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Identification and Extraction of Landscape Genes in Traditional Villages in Yuntai Mountain Global Geopark—A Case Study of Shuangmiao Village

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Abstract: *Traditional villages are cultural landscape carriers formed by the long-term integration of regional natural environments and historical-cultural systems. Landscape genes are the core units for analyzing village characteristics and inheriting regional cultures. Taking Shuangmiao Village in the Yuntai Mountain Global Geopark, Jiaozuo City, Henan Province as the research object, this study, based on the landscape gene theory, systematically identifies and extracts its landscape genes from four dimensions (environmental characteristics, layout characteristics, architectural characteristics, and cultural characteristics) in accordance with four recognition principles, namely intrinsic uniqueness, extrinsic uniqueness, local uniqueness, and overall dominance. A dominant-recessive dual-structural landscape gene atlas is constructed herein. The results show that the landscape genes of Shuangmiao Village are characterized by the geological foundation of the Yuntai landform, the stepped settlement layout in mountainous areas, the all-stone residential building system, the culture of the civil and military imperial examinations, and the folk culture of temple fairs, which integrate the uniqueness of natural geology, regional construction techniques, and the scarcity of historical and cultural resources. Traditional villages in geoparks exhibit a high coupling of natural and cultural genes as well as a symbiosis of material and non-material genes. The research results can provide theoretical support and practical references for the style protection, living cultural inheritance, and sustainable development of rural tourism in traditional villages within geoparks.*

Keywords: *Traditional Village; Landscape Gene; Yuntai Mountain Global Geopark; Shuangmiao Village*

1. Introduction

Traditional villages are complex cultural landscapes formed by the long-term coupling of natural environments and human historical development [1], and are known as the "living fossils" of regional cultures. Early domestic studies mainly focused on traditional dwellings [2], the middle-stage studies gradually expanded to spatial layout [3], street planning [4], and other aspects. In the later stage, scholars have gradually recognized the cultural connotations and values of traditional villages, and carried out interdisciplinary practical explorations involving protection measures [5], protection methods [6], and protection and development models [7]. Based on the biological concept of "gene" [8], the landscape gene theory provides a new perspective for analyzing the characteristics and formation mechanisms of natural and humanistic landscapes in settlements. Through continuous improvement by scholars, the landscape gene theory has been widely applied and has become a research hotspot in the field of traditional village studies, covering the identification of landscape genes in traditional settlements [9-12], the construction of landscape gene atlases [13-15], the protection of traditional settlements [16-18], the development, protection and tourism planning of traditional villages [19-20], and the research prospects of landscape genes in traditional villages [21]. By adopting the logic of genetic inheritance and variation in biology, the landscape gene theory deconstructs village landscapes into identifiable, inheritable and expressible cultural units, thus providing a new approach for the protection and revitalization of traditional villages.

The Yuntai Mountain Global Geopark takes the Yuntai landform as its core resource, and the traditional villages within the park possess the dual attributes of natural geological heritage and human settlement heritage. As a National Traditional Village and a National Famous Historical and Cultural Village of China, Shuangmiao Village is located in the deep mountainous area of the southern Taihang Mountains. Based on the Cambrian-Ordovician limestone landform, it has formed a complete stone settlement pattern, retaining a historical context of thousands of years and architectural relics from the

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Ming and Qing dynasties. Therefore, it serves as a typical sample for the research on landscape genes of traditional villages in geoparks.

2. Overview of the Study Area and Research Methods

2.1 Overview of the Study Area

Shuangmiao Village is situated in the deep mountainous area in the north of Xicun Township, Xiuwu County, Jiaozuo City, Henan Province, with the geographical coordinates of 35°19′N and 113°15′E. It has an average altitude of approximately 800 meters, a village area of 4.6 square kilometers, and is 40 kilometers away from the seat of Xiuwu County. First founded in the Sui and Tang dynasties, it was one of the thirteen passes on the ancient Jin-Yu Road, and was known as the "Gateway to the entire Jin Region". In 1956, its administrative jurisdiction was adjusted from Jincheng in Shanxi Province to Xiuwu County in Henan Province.

Up to 2026, the village has 69 households with a total population of 236 people and 292 mu of arable land. It has been successively listed as a National Traditional Village (2013), a Famous Historical and Cultural Village of Henan Province (2014), and a National Famous Historical and Cultural Village (2019). Located in the deep fault zone in the front of the Taihang Mountains and within the Qinglong Gorge Scenic Area of the Yuntai Mountain Global Geopark, the village presents a spatial pattern of "being surrounded by mountains on three sides and sandwiched between two gorges". Most of the buildings are constructed with bluestone, and historical relics such as the Sansheng Temple and the academies for civil and military imperial examinations are well preserved, boasting prominent landscape uniqueness and cultural scarcity.

2.2 Research Methods

2.2.1 Recognition Principles of Landscape Genes

In the long-term development process, the landscape genes of traditional villages are comprehensively influenced by natural environments, social cultures, economic activities and other factors, thus forming diverse external manifestations. In the identification and extraction of these landscape genes, careful screening is required to identify the core genes that not only shape the landscape forms but also play a key regulatory role in the overall development of the village.

This process requires not only focusing on the superficial characteristics of the landscape, but also exploring the internal driving factors behind it, and clarifying the formation and evolution mechanisms of landscape genes under specific historical and social backgrounds. To achieve this goal, a comprehensive analysis of the cultural landscapes of traditional villages is an essential preliminary work, which involves in-depth research on natural environments, architectural styles, cultural customs, social structures and other aspects. On this basis, the landscape genes of Shuangmiao Village are identified in accordance with four important principles of the landscape gene theory [25], namely intrinsic uniqueness, extrinsic uniqueness, local uniqueness and overall dominance.

The intrinsic uniqueness of the landscape genes of traditional villages is reflected in their unique cultural connotations and historical inheritance. Each traditional village has its distinctive historical background, cultural tradition and folk customs, which determine the uniqueness of the village landscape. Extrinsic uniqueness refers to the unique expressions of the traditional village landscape in terms of form, structure and appearance, including the village layout, architectural style, street pattern and public space design of Shuangmiao Village. Local uniqueness emphasizes the particularity of specific areas or elements in traditional villages. There are local landscape elements with special functions or cultural significance within the village, such as temples and ancient wells. These elements are not only unique in form, but also irreplaceable in cultural inheritance and social functions, thus forming an important part of the village landscape genes and reflecting the internal differences and diversity of the village. Overall dominance means that certain landscape features or elements dominate the overall landscape pattern of traditional villages and become prominent symbols and advantageous characteristics. These advantageous genes may include the overall layout of the village, the style of the main buildings, and the integration with the unique natural environment. These principles highlight the uniqueness, systematicness, stability and identifiability of landscape genes, and can accurately identify the core and representative genes from complex landscape elements, thereby providing a solid theoretical basis and practical guidance for the protection, inheritance and development of Shuangmiao Village.

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The logic of landscape gene recognition principles is shown in Figure 1.

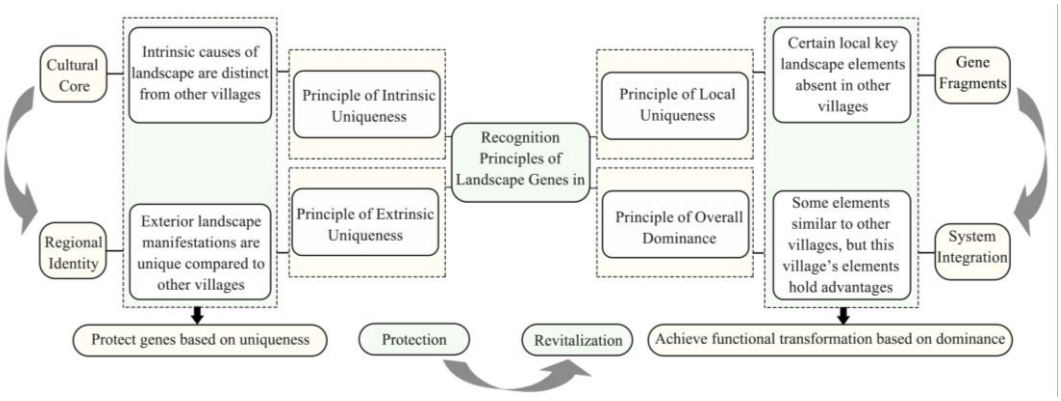

Figure 1 Logic Diagram of Landscape Gene Identification Principles

2.2.2 Classification of Landscape Gene Elements

The landscape genes of traditional villages can be classified according to their inherent attributes and expressive forms (see Table 1). Based on inherent attributes, landscape genes are divided into core genes, attached genes, hybrid genes and mutated genes. Core genes refer to the most prominent landscape characteristics of villages, such as unique architectural styles and village layout patterns. Attached genes are dependent on core genes, such as carvings and door and window styles on buildings. Hybrid genes have complex compositions and may integrate multiple functions and cultural elements. Mutated genes are evolved from the original landscape genes, which retain traditional elements while incorporating new characteristics. According to expressive forms, landscape genes are divided into dominant genes and recessive genes. Dominant genes have material forms and are easy to observe directly, such as stone houses, ancient streets and natural landscapes [23], which constitute the unique material landscape of villages. Recessive genes have no material forms but exert a profound influence on village culture and landscape construction, such as folk activities, folk beliefs and handicraft inheritance, which require in-depth investigation and field experience to perceive and identify.

Table 1 Classification Table of Landscape Genes in Traditional Villages

Classification Criteria	Gene Classification	Specific Manifestations
Manifestation Form	Dominant Genes	Refers to genes that can be directly observed in the landscape with obvious material morphological characteristics, playing a dominant role in the overall style and visual features of the village landscape.
	Recessive Genes	Refers to genes that are not easily directly observed in the landscape with non-material morphological characteristics, reflecting the inner spirit and cultural connotation of the traditional village landscape.
Intrinsic Attributes	Core Genes	The most prominent attribute with foundational dominance, which can influence the fundamental properties of the landscape and play a decisive role in shaping the overall style of the settlement landscape.
	Attached Genes	Exist dependent on core genes; although they cannot determine the overall village style, they can enhance the integrity of the landscape and enrich its content.
	Hybrid Genes	Have complex composition, rich content and polymorphism, representing specific landscapes existing in a particular settlement as a manifestation of the integration of multiple elements.
	Mutated Genes	The result expressed after the original landscape genes are impacted by social history and natural environment, featuring new-born characteristics while retaining partial attributes of the original landscape form.

2.2.3 Extraction Methods of Landscape Genes

The extraction methods of landscape genes in traditional settlements include element extraction, pattern analysis, structure extraction, connotation excavation, feature deconstruction extraction,

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landscape gene atlas construction, the landscape gene information chain theory, GIS technology application, comparison method, data recording method, field observation method, and spatial and cultural gene recognition. From different perspectives, these methods cover the analysis of material and non-material cultural elements, the identification of spatial layout, architectural forms and decorative patterns, the extraction of overall structural and skeleton characteristics, the interpretation of cultural connotations, and the application of modern technologies, thus forming a comprehensive extraction system.

For the extraction of landscape genes in Shuangmiao Village, the recognition and extraction methods proposed by scholars are integrated to achieve a more comprehensive identification. Professor Liu Peilin proposed a four-dimensional recognition method, including 2D representation, 3D representation, visual perception representation and spatial structure representation [24], which is conducive to grasping the overall characteristics of the village from the perspectives of morphology and structure. 2D representation focuses on the planar layout of settlements, analyzing the morphological characteristics of individual buildings (e.g., roofs, gables and facades) and their planar arrangement. 3D representation focuses on the spatial structure of settlements, studying the organic configuration and spatial distribution of individual buildings, as well as the prominent expression of landmark buildings in 3D space. Visual perception representation perceives the overall landscape image of settlements through field observation and investigation, and analyzes architectural technologies, modeling techniques, decorative arts, cultural beliefs and other characteristics. Spatial structure representation analyzes the individual buildings, building groups, spatial layout and landscape construction techniques of settlements to comprehensively grasp their overall landscape characteristics.

Hu Zui and other scholars emphasized four identification methods for material landscape genes, namely element extraction, connotation excavation, structure extraction and pattern extraction [25], which focus on the in-depth analysis of specific elements and cultural connotations. In the study of Shuangmiao Village, Liu's four-dimensional method is adopted to grasp the morphological and spatial characteristics of the village at the macro level. Element extraction identifies and extracts the basic elements in settlements (e.g., building components and decorative details) as the basic units of landscape genes. Connotation excavation explores the cultural connotations and historical significance behind settlements, and transforms non-material cultural elements such as cultural traditions, legends, social structures and spiritual beliefs into tangible landscape gene connotations. Structure extraction analyzes the overall structure of settlements, extracts skeleton characteristics such as road networks and water system distribution, and explores their internal correlations with cultural genes. Pattern extraction identifies patterns and symbols with cultural inheritance significance (e.g., architectural decorative patterns and layout forms) as important expressive forms of landscape genes.

To extract the landscape genes of Shuangmiao Village, the morphological and spatial characteristics are first grasped at the macro level, and then the specific landscape elements and cultural symbols are extracted at the micro level. These two methods complement each other, and the landscape genes are identified and extracted from the four dimensions of environmental, layout, architectural and cultural characteristics in a logic from macro to micro and from form to connotation (see Figure 2).

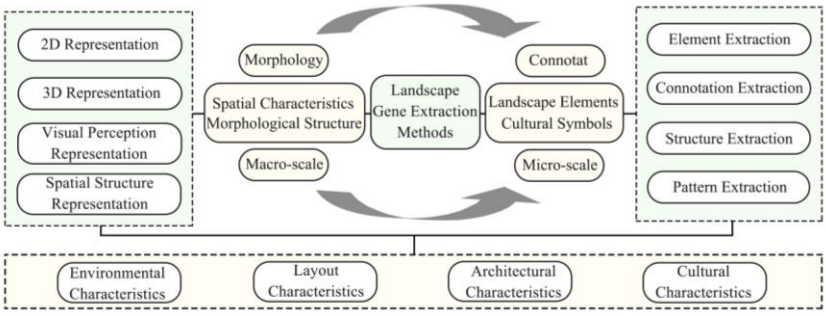

Figure 2 Diagram of Landscape Gene Extraction Method in Shuangmiao Village

3. Systematic Analysis of Landscape Genes in Shuangmiao Village

Dominant genes refer to the directly observable material landscape elements, including environmental genes, layout genes and architectural genes. Recessive genes are non-material genetic units carrying cultural connotations, mainly including cultural genes such as historical context, village

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culture and folk customs.

3.1 Environmental Genes

(1) Geological environmental genes: The village is located in the Cambrian-Ordovician limestone distribution area, which is controlled by the Taihang Mountain fault zone and neotectonic movement, thus forming the Yuntai landform characterized by canyons, cliffs and springs. The terrain is high in the north and low in the south, with cliffs serving as natural barriers in the north and gentle terraces in the south, presenting a spatial pattern of "backing onto mountains and facing farmlands, embracing yin and gathering yang".

(2) Natural environmental genes: The village is surrounded by 19,000 mu of national public welfare forests with high vegetation coverage, and there are ancient trees such as Sophora japonica, pines, hawthorns and walnuts in the village, forming a composite ecosystem of "mountain-forest-farmland-village".

(3) Village environmental genes: The village is built on fault cliffs, with mountains surrounding it on three sides and an open southern side, forming a natural defensive barbican structure, which is in line with traditional feng shui concepts and the survival needs of mountainous areas. The ancient village is constructed in accordance with the natural terrain, and each part is connected by winding stone steps, showing an exquisite, profound, ancient and mysterious spatial feature. The village is surrounded by blooming flowers for three seasons a year, and the terraced fields with a history of thousands of years constitute a beautiful living environment, conveying a leisurely cultural artistic conception.

3.2 Layout Genes

(1) Village form genes: The construction area of Shuangmiao Village adopts a centralized layout pattern. With the Sansheng Temple on the northern slope and the Buddha and Guanyin Temple on the southern slope as the core public spaces, a north-south central axis is formed, and historical buildings such as the former residences of the civil and military imperial scholars are well preserved. The northern area has a steep terrain, where buildings are distributed vertically along the contour lines, forming a stepped settlement pattern; the southern area has a gentle terrain, with courtyard houses and fishbone-shaped streets as the main features. All houses are constructed with stone materials, scattered along the mountain slope, and connected by winding bluestone paths and stone steps, forming a simple and layered spatial texture.

(2) Spatial layout genes: Shuangmiao Village adopts a function-oriented fishbone-shaped street system, with one main street running through the whole village and multiple short branch lanes connected vertically to it. The bluestone paths are constructed in adaptation to the terrain, integrating the functions of transportation, drainage and landscape viewing. The spatial axis is formed by the Sansheng Temple (Upper Temple) on the northern slope and the Buddha and Guanyin Temple (Lower Temple) on the southern slope, which connects various public spaces and residential communities in the village. The public spaces in the village are centered on temples, stages, village squares and antique commercial streets, integrating the functions of religious belief, social communication and tourism services.

3.3 Architectural Genes

(1) Building type genes: The western old village is dominated by traditional stone buildings, including ancestral temples, residential dwellings and imperial examination academies; the eastern part is mainly modern brick-concrete buildings serving tourism development, forming a dual spatial structure of "traditional old village + tourism new village".

(2) Architectural form genes: Five typical spatial layout patterns are summarized in Shuangmiao Village: ① I-shaped stone houses extending horizontally along the ridge contour lines; ② L-shaped semi-courtyards with single-slope wing rooms added to form small patios; ③ U-shaped courtyards consisting of a main room, two wing-rooms and a gate tower; ④ "Eye"-shaped two-entry courtyards represented by the academies for civil and military imperial examinations; ⑤ the combined "shop in the front and accommodation at the back" modules in the new tourism street. These layout patterns constitute a complete system featuring "adapting to mountainous terrain and expanding from points to zones".

(3) Architectural style genes: The architectural style integrates the rugged and grand characteristics of Shanxi architecture and the ritual layout of Beijing courtyard houses, with an all-stone structure as the

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core feature, grayish blue as the main color tone, and natural log color components as the supplement. The architectural details are decorated with bas-relief stone carvings themed on auspicious animals, flowers and the characters of "Fu, Lu and Shou". The buildings adopt local bluestone for wall construction and slab stone for roof laying, and their foundations, steps and walls are all adapted to the mountainous terrain, which highlights the defensive and practical functions of the buildings.

3.4 Cultural Genes

(1) Historical and cultural genes: Founded in the Sui and Tang dynasties and prospering in the Ming and Qing dynasties, Shuangmiao Village was an important pass on the ancient Jin-Yu Road with a development history of more than a thousand years. In the Qing Dynasty, Guo Zaifen (a military imperial scholar) and Guo Jingfen (a civil imperial scholar) emerged in the village, forming a cultural context of "civil and military double scholars", with flagpole stones and imperial examination academies as its material carriers. In 1943, the Eighth Route Army built grain storage caves here, making the village an important node of the Taihang Anti-Japanese Base.

(2) Intangible cultural heritage genes: The temple fair held on the 18th day of the third lunar month has a history of more than 200 years, which integrates religious sacrifice, fire performance, opera performances and commodity exchange. Taihang root carving and folk paper-cutting are the representative intangible cultural heritages of the village, which adopt local materials and simple crafting techniques, reflecting the artistic characteristics of the folk art in the Taihang mountain area.

(3) Folk custom genes: The folk customs of the village are deeply rooted in its millennial history and folk beliefs, with temple sacrifices as the core. The name of the village originates from the Buddha Temple and the Guanyin Temple in the village. A temple fair is also held on the second day of the second lunar month to pray for favorable weather and good harvests. With the development of the times, folk festivals featuring cheongsam shows and Huaibang opera performances have injected new vitality into the ancient village, reflecting the integration of tradition and modernity. The dietary characteristics of the village are summarized as "two dishes and one noodle", namely salty rice, braised stew and mixed noodles, forming a rural dietary style in northern Henan Province based on mountainous local ingredients.

4. Construction of the Landscape Gene Atlas of Shuangmiao Village

4.1 Results of Landscape Gene Extraction in Shuangmiao Village

Based on the above research and analysis, the results of landscape gene identification for Shuangmiao Village are divided into two major categories: dominant genes and recessive genes. The dominant genes include environmental characteristics, layout characteristics and architectural characteristics. In terms of the environment, the village is located in the Yuntai Mountain Global Geopark, and relying on the fault zone in the front of the Taihang Mountains, it forms a typical landscape featuring canyons and cliffs. The village is built on a fault cliff, with mountains on three sides and an open south side, forming a natural barbican structure, and preserves ancient trees such as Sophora japonica, pines, hawthorns and walnuts. In terms of layout, the village presents a stepped and compact layout pattern, with a fishbone-shaped and function-oriented street system: one main street runs through the entire village, and the short branch lanes are flexibly arranged with variable widths. The public space elements of the village include temples, stages, village entrance squares and other facilities. In terms of architecture, traditional buildings are concentrated in the western old village, which are constructed in accordance with the terrain. Their floor plans can be summarized into five spatial patterns: the "I"-shaped stone house, the "L"-shaped semi-enclosed courtyard, the concave-shaped three-sided courtyard, the "Eye"-shaped two-entry quadrangle courtyard, and the contiguous "shopfront in the front and lodging at the rear" module. The architectural style is based on the Shanxi school of architecture, integrates the quadrangle courtyard form of the Beijing school, and is deeply adapted to local geographical conditions, forming a distinctive regional stone-built vernacular dwelling style. The color palette is dominated by the bluish gray of local bluestone, supplemented by natural wood tones, and interspersed with bright colors from folk activities on specific occasions. The architectural details are decorated with bluestone bas-reliefs depicting auspicious characters such as "Fu (fortune)", "Lu (prosperity)" and "Shou (longevity)", which are concentrated on the roof ridges, chitou (decorative upper corners of gable walls) and courtyard wall cappings.

Recessive genes are reflected in the cultural characteristics of the village. First founded in the Sui and Tang dynasties, the village has historically produced both a military imperial scholar and a civil imperial scholar, and boasts a rich red cultural heritage (revolutionary heritage). The temple fair culture has been

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inherited for more than 200 years, and the village also preserves intangible cultural heritages such as root carving and paper-cutting. The folk customs include festival sacrificial activities and Huaibang opera performances, and the local food culture is characterized by the "two dishes and one noodle" diet (salted rice, mixed stew and miscellaneous noodles). On the whole, the landscape gene system of Shuangmiao Village is complete, in which the dominant material elements and recessive cultural connotations complement and promote each other, forming a traditional settlement heritage with distinctive regional characteristics.

4.2 Landscape Gene Map of Shuangmiao Village

Based on the above analysis, the landscape gene pedigree of Shuangmiao Village is summarized in Figure 3, which is divided into two categories: dominant genes and recessive genes. The dominant genes include 3 primary landscape elements, 8 secondary landscape elements and 12 tertiary landscape factors; the recessive genes are mainly embodied in cultural characteristics, including 3 secondary landscape elements and 6 tertiary landscape factors.

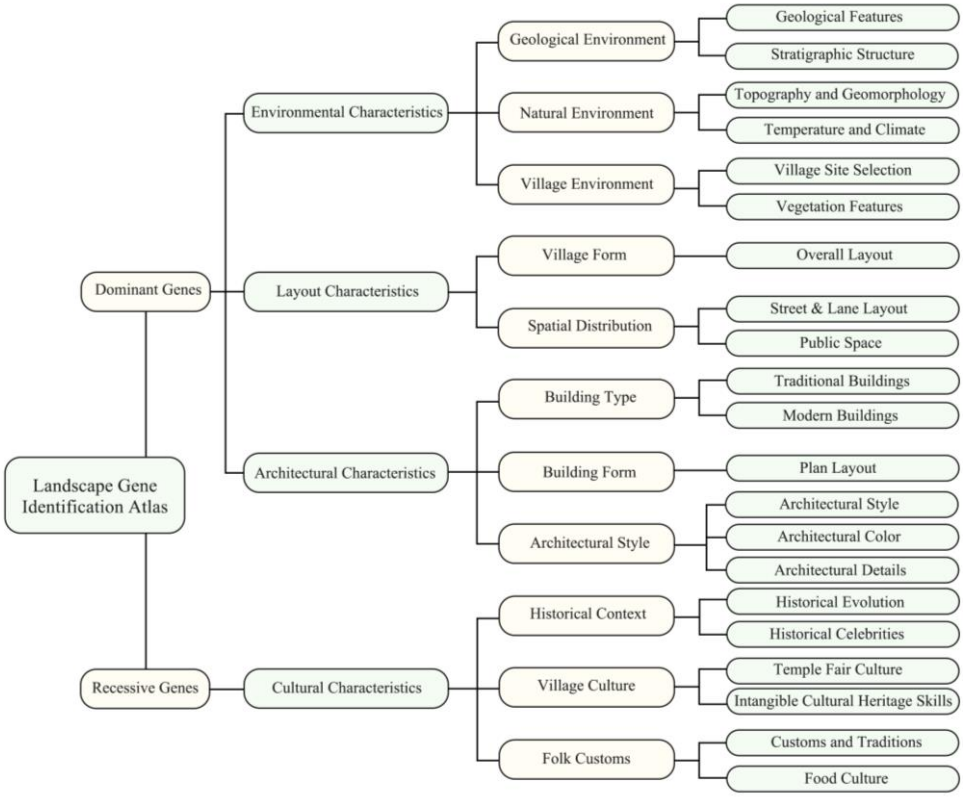

Figure 3 Landscape Gene Atlas of Shuangmiao Village

5. Conclusion and Discussion

5.1 Conclusion

(1) The landscape genes of Shuangmiao Village consist of four systems, namely environmental genes, layout genes, architectural genes and cultural genes, with a high coupling of natural and cultural genes as well as material and non-material genes, thus forming a unique landscape gene system of traditional villages in geoparks. (2) The core landscape genes of the village have significant uniqueness and competitive advantages: the Yuntai landform provides a natural geological foundation, the fishbone-shaped streets and stepped settlement layout reflect the adaptability to mountainous terrain, the all-stone dwellings embody the regional construction techniques, and the culture of civil and military imperial examinations and temple fair folk culture constitute the cultural core of the village. (3) The research framework of "four principles-two methods-four dimensions" is applicable to the identification and extraction of landscape genes in traditional villages in northern mountainous areas and geoparks, which provides a methodological reference for the relevant research of similar villages. (4) The landscape gene

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atlas intuitively presents the composition and distribution characteristics of the landscape genes of Shuangmiao Village, providing an accurate scientific basis for the protection planning, tourism development and cultural inheritance of the village.

5.2 Discussion

As a superposition carrier of natural geological heritage and cultural village heritage, the protection and development of Shuangmiao Village should adhere to the principle of priority for the authentic protection of landscape genes: strictly protect the dominant genes such as geological landforms, street textures and stone buildings; inherit the recessive genes such as temple fair culture, intangible cultural heritages and dietary culture in a living way; and avoid style homogenization in the process of tourism development to maintain the integrity and uniqueness of the village's landscape genes. In the future, in-depth research can be carried out on the inheritance mechanism, activation paths and digital expression forms of landscape genes, so as to further promote the sustainable development of traditional villages in geoparks.

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