Construction and characteristic analysis of landscape gene maps of traditional villages along ancient Qin-Shu roads, Western China

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Abstract

The landscape of traditional villages reflects specific geographical and cultural environments, with distinct regional cultural and living space characteristics. An exploration of the deep genetic core of traditional villages from the perspective of "cultural landscape genes" can help reveal the mechanism of historical evolution of regional settlements and provide a reference for maintaining the regional characteristics of traditional villages today. This study focuses on 23 nationally recognized traditional villages along the northern roads of the ancient Qin-Shu roads. The "landscape-gene" theory, centred on both artificial construction and cultural inheritance in traditional villages, was used to develop a method for identifying and extracting the northern roads of the ancient Qin-Shu roads landscape genes in "architecture culture". Then, a genome of the cultural landscape of traditional villages was constructed. Six different dimensions with identified genes, including environmental layout, landscape, architectural landscape, material culture, behavioural culture and mentality culture, were analysed. The results showed the following: (1) the traditional villages on the northern roads of the ancient Qin–Shu roads have 8 genes in the constructed landscape, including 'location layout mainly along mountains and ancient roads, supplemented by water and pictographic patterns', 'orderly, flexible and changeable spatial form', 'natural landscape surrounded by mountains and rivers, culture and scenery blend', 'water in the south and drought in the north', 'agricultural main forest auxiliary production landscape', 'single north section, complex south section courtyard layout', 'load-bearing diversity, good utilization of the gable building structure', 'combination of earth, stone and bamboo, recycled and reused building materials' and 'atmospheric regularity, exquisite and gorgeous building decoration'. (2) There were six cultural landscape genes, such as 'strong personalities and regional customs', 'preference for flavourful and spicy foods, wine and meat', which characterized material culture. 'Romantic history and thrifty values', and a 'combination of elegance and vulgarity' characterized behavioural culture. The mentality of the region was characterized by 'Xiangtu and Shengxing', 'open and inclusive values', and 'varied' beliefs. (3) Philosophical and cosmological underpinnings such as the 'unity of heaven and humanity' and the 'yin-yang and five-element' theory guide human settlements in traditional villages along the northern roads. This study aims to clarify the characteristics of cultural landscapes in traditional villages through the analysis of cultural landscape genes and a resulting mapped genome, which will provide a scientific basis for the sustainable development of cultural landscapes in traditional villages. Cultural genes can protect the inheritance of regional culture and provide a new perspective for the study of traditional villages along linear cultural heritage zones.

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Introduction

Linear cultural heritage is a new type of world heritage [1]. The ancient Qin–Shu roads connects Guanzhong in Shaanxi and the Chengdu Plain in Sichuan and is a cultural channel for the integration of civilization in the Yellow River Basin and the Yangtze River Basin [2, 3]. This cultural channel enables the widespread dissemination of Central Plains culture in the southwest region as well as the integration of local cultural elements, further enriching the connotation of China Central Plain Culture and highlighting both the prosperity of China's transportation civilization and the importance of integrating and developing diverse cultures in China. In 2009, China initiated the application of the World Heritage Site for ancient Qin–Shu roads, after continuous efforts, it was successfully included in the World Heritage Reserve List in 2015. In 2018, the ancient Qin–Shu roads was officially included in the Chinese civilization identification system, forming an important precedent for the protection of Chinese cultural heritage along with the Silk Road, Grand Canal, and others [4]. As an important part of the ancient Qin–Shu roads, traditional villages have much value. However, the current research focuses too much on phenomena and lacks in-depth analysis, resulting in scattered protection of cultural heritage, homogenization of construction and insufficient development of cultural tourism. The above problems can be effectively resolved only by systematically sorting out the cultural landscape elements of traditional villages along the ancient Qin–Shu roads, exploring their internal genetic characteristics, and constructing a macroscopic genetic system for cultural landscapes as a whole. Thus, the sustainable development of traditional villages in linear cultural heritage zones and the protection and inheritance of regional cultural characteristics can be realized.

At present, a series of studies have been carried out by international scholars. Research on traditional villages is mainly carried out on ancient villages, historical and cultural blocks, rural cultural heritage sites and other cultural monuments. Throughout previous studies, traditional villages have made several transitions: from identification as "cultural relics and monuments" to "historical buildings", from systems that allow the "protection of individual buildings" to ones that allow the "protection of historical sites", and then to inclusion within the "overall and regional protection of regions and settlements" [5]. Research coverage ranges from the early implementation of relevant laws and policies [6–9], the study of settlement geography [10, 11], and the movement to protect traditional villages [12, 13], to a range of more specific topics, such as the morphological characteristics of settlements [14, 15], spatial distributions [16], protection and renewal strategies [17, 18], human behaviour and psychological influence [19, 20], and tourism development [21, 22]. Research methodologies are cross-integrated with ecology, anthropology, settlement science, geography and other disciplines, mainly using field investigation [23], GIS spatial analysis [24, 25], qualitative analysis of UGC data [26, 27] and so on. In terms of research perspective, more attention is paid to historical architecture and traditional cultural landscapes, involving archaeology, history and architecture, etc. At the same time, some scholars actively explore the pathways of modern development and put forwards topics such as cultural landscape inheritance [28, 29], ecological museum construction [30, 31], landscape morphology [32, 33], settlement typology [34, 35] and perspectives from human geography [36, 37]. In addition, there are a small number of studies on traditional villages along linear cultural heritage zones in the world. Zhou et al. [38] proposed a strategic model of the multicultural route. Zouridaki et al. [39] conduct an overall assessment of the cultural heritage routes in an archance village. Bi et al. [40] studied the ancient village to explore how human settlement environments were constructed. Ballesteros et al. [41] activated the cultural tourism along the Palaeozoic villages route through.These results have enriched the study of traditional villages from the perspective of the overall protection and development of linear cultural heritage and provided references for this study.

In recent years, scholars have gradually increased the depth of research on the construction of landscape space in traditional villages, pointing out that the development of landscape space in traditional villages can occur in two dimensions: external material expression and internal spiritual core. On this basis, some scholars have carried out research on the landscape space of traditional settlements based on gene theory. The concept of the cultural gene originated in biological genetics, in which the gene is the carrier of genetic information that produces traits in the offspring that match the parents through self-replication. At the end of the twentieth century, the concept of 'Culturgen' was put forwards by Richard et al. [42], who pioneered the study of

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cultural genes. Taylor [43] introduced the concept of genes into the study of traditional settlements, which provided a new model for the study of settlements in cultural landscapes. Conzen [44] applied botanical theory to the study of the landscape of ancient towns and cities, trying to extract the common morphological genes for the planar and three-dimensional structures of ancient urban settlements. Liu Peilin [45] introduced the concept of cultural landscape genes (CLGTS) into the study of traditional villages for the first time He put forwards the concept of "settlement landscape genes", summarized the methods for recording traditional village landscapes and established the principles for judging the cultural landscape genes in a settlement along with the technical framework for gene recognition and extraction [45, 46]. Shen Xiuying, Hu Ji et al. [46, 47] divided the traditional Chinese settlement landscape into units of flora and fauna and established landscape gene maps reflecting the evolution and interrelationship of each fauna in the settlement landscape. From the perspective of cultural ecology, Wang Xingzhong et al. [48] extended the three ecological levels of "patch, corridor and basement" to the genetic study of regional cultural heritage landscapes, resulting in a gene map. In terms of research methods, scholars have analysed traditional settlements through geographical methods such as 3 s [31] and space syntax [49] and scientific methods such as CAS (complex adaptive system) [50] and gene chain methods [51] to establish a set of scientific and feasible landscape map identification methods and improve the underlying theory. These studies generally agree that cultural landscape genes have the characteristics of heredity, variation and selection similar to biological genes and propose research methods for gene identification, coding and mapping of traditional village cultural landscapes. However, at present, most of the studies focus on single villages and regional traditional villages within the province [51–53], and there is a lack of research on traditional villages along the linear cultural heritage zones that break through the restrictions of administrative divisions.

Therefore, with the help of cultural landscape gene (CLGTS) theory, this study focuses on traditional villages along the ancient Qin–Shu roads and carries out systematic research on the construction, recognition and extraction, interpretation and expression of cultural landscape gene systems, aiming to provide theoretical references for the internal gene interpretation, cultural inheritance, landscape cultivation and shaping of traditional villages along the ancient Qin–Shu roads. This study thus provides beneficial support for the protection and utilization of traditional villages along linear cultural heritage zones.

Data source and research methods
Study area
In ancient China, people called the Central Plains and the surrounding areas Qin, while the Bashu Plain was called Shu, and the series of transportation routes connecting the two places were collectively called ancient Qin–Shu roads, also known as the Zhou Road, Qin Road, Qin Shu Road, etc. The ancient Qin–Shu roads originated in the Guanzhong area of Shaanxi Province, passed through southern Shaanxi Province, and ended in the Bashu area, with a total length of approximately 4000 kms. At present, it is generally believed that it consists of seven main routes, namely, four northern passages (Chencang Road, Baoxie Road, Tangluo Road and Ziwu Road) through the Qinling Mountains and three southern passages (Jinniu Road, Micang Road and Litchi Road) through the Bashan Mountains. Among these ancient roads, compared with the southern roads, the northern roads have a longer route, more concentrated traditional villages, and a higher degree of protection, leaving behind much cultural heritage, such as ancient architecture, folk arts, poetry and literature, and stories and legends. These material and intangible relics cover almost all aspects of nature and humanity, fully demonstrating the cultural diversity of the ancient Qin–Shu roads. Therefore, the scope of this study is defined as the northern roads of the ancient Qin–Shu roads.

The northern roads are located between 105° 49' N and 110° 23' N, 31° 73' E and 35° 08' E. It borders Hubei in the east, Gansu in the west and Sichuan in the south and covers the four cities of Xi 'an, Baoji, Hanzhong and Ankang in China's Shaanxi Province. It runs through the Qinling Mountains, the "boundary line between the north and the south of China", crosses the Yellow River and the Yangtze River, the "Mother River of China", and spans the North–South climate transition zone. As one of the birthplaces of Chinese civilization, the region has a long history and is the birthplace of Qin culture, Shu culture and Chu culture. The northern roads contains three subnations, namely, Guanzhong, Bashu and Hakka, and 23 Chinese national traditional villages (Fig. 1). With its unique geography, climate and cultural environment, the region has a living environment that integrates southern and northern China. It is known as a "museum" of traditional villages integrating multiple cultures and an important research base for world folk cultures and traditional village landscapes.

Data source
The data in this study are mainly from (1) traditional villages. From the first four batches of nationally recognized Chinese traditional villages published online by the Ministry of Housing and Urban–Rural Development
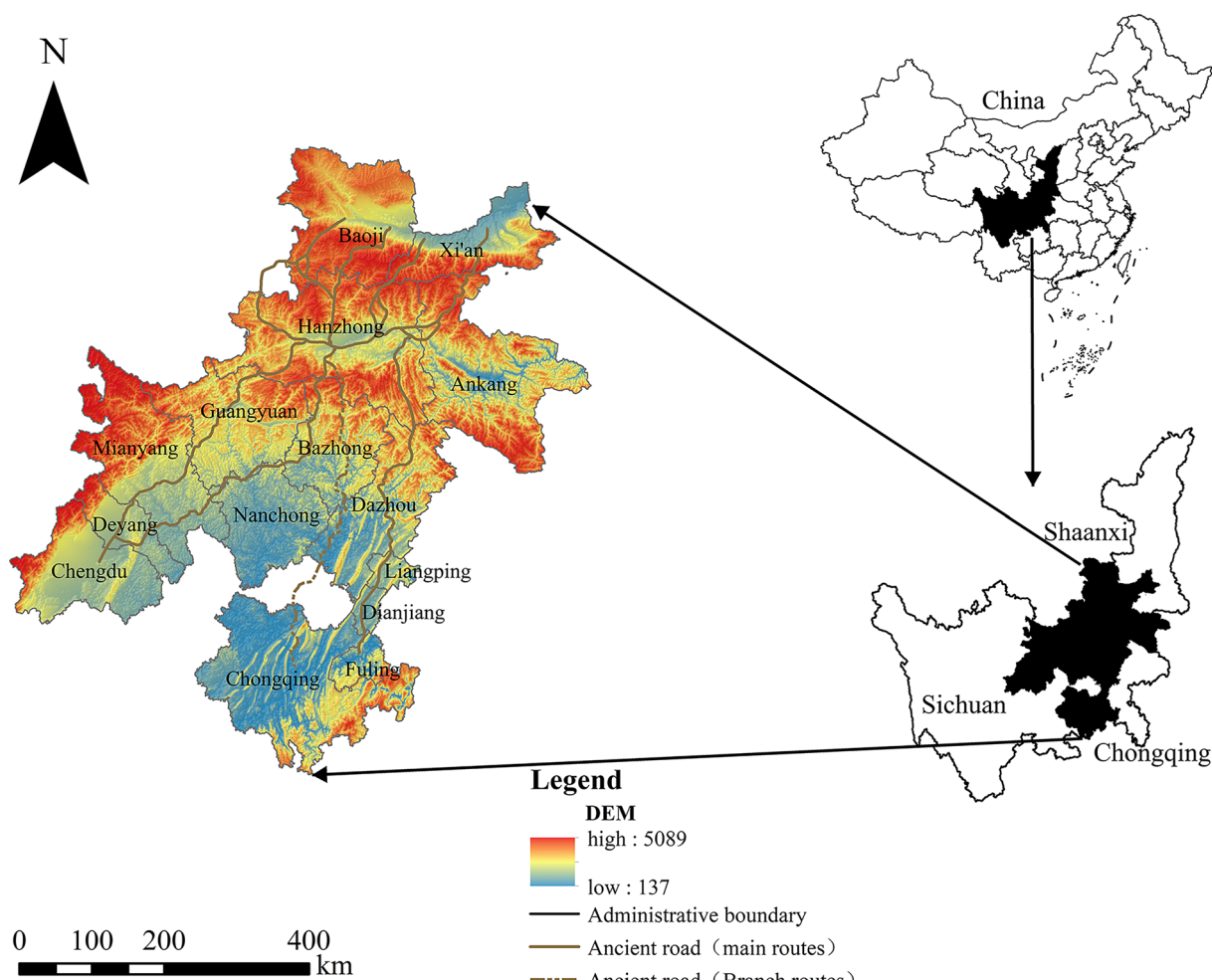
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Fig. 1 Location of Qin–Shu Ancient Roads and the distribution map of traditional villages

of China, 23 typical traditional villages were chosen for research, following principles to achieve a balanced distribution of traditional villages, the completeness of research data, the completeness of village types and a diversity of regional culture. (2) Geographic information. The coordinates of traditional villages were obtained using the Baidu coordinate selection tool, and the satellite remote sensing images and block data of traditional villages were collected by BIGEMAP map downloader. The basic geographic data mainly came from the national basic geographic information website. (3) Literature. By means of network text extraction, textual data in literature related to the cultural landscape were collected, including provincial, county and village records of Shaanxi Province, texts relating to the Shu Road of China, and the study Research on the Fauna and Characteristic Maps of Traditional Settlements in Southern Shaanxi Province. Additional sources included Chinese traditional villages in digital museums (www.

dmctv.cn), Shaanxi Province nonmaterial cultural heritage data (https://www.sxlib.org.cn/dfzy/feiwuzhi/sjyp/) and other network data, such as the detailed planning of tourism texts for the ancient Qin–Shu roads, etc. (4) Field research. During the field investigation from May to August 2022, interview recordings, questionnaires, aerial photography, surveying, mapping, street-level photography and other graphic materials were obtained, some with the assistance of drones. Using ArcGIS software, a gene map of the cultural landscape of traditional villages along the northern roads of the ancient Qin–Shu roads was drawn.

Research methods
Theoretical framework
This study uses the logical framework of gene recognition and extraction, interpretation and expression, and gene analysis [54] to identify the cultural landscape genes of traditional villages along the northern roads and decode

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the external behaviours and internal cultural concepts embedded therein. In addition, this study extracted the gene map of traditional villages in the "construction-culture" dual coupling mode from the perspective of linear cultural heritage and the methods of graphics, elements, text and structure (Fig. 2).

Construction of a cultural landscape gene system

Following the principles of "internal uniqueness, external uniqueness, local uniqueness and overall superiority" [44], through literature research, case analysis and typology, this paper proposes a dual coupling system of "construction-culture" for cultural landscape genes. There were six dimensions for traditional villages along the Qin and Shu Ancient Roads, namely, environment layout, landscape, architectural landscape, material culture, behaviour culture and mentality culture. Further proposed subdivisions resulted in a detailed traditional village "dual coupling model" with six dimensions and fourteen categories in the cultural landscape gene system. Based on the CIDOC CRM model [55] and the dual coupling model of "construction-culture" in traditional villages, model information about material culture, behaviour and mentality at different depths is added from the perspective of the ontology of cultural knowledge in addition to the basic information about various cultural landscapes in traditional villages. From the perspective of construction-oriented ontology,

macro- to microscale model information is added concerning environment layout, landscape and the architectural landscape. Elements at all levels jointly define the framework for information translation, thus forming the ontological semantic model of the "construction-culture dual coupling model for a cultural landscape gene map" based on traditional village protection (Fig. 3).

Process of cultural landscape gene extraction and coding

There are many traditional villages along the northern roads, and the cultural landscape genes are complicated. Therefore, it is necessary to analyse various types of data systematically to quickly collect and obtain information. First, in the process of information collection, the characteristics of the constructed landscape are mainly collected by geographic information system (GIS) technology, UAV oblique photography and digital photography. The characteristics of the cultural landscape are collected by means of historical documents, ethnography, oral history, audio and video. Second, using the methods of "structure extraction, element extraction, figure extraction and meaning extraction", the cultural landscape genes were extracted from 23 traditional villages along the northern roads. Finally, using the typology principle and N-level coding theory for reference, the cultural landscape gene information chain was encoded (Fig. 4).
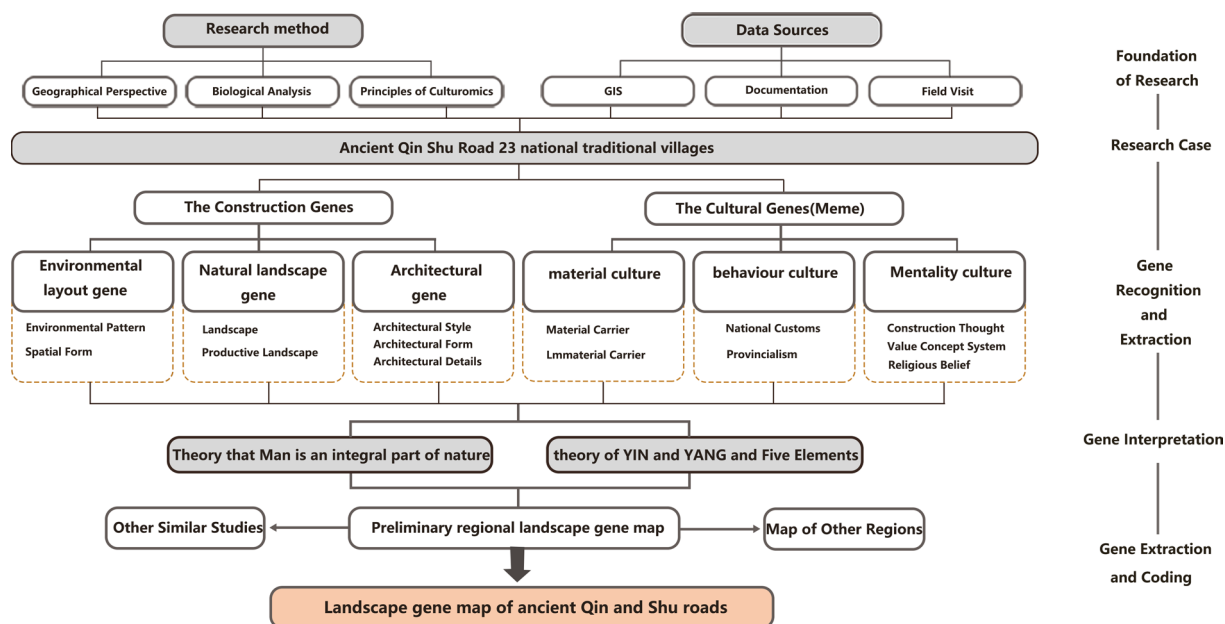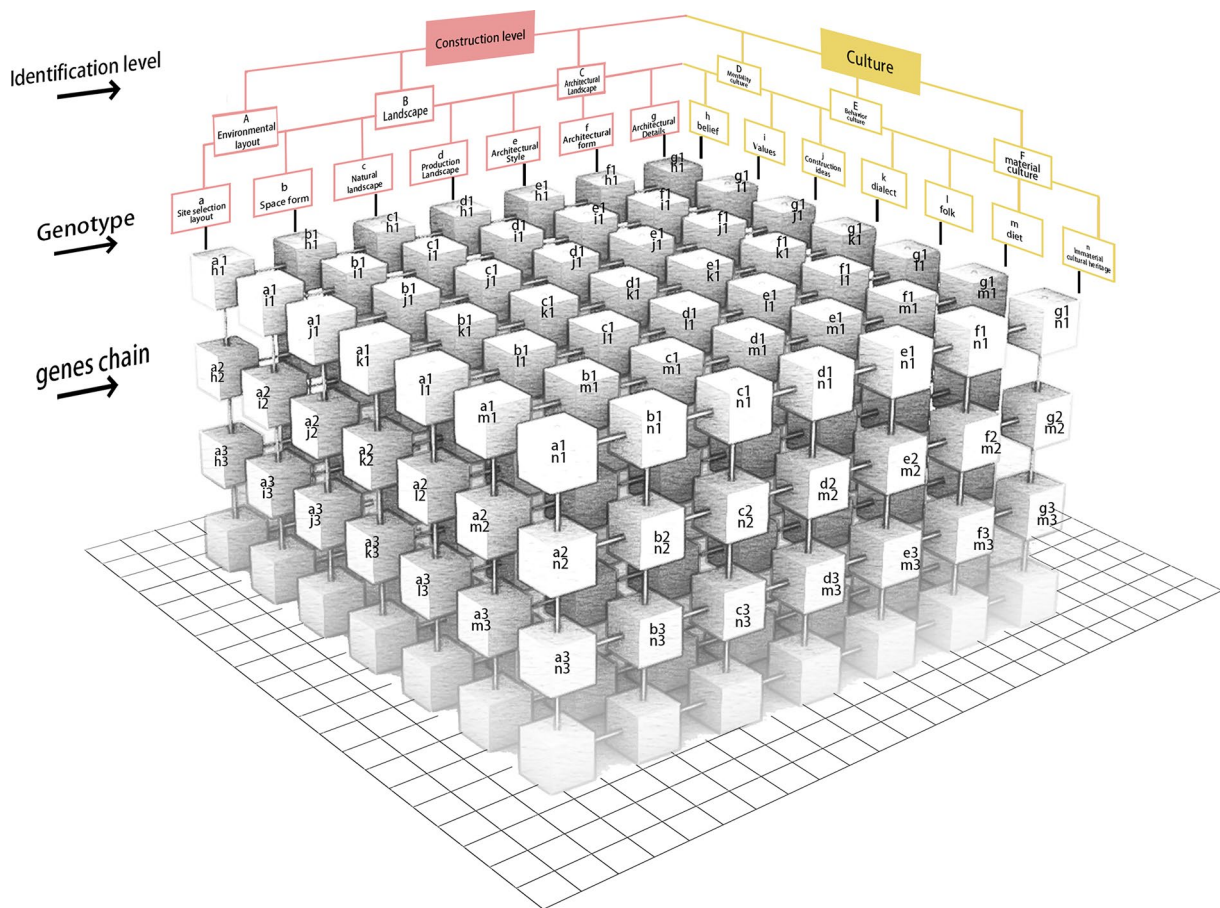

Fig. 2 Theoretical framework of this study

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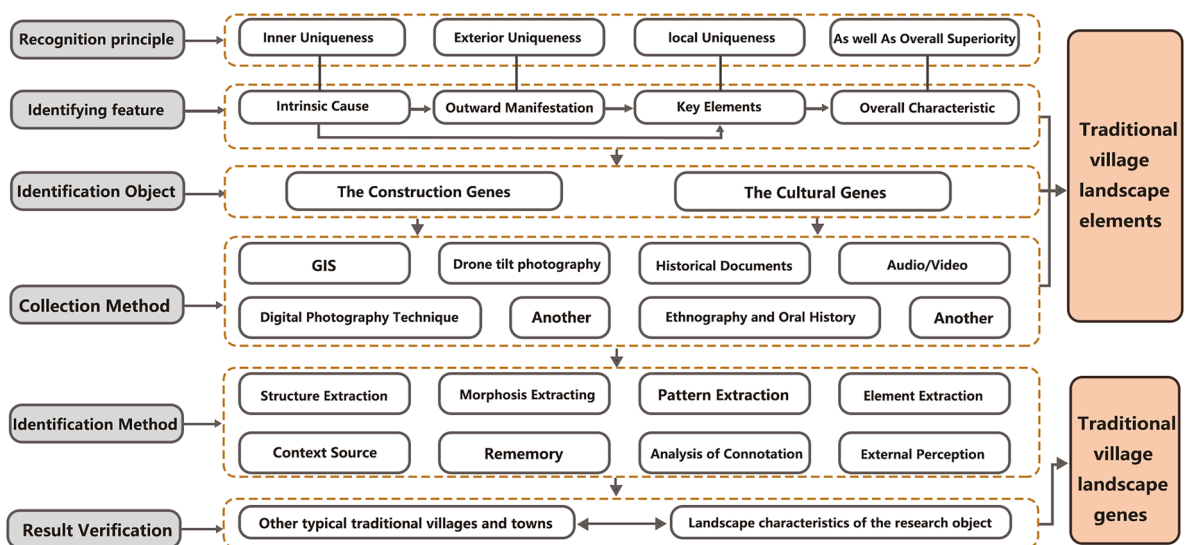**Fig. 3** Ontological semantic model of the "construction-culture" dual coupling model for a cultural landscape gene map

Fig. 4 Process of gene extraction and coding of the cultural landscape in traditional villages along the ancient Qin-Shu roads

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Cultural landscape gene identification of traditional villages along the northern roads of the ancient Qin-Shu roads
Identification of construction landscape genes
Environmental layout

(1) Location layout: mainly along mountains and ancient roads, supplemented by water and pictographic patterns.

The location layout of traditional villages along the northern roads of the ancient Qin-Shu roads accounts for natural geomantic omen, various terrains, clan ethics, and ecological wisdom; it falls mainly along the mountain and river ancient road, supplemented by water and pictographic patterns (Fig. 5).

The northern roads of the ancient Qin-Shu roads are located between the Qinling Mountains and the Bashan Mountains, so the traditional villages here maximize the position of the mountain in their layouts, forming three typical types of villages built near the mountains: valley platform villages, deep gully villages and hillside villages. These villages show the characteristics of attaching importance to the transformation of fields and adapting to the terrain. At the foot of the mountain, valley terrace villages are distributed in flat and open terrain areas such as floodplains, estuaries and river alluvial fans, where abundant water is conducive to the formation of large villages. In the high mountains and deep valleys, which are affected by the steep mountains and narrow rivers, villages are scattered in the gentle areas at the foot of the mountains; most of these villages were built to escape war and famine. Hillside villages are usually built on the sunny side of the mountains, where the lighting conditions are sufficient, which helps to illuminate the buildings and provide a comfortable living environment for residents.

Due to the needs of military, political, commercial and transportation, the layout of traditional villages here usually unfolds along ancient roads. In the early days, most of these villages were official posts, but over time, they gradually developed into living and commercial areas and eventually became complete villages. Currently, the main function of these villages is to carry out commercial trade, so important commercial buildings are usually distributed on both sides of the ancient road, creating a bustling commercial street.

In the traditional villages in the valley plain area of the southern section of the ancient road, the environmental patterns are often based on water resources, presenting three typical types: surrounding water system, penetrating water system, and interlocking water network. Villages with penetrating and surrounding water systems usually use rivers as the basis for village layout, with a layout characterized by two or three surrounding and penetrating sides. These water resources not only provide convenience for the villagers but also undertake various functions, such as farmland irrigation and water transportation. Villages with intertwined water networks are often located on flat alluvial plains, where rivers and ditches are connected, which facilitates not only farmland irrigation but also flood control and drainage.

In addition, in the Guanzhong area of the northern section of the ancient road, villagers generally worship their ancestors, so they usually set up a "Ming Tang" in the centre of the village for this purpose; other buildings then surround the "Ming Tang". The full utilization of mountain and water resources has created a layout of good fortune, thus creating wealth. This layout not only benefits villagers in ancestor worship and social activities but also increases their physical sense of security.

(2) Spatial form: orderly, flexible and changeable.

The spatial form is composed of the layout form and the street form, which as a whole shows the gene of "orderly gathering and dispersing, flexible and changeable". The layout forms are linear, trapezoidal, planar and point-like. There are five typical types of street shapes: "之" type, "一" type, fishbone type, grid checkerboard type and free type.

The construction of linear traditional villages is often arranged along ancient roads, rivers and contour lines. Its street shape is "一" type or fishbone distribution, which is typical of ancient road villages. The trapezoidal traditional village expands and develops along the slope, showing the characteristics of a ladder. Its street shape is mainly "之" type, which is typical in Miaotaizi village and other villages. Planar traditional villages are usually located on a large area of flat land, such as plains or valley terraces, and have a square or circular shape. This kind of village is large in scale, and the streets are mainly grid checkerboard type or free type. A point-like traditional village is a reduced version of a planar village, with no clear centre and a small scale and scattered distribution. The streets of this kind of village are mainly fishbone shaped, and each group is connected by branch roads. Yangjiaying Village and Moping Village belong to this type.

In brief, the geographical layout of the traditional villages on the northern roads of the ancient Qin-Shu roads was influenced by the landscape environment; at the same time, the traditional villages adopted the principle of adapting to the local conditions of ancient people, which is similar to traditional villages in many areas of China. For example, traditional villages in Guangxi,
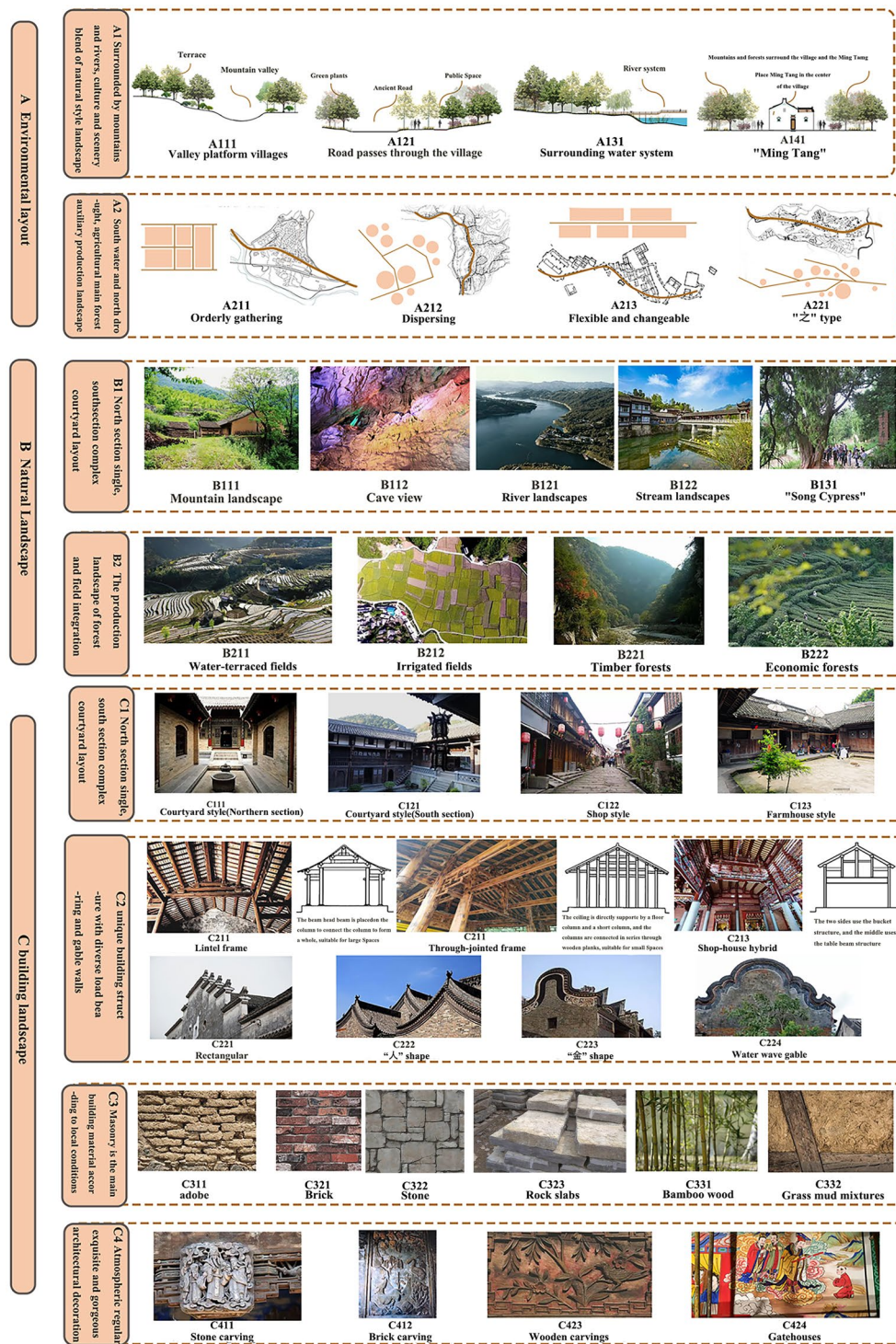
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Fig. 5 Gene map of the traditional village constructed landscape along the northern roads

Shandong, southern Anhui and other places also embody coordination with the natural and cultural environment. However, compared with those on the northeast plain, North China Plain and the middle and lower reaches of

the Yangtze River plain, the site selection of traditional villages along the northern roads of the ancient Qin-Shu roads is more dependent on convenient transportation, which results in a typical form of living along the ancient

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road. Compared with ethnic minority areas, which have large differences in natural and cultural environments, more attention is paid to etiquette in spatial layout in these traditional villages. In particular, villages in the Guanzhong area often have a Ming hall at the core of the village, which is used to handle village affairs and hold activities such as ancestor worship. This is because "Zhou rites", the source of Chinese rites, originated in the Guanzhong area of Shaanxi Province, and the rites and rules emphasized by these rites had a profound impact on the layout of villages in the Guanzhong area. These regular and orderly village layouts are not common in ethnic minority areas. These similarities and differences provide valuable information for the study of the location and layout of traditional Chinese villages.

Landscape

This study draws on the concept of landscape expressed by the Japanese literary master Keno Okno in Original Landscape in Text and divides the landscape of traditional villages into natural landscapes and production landscapes.

> (1) Natural landscape: surrounded by mountains and rivers, with culture and scenery blended.

The natural landscape of the traditional village on the northern roads of the ancient Qin-Shu roads fully demonstrates the genes of surrounding mountains and rivers and blended cultural scenery, specifically manifested as the natural landscape of the mountain, the secondary role of the main cave, the coexistence of rivers and streams, and the protection of the ancient road by ancient cypress trees.

It is rich in natural resources, such as mountains, caves, water and cypress trees. Many villages are built in the mountains and exhibit a mountain style. The cave landscape is distributed in a small number of villages in the Hanzhong section, where villagers use them as natural grain storage spaces. Due to the abundant water resources, the villages have been built along rivers or streams, presenting two typical water body landscapes: river landscapes and stream landscapes. Outside the village, the villagers have planted cypress trees along the ancient road since ancient times; some of these are 2300 years old. These cypress not only help protect the road and provide shade for pedestrians but also bear witness to history and stories. For example, "Song Cypress", "Zhang Fei Cypress", and "Couple Cypress" represent the integration of history and culture with plants, forming a unique natural landscape.

> (2) Production landscape: water in the south and drought in the north, with agriculture as the primary industry and forestry as the auxiliary industry.

The traditional production landscape of the northern roads of the ancient Qin-Shu roads originates from agricultural civilization and has the gene of "south water and north drought, agriculture as the main and forestry as the auxiliary". Specifically, the landscape is manifested as water-terraced fields, irrigated fields, scattered flower-planting paddy fields, flat dry fields, sloping dry fields, scattered flower-planting dry fields, timber forests, economic forests, special forests, and natural forests.

Farmland is the most important productive landscape in the region. Due to the difference in landforms and rainfall in the northern and southern sections, a unique farmland landscape of "water in the south and drought in the north" has formed. The hillside villages in the southern section have relatively little land available for production, so the villagers choose to build water terraces in relatively flat locations. The formation of these terraces not only reflects the intensive cultivation of the land by the villagers but also creates a unique farmland landscape. Villages in the valley have plenty of productive space. The interlaced water network, sufficient water source and suitable temperature enable two rice harvests a year or three rice harvests in 2 years, forming two typical farmland landscapes of irrigated fields and sporadic flower-planting paddy fields. The Qinling Mountains block the northern section of the ancient road, thus preventing the southeast monsoon from impacting this area. The resulting lower rainfall levels have led dry farmland to become the main farmland landscape. Wheat, corn and sweet potato crops are generally harvested once a year, forming three typical types of flat dry fields, slope dry fields and sporadic flower-planting dry fields.

The Qinling Mountains are rich in forest resources, and the forest landscape has become the traditional village auxiliary production landscape on the northern portion of the ancient Qin-Shu roads. There are four types of forest: timber forest, economic forest, special forest and natural forest. The timber forest is mainly conifer, including platycypress, Masson pine, and nanmu. These trees have high wood value and are widely used in the construction of houses and the manufacturing of household tools and decorations. Special forests are used for special purposes, such as soil and water conservation, flood disaster and landslide prevention, and are of great significance for maintaining

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the local ecological environment; they contain aspen, hemlock, spruce, and Qinling Abies. Tea, persimmon, oranges, herbs, fungi, bees and other resources derived from economic forests and natural forests are also important forestry production resources, as they provide the basis of and support for the lives of local villagers.

In brief, the natural environment and production mode determine the natural landscape of a village. The dense forests of the Qinling Mountains add a unique landscape to the environment of the northern roads of the ancient Qin-Shu roads, forming the unique plant landscape of the "ancient cypress Road". This style is unique to traditional Chinese villages, as it highlights the unique charm and historical heritage of the northern roads of the ancient Qin-Shu roads. In addition, the production landscapes of the villages along the northern roads of the ancient Qin-Shu roads are significantly different from those of the nomadic production landscapes in Xinjiang, Inner Mongolia, Qinghai, Tibet and other minority areas. Nomadic areas are focused on the development of animal husbandry and handicrafts. The production modes and laws of these industries are different from those of agriculture, making the landscape layout of village production in nomadic areas freer and more flexible. In contrast, the villages on the northern roads of the ancient Qin-Shu roads mainly used agriculture as the mode of production, and their landscape layout was orderly and fixed. This layout is consistent with the regularity and stability of agricultural production and reflects the harmonious symbiosis between human beings and the natural environment. This diversity also enriches the world's culture and demonstrates the inexhaustible power of human ingenuity and creativity.

Architectural landscape

(1) Courtyard layout: a single form in the north section, and a complex form in the south section.

Through on-site surveying of typical architectural courtyards and the use of the "graphic extraction" method, the traditional village architectural form of the northern roads of the ancient Qin-Shu roads has been analysed. The result indicate the layout genes of courtyard style in the northern section of the ancient road, courtyard style in the southern section of the ancient road, shop style, and farmhouse style mixed courtyards.

The buildings in the northern section of the ancient road are influenced by traditional Confucian ideas, and the layout is rigorous and orderly, emphasizing family ethics and orderliness. The head of the family usually lived in the main room, the adult males lived in the side rooms, and the women lived in the inner courtyard.

This layout reflects the Confucian traditional ethics and morality of the distinction between the superior and the inferior, the primary and the secondary. The southern section of the ancient road is more flexible and less constricted, adapted to the complex terrain, and uses a variety of architectural forms, such as patio, shop and farmhouse styles. The Tianjing courtyard by the main hall is encircled by wing rooms, gatehouses and other structures, with a "four waters return to the hall" geomantic pattern, which gathers wealth and air. A shop-house courtyard is a combination of residences and shops, with a shop in the front and house in the back, which is convenient for both business activities and daily life. Rural farmhouses exist in mountain villages, and the layout of the courtyard is simple, usually using a "一" type or "L" layout, leaving more spacious courtyards for people to dry grains, park farm tools, etc.

(2) Building structure: Load-bearing variety and adept at utilizing mountain walls.

On-site surveys of typical architectural courtyards and the use of the "structural extraction" method showed that the traditional village building structures on the northern roads of the ancient Qin-Shu roads have diverse load-bearing capabilities and are adept at utilizing the genes of mountain walls. Specifically, these structures include the lintel frame, through-jointed frame, shop-house hybrid, as well as rectangular, "人" shape, "金" shape, and water wave gable.

From the point of view of load-bearing structure, the buildings in Guanzhong area of the northern section of the ancient Road mainly adopt the lintel frame. This frame can provide a large interior space to meet the needs of residents. At the same time, the flat terrain of the Guanzhong Plain has enabled the construction of larger-scale buildings. In the southern part of the Hanzhong and Ankang southern mountain areas, the traditional village buildings mostly use the through-jointed frame. The advantages of this structure in terms of structural weight, construction simplicity and seismic performance make it particularly suitable for the topographic conditions of the southern mountainous region. In addition, the shop-house buildings along the ancient road have adopted a shop-house hybrid. This structure effectively combines the advantages of the lintel frame and the through-jointed frame; the middle section adopts the lintel frame, and the two sides adopt the through-jointed frame. This design not only reduces the cost of materials but also expands the space for commercial activities on the first floor.

The gables of the northern section of the ancient road are characterized by practicality and durability; they are mainly rectangular, with simple decoration on the

surface, such as plastering and tiling, to resist wind sand evasions. In contrast, the architectural gables of the southern section of the ancient road are characterized by decorations and culture. The gables are made of black or grey brick and painted. The shape of the gable is greatly influenced by Hakka architectural styles, such as Bashu architecture, Huizhou architecture, and Hunan architecture, mainly in the form of "human" shapes, "gold" shapes and water waveforms. The decorations integrate the local cultural characteristics and historical traditions, such as the natural scenery of mountains and rivers and the cultural elements of the three countries.

> (3) Building materials: combination of soil, stone, and bamboo, recycled and reused material.

There are significant differences in the building materials between the northern and southern sections of the northern roads of the ancient Qin-Shu roads. The use of "meaning extraction" analysis demonstrated that the material was a combination of soil, stone, and bamboo, with genes for recycling, including adobe, brick, stone, rock slabs, bamboo wood, and grass mud mixtures.

The building materials in the Guanzhong area of the northern section of the ancient Road are mainly adobe and brick. These materials have good durability and excellent heat retention and can adapt to the dry and cold climate environment in Guanzhong. In contrast, the construction materials of the southern section of the ancient road are more diverse, such as stone, raw soil, bamboo and wood, grass and mud mixture. Pebbles, bluestones, rock slabs and other sturdy stones are used to build walls or lay on roofs to prevent rain erosion of the building. Bamboo, which is abundant in the area, is used as the "bone" of the walls of the building. Bamboo slices are cleverly interwoven to form a skeleton, which is then reinforced by a layer of soil. This method has strong stability, light weight, good air permeability, and distinct local characteristics. In addition, in some villages, bamboo, slate, brick and other materials are used as walls, blending the architectural styles of Guanzhong and Bashu and forming a dialogue between the northern and southern cultures.

> (4) Architectural decoration: atmospheric regularity, exquisite and gorgeous.

Architectural decoration focuses on the beams, columns, handrails and structural auxiliary parts of the building. It not only is the embodiment of building skills but also reflects cultural characteristics and is an extension of symbolic and spiritual aspects. The architectural details of the traditional villages on the northern roads of the ancient Qin-Shu roads show atmospheric regularity and exquisite and gorgeous genes.

The northern ancient road traditional village is deeply influenced by Qinlong culture, and its architectural decoration techniques are exquisite and diverse, mainly reflected in the detailed design of stone carving, brick carving, screen walls, eaves and flower windows. These decorative patterns are simple and atmospheric, the layout is regular and orderly, and the patterns are mainly auspicious ones, fully reflecting the distinct moral and ethical concepts of the Qinlong area, such as "Dragon and phoenix auspicious", "flowers and riches", "longevity" and other symbols of auspice, longevity and happiness.

The traditional villages in the southern section of the ancient road are deeply influenced by Bashu culture and immigrant culture, and their architectural decoration styles are unique and diverse. Here, natural scenery and ethnic characteristics blend together to shape the unique style of the village. The architectural decorations are mainly made of wood, which is reflected in flower windows, eaves and corridors, wooden carvings, gatehouses, and horse head mountain walls. These decorative styles are small and exquisite, magnificent yet delicate, showcasing the unique pursuit of beauty in traditional villages in the southern section. Plants, animals, or historical legends are the dominant elements in these patterns. This theme vividly reflects the village residents' reverence and reverence for nature, as well as their love and expectations for life.

In terms of the architectural landscape, the village architecture on the northern ancient Qin-Shu roads has many similarities with rural architecture in other parts of China. Such as attention to details in architectural decoration and displays of traditional Chinese crafts and culture through carvings and paintings. In the selection of materials following local conditions, local materials consider ventilation and lighting structures. However, the rural architecture of the northern roads of the ancient Qin-Shu roads also shows particularity because of their unique geographical location. For example, the northern roads of the ancient Qin-Shu roads show a simple and magnificent style, while the southern section displays delicate and beautiful features, thus demonstrating the integration of traditional Chinese villages from the north to the south. In addition, the architectural style of the northern roads of the ancient Qin-Shu roads was strongly influenced by traditional culture, such as "Zhou rites" and Confucianism, which involved paying attention to the ritual system and symmetry and regularity. In contrast, rural architecture in some areas of China is influenced more by local traditional culture, national customs and other factors, revealing different styles, for example, the southern Hui Style Architecture, Earth Building in Fujian

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Fig. 6 Gene map of the traditional village cultural landscape along the northern roads

and so on. In terms of architectural structure, the rural buildings on the northern roads of the ancient Qin-Shu roads were mainly wooden structures, and traditional structural methods such as lifting beams and piercing were adopted. The walls are mostly made of earth, stone and other materials, and the roofs are mainly made of tiles. This structure is different from that of bamboo buildings in Southwest China and rammed earth cave dwellings in northern Shaanxi. This diversity enriches China's architectural culture and provides us with valuable materials to better understand and protect traditional villages.

Identification of cultural landscape genes
Material culture

Material culture is the material surface and "physically" perceptible part of culture, which is reflected most intuitively in villagers' daily work and life, including utensils and diet.

(1) Traditional cultural forms: strong personalities and regional customs.

The traditional villages along the northern roads of the ancient Qin–Shu roads nurtured a wealth of traditional cultural forms, such as traditional music, drama, handicrafts and folk customs. It presents the genes of 'strong personalities and regional customs' (Fig. 6): Traditional

drama, represented by Qinqiang opera and shadow puppetry, embodies the bold and rough character of the northwest people. The traditional handicraft represented by Western Qin embroidery and Hanzhong rattan weaving shows a fresh and beautiful aspect of local culture. The local customs of the Yan Emperor's Sacrifice, the folk Shehuo and meeting the local gods represent folk customs with a history of thousands of years. Tong Sheng Xiang lamb paomo (mutton and bread pieces in soup), Xi'an JiaSan soup dumplings and other representative foods are renowned at home and abroad.

(2) Dietary habit: strong flavours, spicy food, wine and meat.

The traditional villages along the northern roads have rich food cultures, sharing a dietary gene of 'favouring flavourful, spicy foods, wine and meat'. These tastes specifically manifest four aspects: sour, spicy, meat and wine.

In terms of favouring sour food, the northern area of the ancient Qin–Shu roads has an alkaline water quality due to soil conditions. Local people use the acidity of vinegar to neutralize this effect, thus forming a preference for sour flavours. The southern region has numerous mountains and rivers and inconvenient transportation. Pickled cabbage is easier to preserve and transport, so it has become a common element in the local daily diet. Under the continuous influence of the northwest winds

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on the northern part of the road, residents adopted chili peppers to prevent chills, making use of the heating effects of spicy foods. The southern region is close to Sichuan, and similar environmental conditions make local eating habits similar to those in Sichuan. Locals like to eat chili peppers and Sichuan peppers to drive humidity and heat from the body. In terms of eating meat and drinking alcohol, the Qinling Mountains has rich animal and plant resources, and the local people have a long tradition of hunting and brewing. The abundant resources of cattle, sheep, rabbits, persimmons, bracts, barley, etc., have led to the formation of a local 'no wine and no meat' dietary habit.

Behavioural culture
Behavioural culture refers to the deeper and nonmaterial part of culture, which is the accumulation of specific behavioural patterns and results shown by people in daily work and life. As the crystallization of the wisdom and practices of the working people in the refinement of their skilled labour, these behavioural patterns are reflected in all aspects of work and life, artistic creations, and ethics and morals.

(1) Folk customs: Romanticized history, with simple, diligent values.

'Romanticized history, with simple and thrifty' customs is the core concept pursued by the villagers on the northern roads. Shaanxi Province, home to the northern roads, are where thirteen dynasties were founded and has a profound history and culture. It is known as a "natural history museum" and the "hometown of Chinese folk culture and art", with extensive and profound cultural traditions. Therefore, the local villagers' pursuit of culture is very strong. The simple, industrious and thrifty folk customs are caused by the special geography and culture of the northern roads. The Shaanxi Guanzhong Plain is not only flat but also rich in water resources. Since ancient times, the region has been aphoristically known for "eight hundred miles of flat rivers" and "eight rivers around Chang 'an". Excellent natural conditions facilitated the development of agricultural production. Locals are skilled at farming and prospered with hard work. In the southern Shaanxi Mountains, the economic conditions are relatively underdeveloped. Therefore, Shaanxi people who grew up here uphold values that emphasize frugality; they generally lead very simple lifestyles and do not pursue habits that are too luxurious.

(2) Dialect: Combination of elegance and vulgarity.

The northern roads are one of the most complex areas in China, genetically related in dialects by "combining elegance and vulgarity". The dialects can be divided into two main categories, namely, local dialects composed of zhongyuan Mandarin and southwest Mandarin and the Hakka dialects composed of Jianghuai Mandarin, Hunan dialect and Jiangxi dialect.

Zhongyuan Mandarin is the prevailing local dialect. It is divided into the Guanzhong area, Qinlong area and Nanlu area. It is characterized by clear and accurate pronunciation, obvious intonation and standardized pronunciation. The Guanzhong area includes Xi'an, Xianyang, Baoji, and other areas near the northern part of the northern roads. The Qinlong area includes Lvyang, Nanzheng, Mianxian, and Ningqiang, which are concentrated in the northwestern part of the road and the area bordering Gansu Province. The Nanlu area is located in the northeastern part of the northern roads near Henan Province, including Baihe and Shangnan. Southwest Mandarin is spoken by relatively few people and is divided into the southern Shaanxi dialect and Chengdu-Chongqing dialect. It is light, soft, quick and easy to understand. The southern Shaanxi dialect is mainly distributed in Hanyin, Ningshan, Ziyang and other places southeast of the northern roads. The Chengdu-Chongqing dialect is distributed in Zhenping, Liuba, Zhenba and other places, which are located southwest of the northern roads, bordering Sichuan.

Under the influence of migration flows from Huguang to Sichuan in the Ming and Qing dynasties, people from different regions and nationalities brought a variety of Hakka dialects to the northern roads, including the Zhuza area (Baihe, Pingli, etc.) in Jianghuai Mandarin, Changyi area (Hanyin, Shiquan) in Hunan dialect, and the Datong area (Shanyang, Xunyang) and Huaiyue area (Shangnan, Danfeng) in Jiangxi dialect. These dialects are widely distributed and differ greatly. As a whole, they are characterized by a loud, musical quality which is easy to speak with a rich and colourful vocabulary, which makes these dialects more popular than Mandarin.

Mentality culture
Mentality culture refers to the deepest, intangible and "metaphysical" part of culture, which has certain psychological characteristics and qualities that people have nurtured in daily work and life. The cultural landscape genetically connects the regions of the northern roads at the level of mentality through the construction of 'Xiangtu and Shengxing', the values of 'openness and inclusiveness', and the varied religious beliefs. These are the core traditional ideologies of traditional villages on the northern roads.

The idea of 'Xiangtu and Shengxing' includes the idea of examining the surrounding environment before the

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village is built. In the process of construction, the concept of "victory over nature" is built by using the terrain, forests, water resources, mountains and rivers to local advantage. The specific execution of these ideas is represented by the location layout as juxtaposed with local conditions, balancing life and work in human settlements according to the environmental conditions of the mountain landscape, water systems, seasons, and growth patterns of agriculture and forestry. The principle maximizes the use and protection of mountain forests and water environments.

'Openness and inclusiveness' is a value formed by traditional villagers along the northern roads after a long history of cultural mixing. This principle is embodied by two factors: 'learning from the strengths of others' and 'compatibility and inclusiveness'. 'Learning from the strengths of others' is the excellent result of villagers' bold integration of northern and southern cultures (Qinlong, Bashu, Jingchu, Heluo), absorbing the characteristics of different cultures, and making various excellent cultural achievements for their own use. 'Inclusiveness' includes cultural fusions and blending after collisions. Fusion transformations represent the differences between the traditional villages on the northern roads. External collisions refers to the clash and blending of northern and southern cultures, indigenous cultures and foreign cultures, including farming and forestry civilizations, ultimately forming a dynamic balance and interdependent pattern.

Because the northern roads are where the great integration of Han and minority nationalities occurs, it is genetically related by 'varied' beliefs, including ancestor worship, nature worship, totemism and spirit worship. Ancestor worship had two organizational forms: Guanzhong clan and Shuzhong clan. The local villagers rely on the ancestral halls to maintain a close relationship between the individual and the clan, along with the present world and the ancestors, emotionally and psychologically. In nature worship, phenomena or objects that affect human existence are worshipped, such as a mountain god or fire god. These beliefs are relatively unsystematic. Totemism, on the other hand, is derived from nature worship, and frequently deifies creatures closely related to their ethnic groups, which has some characteristics of ancient religions. For example, the Qiang ancestors in Aokichuan Village survived by sheep herding and regarded the sheep as their tribal gods. The local Qiang people use ornaments such as sheep teeth and horns at home or as jewellery and add sheepskin ribbons to their clothes and buildings for protection and luck. Traditional Chinese mythology, as the main representative belief system of spirit worship, presents a diversified lineage of gods and worship methods, such as dragon dances and temple fairs. Activities are held regularly and extend deeply into daily life, such as in behaviours like showing respect for ghosts and staying away from them.

Like most traditional villages in China, the ancient Qin–Shu roads village has many historical features and traditional culture, including ancient architecture, traditional handicrafts and folk culture. The villagers inherited the virtues of simplicity, diligence and hospitality. However, the cultural landscape of the northern roads of the ancient Qin–Shu roads Village is different from that of other traditional villages in China; this is mainly due to Guanzhong in the north, Sichuan in the south, Hubei and Henan in the east, and Longnan in the west, which are located at the intersection of several major cultural plates. In addition, there have been several major migrations throughout history, leading to the formation of the region's east–west integration and North–South convergence of the regional cultural landscape. For example, in terms of eating habits, the villagers of the northern plank Road preferred noodles, while the villagers of the southern section preferred rice, which was determined by the agricultural conditions at these two places. In terms of traditional cultural forms, sports activities are influenced by the integration of the north and the south. For example, dragon boat activities are very similar to the Chu style, and traditional festivities contains Qin culture, Chu culture and Qiang culture. By deepening our understanding the cultural landscape genetics of the northern roads of the ancient Qin–Shu roads Village, we can better understand the lifestyles, values and historical evolution of the people on this land.

Gene interpretation and map generation of the cultural landscape of traditional villages along the northern roads
Gene interpretation of the cultural landscape
The cultural landscape genes of the traditional villages along the northern roads of the ancient Qin–Shu roads were gradually formed by local residents through the process of continuous adaptation and transformation of the environment. These changes were affected by multiple factors, such as the local natural environment, regional environmental culture and the traditional Chinese view of the environment around the human settlement. The 'oneness of man and nature' and the 'yin-yang and five-element' theory constitute the traditional village living concepts.

The idea of the 'harmony of heaven and humans'
The 'oneness of man and nature' is representative of the simple materialist philosophical concepts in ancient China, which had a profound impact on the construction of ancient Chinese villages [56]. Under the cosmological view of 'harmony of heaven and humans', nature

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is regarded as an organic whole, which is composed of three parts: heaven, earth and humanity. All things are generated by 'qi' and are sentient to each other. There is an internal ethical relationship between humanity and heaven and earth, and through coordination and interdependence, all parties can strengthen and transform each other, thus forming a harmonious relationship in which the whole is greater than the sum of its parts [57]. According to this principle, two major genes connect the development of the construction of villages along the northern roads: one is the traditional Chinese principles of construction represented by 'Xiangtu and Shengxing' (reasonable construction based on the geographical environment through the identification of natural characteristics), and the other is the ancient Chinese work and life practice represented by 'harmony of heaven and humans' (following nature and arranging production and life according to natural laws).

The construction concept of 'Xiangtu and Shengxing' has a strong guiding effect on traditional villages on the northern roads. Following this principle, village layouts were designed with consideration for the surrounding landscape and local production conditions. The fields were mostly located in valleys, hills, mountains and other areas, which is not only convenient for agricultural production but also produces natural transitions between the boundary of the village and the surrounding environment. The village is thus protected by the natural landscape. In terms of architectural form, the village is in harmony and unity with the local landscape. For example, Zhanjiawan Village of Ankang City is located on a mountainside terrace, and buildings are built along the mountain. Since there is limited space on the mountainside, the buildings are built into the character 'one'-shaped, single-row courtyard, and trees are planted around it. The farmland is scattered on the mountainside terrace, and the overall construction is scattered, harmonious and natural.

The ancient Chinese practice of 'harmony of heaven and humans' (human beings should conform to the laws of nature and maintain a balance with the natural environment) had a great impact on the cultural genes of traditional villages along the northern roads. The residents formed a conscious drive to conform to nature, protect the environment, and resonate with heaven and earth. In terms of material culture, 'harmony of heaven and humans' has deeply influenced folk cultures. For example, Xi'an Drum Music, which has a simple, delicate, beautiful and elegant melody, expresses the players' interest in resonating with heaven and earth. In behavioural culture, 'Harmony between humanity and the world' shows that the local villagers develop a sense of thrift in caring for the environment, moderate their demands on natural resources, and seek a sense of harmony in the friendly coexistence of 'heaven-earth-humanity'. For example, in Zhongshan Village of Ankang City, traditional virtues such as 'caring for the environment and frugality' have been written into village regulations. Every family in the village plants trees in front of their door which cannot easily be moved, so there are many trees that are more than 100 years old. Among these, the oldest large pagoda tree in the old courtyard of the Guo family is respected by the villagers as a god. Whenever there is a disaster, they will pray and worship in front of the tree. In their cultural mentality, this manifests as 'nature worship'. For example, the villagers of Chengguan Village in Hanzhong City worship the mountain god. Before climbing the mountain, villagers need to bow to the mountain god and sacrifice part of the harvest to pray for safety while climbing the mountain.

'Yin-yang and five-element' theory

The theory of 'yin-yang and the five elements' is the core of Chinese classical philosophy, which deeply influenced the beliefs, cultures and behaviours of the ancient Chinese people [54]. The theory of 'yin-yang' states that everything is composed of 'qi' [58], which represents different things, such as yang forces representing the sun, men, active qualities, etc., while yin represents the moon, women, still qualities, etc. [59]. With the evolution of public knowledge, 'yin-yang' has been transformed into a philosophical idea that any phenomenon or thing has its opposite. The 'five-elements' theory refers to the ancient Chinese belief that all things in the universe can be attributed to the five elements according to their nature,

Fig. 7 Chinese 'Yin-yang and five-element' diagram

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namely, "metal, wood, water, fire and earth". The relationship between the "five elements" can be defined as a cycle of mutual restriction and transformation. "Yin and yang" and the "five elements" complement each other; the "five elements" must be combined with "yin and yang", and "yin and yang" must be combined with the "five elements" (Fig. 7). This theory has influenced and promoted the development of the cultural landscape of traditional villages along the northern roads.

The theory of 'yin-yang and the five elements' has deeply and genetically influenced the construction of traditional villages. The theory of 'yin-yang' states that only when people are full of yang can they be protected from darkness and cold. Under the influence of this thought, 'carrying mountains and facing water, carrying yin and embracing yang' became an important criterion for the location of traditional villages. To receive more 'yang', the buildings in the northern plain area were mostly renovated in the direction of the 'north-sitting, south-facing' model, and the traditional villages in the southern mountainous area were mostly located on the southern slope facing the sun. To prevent the loss of 'yang', 'yin' gas will be stored in the rear of 'yang'; that is, trees will be planted behind the house, and the mountain will store the 'yin' gas. They form a closed space, which can play the role of harmonizing yin and yang. In terms of the theory of the 'five elements', village buildings and farmland are susceptible to fire. In the layout of traditional villages on the northern roads, the idea of 'fire' can be restrained by the use of 'water' in the 'five elements', such that the water system arrangements are almost always considered in the process of village construction. On building doors, windows, firewalls and other architectural details, the representation of 'water' decorations or gods and beasts are carved to help suppress the 'fire' element. At the same time, to prevent the excess of 'water' and affect the balance of the five elements, plants representing 'wood' were planted at the back of the courtyard and on the hill to suppress 'water'. This not only solves the problems of lighting, ventilation, heat insulation, dehumidification, sunshade, fire prevention and drainage but also harmonizes the balance between 'wood, water and fire'.

One typical example of intangible cultural heritage among the traditional villages on the northern roads are the traditional Chinese medicine treatment method called 'Huangyuan Royal phase fire diagnosis and treatment', which fully embodies the simple principles of the 'five-element' theory of yin and yang harmony, in which all things are mutually contradictory and unified. According to Chinese medicine, the human body is a system of 'yin-yang and the five elements'. The five internal organs correspond to the five elements of 'wood, fire, earth, metal and water'. The heart belongs to fire, the spleen to earth, the lung to gold, and the kidney to water. In the 'Huangyuan royal phase fire diagnosis and treatment', the cause of heart palpitations is an uneven balance of the heart fire, in which the liver fire does not fall. To calm the heart fire, we need to regulate the liver and spleen, warm the kidney and the heart, and relieve the empty fire through the kidney. Balancing the liver fire requires regulating the gallbladder and stomach by dredging the liver and lowering the fire in the liver. The treatment process uses the principle of 'yin-yang and five-element' harmonization. In addition, the eating habits of the villagers on the northern roads were deeply influenced by the theory of 'yin and yang'. Affected by the mountains, the climate is humid, and the environment has 'too much yin qi', which must be balanced out by human beings. Therefore, eating 'yang' foods represented by chili, rice vinegar, etc., can balance the two levels of yin and yang so that body functions can be restored to a full potential to resist disease.

The gene map of the cultural landscape

Through the extraction of the cultural landscape genes, the landscape of the traditional villages in the ancient Qin–Shu roads was encoded. In this process, the dual coupling of 'construction and culture' as landscapes moulding traditional villages was used as a model, referring to the information and coding classification of China's resources and environment in public databases along with N-level coding theory. From high to low, the coding is divided into three levels: major, medium and small. Each level is composed of letters and numbers. The specific structure uses a "AXXBXX" 6-digit character code, and thus, the genome map of the traditional village landscape on the northern roads of ancient Qin–Shu roads was constructed (Fig. 8). Through the above model codes, the categories, characteristics and interrelationships of landscape genes affecting traditional villages can be quickly identified, resulting in a knowledge network about the construction and cultural inheritance of traditional village cultural landscapes. The genetic network enables the traditional villages to more easily acquire exploration, analysis, guidance and management.

The traditional villages on the northern roads of the ancient Qin-Shu roads are fully characterized by their integration of northern and southern regional culture and national culture. The natural environment of the plains in the south and mountains in the north, and water in the south and drought in the north, leads to a flexible layout gene along the mountains and ancient roads, supplemented by water and pictographic patterns. Surrounded by mountains and rivers, culture and scenery blends, southern water and northern drought, farmers represent the main forest auxiliary landscape genes. For
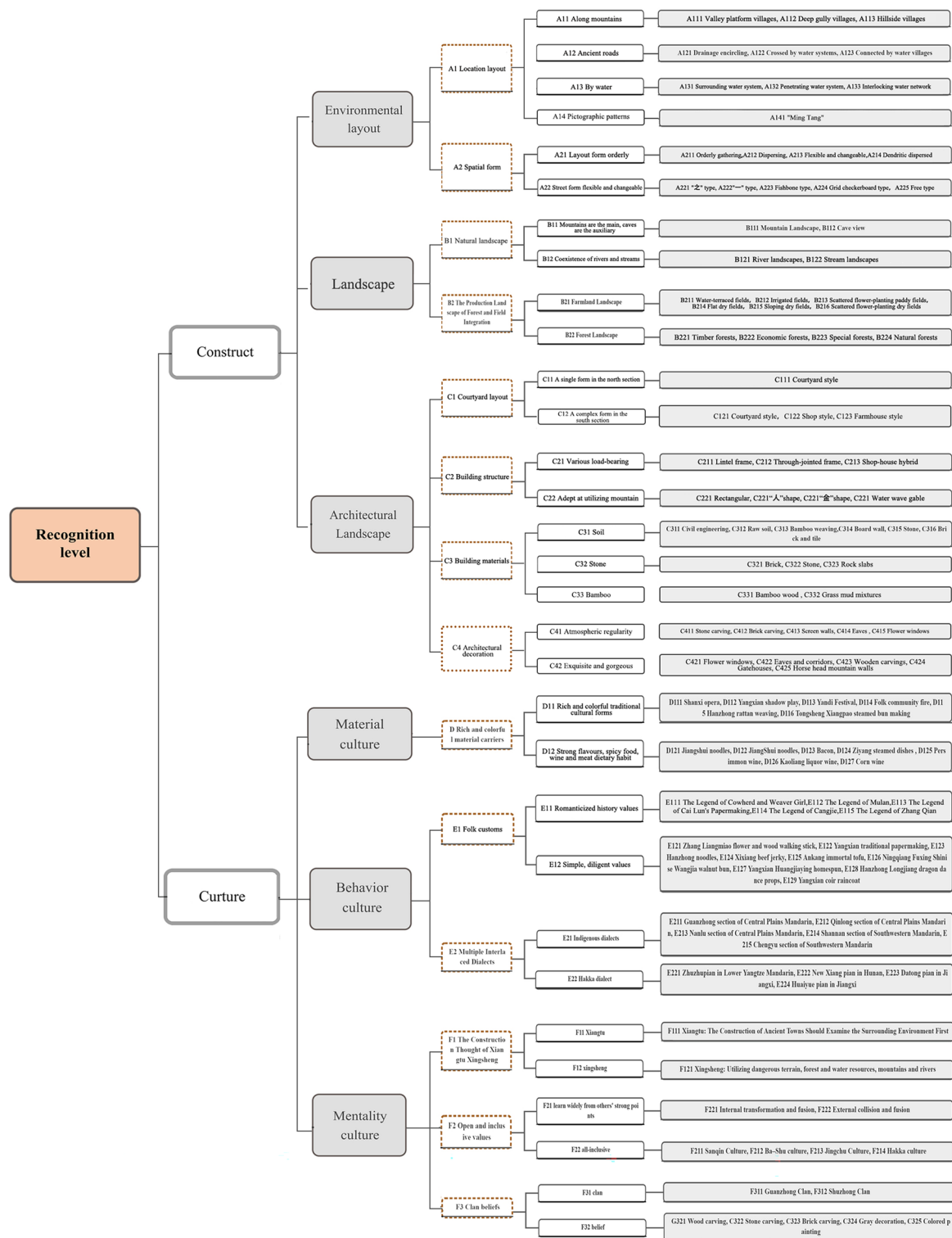
Fig. 8 Gene map of the cultural landscape of traditional villages along the northern roads

their buildings, the north section of the courtyard is single, the south section is complex, and the load-bearing structure is diverse. These buildings adeptly use gables, combine earth, stone and bamboo in their materials, recycle other materials, and decorate with atmospheric, orderly, exquisite and beautiful architectural genes. On the cultural level, under the influence of Chinese geomancy and Confucian culture, a variety of intangible folk customs have been formed here. In terms of food, the physical cultural genes of "strong flavour, good spice, happy wine and meat" have developed, as have the folk customs of a simple, thrifty and loving culture and the behavioural cultural genes of combining elegance and vulgarity. A cultural gene has evolved with the mentality of "matching soil and winning shape", "open and inclusive" and "diverse gathering". The results of this study are similar to those of traditional Chinese villages, but there are obvious regional differences.

Discussion and conclusion
Discussion
Theoretical and practical implications
The characteristic crisis of traditional villages in the present day is the phenomenon of 'one face for thousands of villages and one appearance for thousands of villages', in which standardization in renovation generates a problem shared globally, and many traditional villages are suffering sustained damage. How to protect and inherit the regional cultural characteristics of traditional villages has become an urgent practical problem to be solved.

First, gene identification, extraction and expression using biological and geographical methods have been widely used in many fields. At present, biological and geographical methods are rarely used in the study of traditional village landscape genes. This study adopts the interdisciplinary methods of biology, geography and cultural studies to explore the gene characteristics and internal philosophy uniting traditional village cultural landscapes. The findings of this research can provide an effective reference for future studies. Second, the traditional village cultural landscape is studied from the perspective of linear cultural heritage zones. The methods and research results adopted provide reasonable tools and methods for obtaining the core characteristics of the village landscapes along the ancient Qin–Shu roads and at the same time, provide ideas for the protection of traditional village landscapes and culture along linear cultural heritage zones.

Limitations of the research
This study focuses on the traditional villages along the ancient Qin–Shu roads and introduces the concept of genes into the study of the cultural landscape of traditional villages. Notably, the theoretical system that couples 'construction-culture' as genetic bases for analysis in this study is still in the preliminary stage of exploration, and the research method is relatively simple. In the future, we will continue to pay attention to landscape gene theory research and the in-depth discussion and optimization of research methods. In our current work, due to the limitations of time and funds, this study is restricted to additional representative traditional villages on the northern roads for more case studies, which directly impedes any testing of the generalizability of the theory to the complete ancient Qin-Shu roads.

Future research
As one of the linear cultural heritage zones in the world, the Qin–Shu roads and their traditional village landscape have certain similarities with other linear cultural zones. However, there are many linear cultural heritage zones in the world, such as the 'Southern Canal' in France, the 'Frankincense Road' in Oman, the Silk Road in China, the Grand Canal in Beijing and Hangzhou, and the ancient Tea–Horse Road. They greatly differ from each other. The applicability of the results of this study to other linear cultural heritage zones remains to be verified. Therefore, the cultural landscape genes of traditional villages in other linear cultural heritage zones are another direction for future research. In addition, it should be noted that in the interpretation of cultural landscape genes, this study adopts the influence of traditional Chinese philosophical concepts on village construction and culture, while there are different local philosophical and ecological ideas in other regions and countries. Therefore, the study of the influence of human settlement concepts in other regions and countries on their traditional village cultural landscape is another direction for future research.

Conclusion
This study focuses on the protection and development of 23 traditional villages along the northern roads of the ancient Qin–Shu roads to develop the protection and utilization of traditional villages as part of the overall protection of linear cultural heritage zones. Based on landscape gene theory and a model that coupled physical landscape construction and the culture of traditional villages along the ancient Qin-Shu roads, the landscape gene system for local traditional villages was constructed, resulting in the following conclusions: (1) The identification and extraction method of genes belonging to the coupling of 'construction and culture' in the traditional village cultural landscape was proposed. (2) The cultural landscape genes related to the construction of traditional villages on the northern roads were summarized. (3) The interpretation of the cosmological principles of the 'oneness of man and nature' and 'yin-yang and the five-element' theory constitute the concepts driving life in

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the traditional village settlement on the northern roads. (4) A gene map of the cultural landscape of traditional villages along the northern roads of the ancient Qin–Shu roads was generated. The traditional villages along the northern roads of the ancient Qin–Shu roads have a high degree of cultural confidence, highlighting the cultural characteristics of the integration of the north and South cultures, and containing the cultural value and perception of "pluralism and unity". Gene theory and research methods are introduced into the study of traditional village landscape, providing technical support for cracking the "cultural gene" of traditional village landscape, and creating a new perspective and new method for the theoretical study of cultural heritage. The in-depth analysis and research of traditional villages have broadened the vision, method and theoretical system of rural landscape research in north and south China. The final research results provide an important reference for rural development and cultural heritage protection.

Availability of data and materials
The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors have no relevant financial or non-financial interests to disclose.

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