the American midwest. Prof Geogr. 2015;67(3):330–41. https://doi.org/10.1080/00330124.2014.968834.

76. Calvo-Iglesias MS, Diaz-Varela RA, Mendez-Martinez G, Fra-Paleo U. Using place names for mapping the distribution of vanishing historical landscape features: the agras field system in northwest Spain. Landsc Res. 2012;37(4):1–17. https://doi.org/10.1080/01426397.2011.604716.

77. Fuchs S. History and heritage of two midwestern towns: a toponymic-material approach. J Hist Geogr. 2015;48:11–25. https://doi.org/10.1016/j.jhg.2015.01.003.

78. Zhong AN, Wu YK, Nie K, Kang MJ. Using local toponyms to reconstruct the historical river networks in Hubei province, China. Isprs Int J Geo-Inf. 2020;9(5):318. https://doi.org/10.3390/ijgi9050318.

79. Yuan CC, Jiang M. Migration and land exploitation from yuan to qing dynasties: insights from 252 traditional villages in Hunan, China. Sustainability. 2023;15(2):1001. https://doi.org/10.3390/su15021001.

80. Li BQ, Wang J, Jin YB. Spatial distribution characteristics of traditional villages and influence factors thereof in hilly and gully areas of northern Shaanxi. Sustainability. 2022;14(22):15327. https://doi.org/10.3390/su142215327.

81. Li SY, Song YH, Xu H, Li YJ, Zhou SK. Spatial distribution characteristics and driving factors for traditional villages in areas of China based on GWR modeling and geodetector: a case study of the awa mountain area. Sustainability. 2023;15(4):3443. https://doi.org/10.3390/su15043443.

82. Wang FH, Hartmann J, Luo W, Huang PW. GIS-based spatial analysis of tai place names in southern China: an exploratory study of methodology. Ann GIS. 2006;12(1):1–9. https://doi.org/10.1080/10824000609480611.

83. Wang FH, Wang GX, Hartmann J, Luo W. Sinification of Zhuang place names in Guangxi, China: a GIS-based spatial analysis approach. Trans Inst Br Geogr. 2012;37(2):317–33. https://doi.org/10.1111/j.1475-5661.2011.00471.x.

84. Zhang XY, Xiang H, Liu R. Spatial pattern and influencing factors of intangible cultural heritage of music in Xiangxi, central China. Herit Sci. 2022;10(1):1–12. https://doi.org/10.1186/s40494-022-00672-y.

85. Pei HC. Dictionary of ancient and modern place names in Hunan. Changsha: Hunan People's Publishing House; 2000.

86. Zhou HW. Evolution of Hunan administrative region. Changsha: Hunan Normal University Press; 2009.

87. Peng XK. Chronicle of Hunan geographical names. Changsha: Central South University Press; 2016.

88. Department of Civil Affairs of Hunan Province. Hunan gazetteer. Changsha: Hunan Map Publishing House; 2009.

89. Committee HPLRC. Guangxu Hunan chorography. Changsha: Hunan People's Publishing House; 2017.

90. Marin D, Tang M, Ben Ayed I, Boykov Y. Kernel clustering: density biases and solutions. Ieee T Pattern Anal. 2017;41(1):136–47. https://doi.org/10.1109/TPAMI.2017.2780166.

91. Wang JF, Li XH, Christakos G, Liao YL, Zhang T, Gu X, Zheng XY. Geographical detectors-based health risk assessment and its application in the neural tube defects study of the Heshun region, China. Int J Geogr Inf Sci. 2010;24(1–2):107–27. https://doi.org/10.1080/13658810802443457.

92. Song YZ, Wang JF, Ge Y, Xu CD. An optimal parameters-based geographical detector model enhances geographic characteristics of explanatory variables for spatial heterogeneity analysis: cases with different types of

Liu *et al. Heritage Science*   (2024) 12:171

Page 28 of 28

spatial data. Gisci Remote Sens. 2020;57(5):593–610. https://doi.org/10.1080/15481603.2020.1760434.

93. Al-Okaishi A. Exploring the historical distribution of dracaena cinnabari using ethnobotanical knowledge on Socotra Island, Yemen. J Ethnobiol Ethnomed. 2021;17:1–14. https://doi.org/10.21203/rs.3.rs-153442/v1.

94. Atik M, Swaffield S. Place names and landscape character: a case study from Otago region, New Zealand. Landsc Res. 2017;42(5):1–16. https://doi.org/10.1080/01426397.2017.1283395.

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