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The Relationship between Spatial Behavior and External Spatial Elements in Ancient Villages Based on GPS-GIS: A Case Study of Huangshan Hinterland, China

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Abstract: Under rural revitalization and rapid construction in China, the mismatch between contemporary rural communities and villagers' space behavior habits has attracted widespread attention. This study proposes and practices a design methodology for a newly built rural community based on spatial elements and their relationship with the behavior of local ancient villages. We explore the relationship between the two by applying drone-tech aerial photos, GPS, and ArcGIS. The results indicate that: (1) Ancient villages have abundant external spatial elements different from urban communities. Each space element of the ancient village has a specific function corresponding to the villagers' daily life needs. (2) Village space elements are outcomes of the sociocultural process, and their topological structure is not random but follows their use based on hours of the day. (3) About 94.6% of space use behavior in the case of ancient village residents is associated with five space elements. (4) Updating the external spatial elements of ancient villages under the demands of contemporary life makes the application of spatial elements not only continue the villagers' natural life process, but also satisfy the demands of the contemporary way of life on the external space. This study proposes the characteristics of the relationship between ancient village spatial behavior and external spatial elements through scientific analysis methods, which can provide references for contemporary rural planning and help to solve the mismatch problem between contemporary rural communities and villagers' behavior habits.

Keywords: ancient village; rural planning; spatial behavior; external space; space elements

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1. Introduction

Placing rural development planning in context is crucial to deal with the renewed emphasis on the study of villages, in particular, the spatial design of village space. After centuries of exploitation of the rural for sourcing urban consumption (food, industrial inputs, and energy), rural planning emerged as a response to urban problems. In the US [1] and Australia [2], rural planning was initiated by the demand to create villages and small towns that combine the virtues of town and country to minimize city problems. Against the US, Australia, and the UK, rural planning in China emerged as an initiative to balance urban and rural development disparities and further advanced to ecological restoration [2].

Globally, ideological shifts have marked the evolution of rural planning. Post-World War II, decisive government intervention was evident, driven by the goal of utilitarian maximization driven by problems of industrial urbanization. The neoliberal regime shortly seized the government's coordinating role. It commodified rural means of production and land, prioritizing economic gains over social equity and eco-environmental concerns. Within this turbulent regime, governments, in some cases, such as the UK in the 1940s, made efforts to protect specific sectors, like agricultural land and, in the 1980s, the rural in

its own right. Since the turn of the century, the discourse on sustainable development has significantly influenced rural planning.

A close investigation of the literature indicates that rural planning, like any other planning, has been affected by globalization and domestic political governance. On the global scale, lagging countries follow in the steps of leading countries, regardless of ideological differences. At the national scale, while still keeping the global parallel, who assumes this government capacity matters in rural planning. The complete reversal of the UK Labour Party's advocacy for the facilitative role of planning since the second half of the 1990s by the Conservative government in 2010 is evident [2]. In fact, the representation in the polity has demonstrated that its significance is not limited to rural planning, but also in many other sectors such as land and housing (cf. [3–5]).

As an integral part of the polity ideology on the one hand and a matter of local reality on the other hand, there is an existing conflict over rural planning regarding top–down coordination planning versus bottom–up participatory planning that would have substantial spatial outcomes. Top–down planning avails avenues to coordinate localized activities, whereas bottom–up planning is ideal for meeting local needs, including local identity. Because of significant variations in natural comparative advantages, the effects of specific local communities could be grave on others. On the contrary, top–down plans usually affect the potential of specific local communities. This yet-to-be-resolved discussion is the balance to strike, which is a question of balancing collective interest (national or regional scale) and freedom at the local scale, taking externality into consideration.

What we understand is that the importance of polity representation and planning is temporally contingent on global policy dialogs. However, jurisdictional arrangement is another point that needs to be addressed in rural planning. In many countries, rural areas are organized under townships, and the influence of urban planning is evident. On the contrary, in urban versus rural dichotomous jurisdictional territorial arrangements, such as in Ethiopia, rural spatial planning needs to be considered to date.

As part of the overall rural development paradigm, there has been a newfound emphasis on the study of villages as custodians of history and culture [6–12], at least since the 1950s [9]. The spatial structure of ancient villages is a physical manifestation of a society's philosophy regarding the context of man–space relationships. Village spatial structure is not the sole evolution of the daily activity of generations. In oriental countries, particularly China, Japan, and Korea, for instance, the vital importance of village space structure lies in the social wisdom of geomancy [6,10–12]. In a philosophical socio-cultural notion, village space may mean a reflection of the rural way of life, such as neighborliness. In this perspective, Hibbard and Frank [13] argue that rural planning has to depend on the rurality construct for a theoretical base, which suggests that village space planning should be part of the wider rural planning context.

However, the logic of village space structure, which constitutes the core worth of preservation, needs to be researched more from the perspective of the correlation of village space elements and the space behavior of village inhabitants, mainly in ancient villages. The extensive literature on village space is bounded within physical morphology villages [6,14–16]. Behavioral studies are attraction-based observations and need more comprehensiveness in enumerating village space elements. Settlement livability and life-supporting productions are integral to the space generation logic [17,18].

Regarding the logic of the topological built environment and its allied functionalities, the authenticity loss of villages is also attributed to the knowledge and skill limitation of planning authorities [9]. Consequently, plans based on local community participation can enhance quality significantly [9,19]. The involvement of citizens in planning also facilitates further understanding of their local environment [20,21].

In either case, the need for thorough precaution in village spatial planning is that an intervention, once applied, determines the next generations' planning trajectory [22], as it develops into a certain habited culture [7].

This paper explores the relationship between the space elements of ancient villages and the space behavior of ancient village inhabitants, partly as a reflection of the blueprint design application in China and, in part, as an extension of the debate on the village space creation discourse. The next section presents the background of the problem in China, where modular blueprint design negatively affects the logic of the spatial elements of ancient villages and villagers' daily lives. Section 3 presents the methodology. Section 4 presents the field survey results enumerating ancient village space elements and their functions and explores the correlation of space with behavior. Section 5 discusses the logic of space behavior and its interpretations. Section 6 concludes the significance of the paper and indicates its limitations.

2. Background

2.1. The Modularization of External Spatial Elements in Newly Built Rural Communities Has a Negative Impact on the Spatial Behavior of Villagers

Over the past seven decades, the long-tenured and stable government of China has shaped rural areas in many economic, social, cultural, and spatial contexts. Since the republic's foundation, the Chinese government has implemented six consecutive rural development strategies with clear objectives and implementation plans, including the New Rural Construction of the 1950s, which facilitated collectivization, aiming to boost agricultural produce and flowering rural and township enterprises. In the 1980s, the driving paradigm of rural development was tourism. Rural development programs intensified further science at the turn of the century, during which, the government implemented four programs, including the 2006 Socialist Countryside, the 2013 Beautiful Countryside, the 2014 Characteristic Small Town, and the 2018 Rural Revitalization Strategy (Table 1). The common purpose of these seven decades of rural development initiatives, particularly those implemented since the turn of the millennium, is addressing the long-standing urban versus rural development imbalance, promoting comprehensive rural development, and achieving sustainable national development.

Table 1. Summary of the characteristics of the recent four China's rural development strategies.

No.	Strategies	Year	Main Characters
1	The construction of new socialist countryside	2005	The core objectives of this strategy are production development, comfortable life, civilized rural customs, clean environment, and democratic management.
2	The beautiful countryside	2013	This strategy proposes ten rural development models, including industrial development, ecological protection, suburban intensification, comprehensive social management, cultural inheritance, fishery development, grassland pasture, environmental improvement, leisure tourism, and efficient agriculture.
3	Rural tourism	2015	With the natural and humanistic objects with rural characteristics as the tourist attraction, on the basis of traditional rural leisure tourism and agricultural experience tourism, expand the development of conference vacation, leisure and entertainment projects, increase farmers' income, and promote local characteristics and folk culture.
4	The rural revitalization strategy	2017	This is a comprehensive policy initiative to address the development challenges faced by rural areas and promote the sustainable growth of the countryside. The key aspects of this strategy include improving rural infrastructure, enhancing agricultural productivity, diversifying rural economies, improving rural living standards, strengthening rural governance, and coordinating urban–rural development, etc.

Under these development strategies, the modernization of residential houses and the installation of urban-like physical infrastructures have been claimed as positive achievements. In such aspects, the gap between urban and rural areas has reduced significantly. Furthermore, these rural development programs helped to narrow the urban and rural income gap from 3.14 in 2007 to 2.50 in 2021 [23].

On the contrary, new rural planning projects have changed numerous rural areas to urban settlements. Urbanization was once the hegemony of persuasion to increase the number of cities and towns and urban populations, and excessive expansion of the area of urban construction land was regarded as a positive achievement. It has even been theorized that urbanization is unstoppable and should not be so, despite accommodating it. This view is still a point of discussion. The response of policy to the growing urban and rural socioeconomic divide caused by the process of urbanization has transformed villages into cities that threaten the regional characteristics, production, and lifestyle of villages [24]. Erroneously, the destructive construction mode, newly built rural community construction that neglects the rural nature of production and life, and the construction of the "quasi-urbanization" of villages have become the modular models of rural transformation [25,26]. Amidst such turbulent destruction, concern for alternative urbanization emerged under the theme of New Urbanism [27,28], which ultimately has given rise to alternative village modernization that keeps the rural production mode and local identity (built environment fabric and culture, etc.), and regional characteristics are becoming joined to the theme of sustainable development.

The effect of changes in the living environment and daily life of village communities has been drastic [29], particularly in terms of the physical features and structure of rural settlements. The spatial development aspect of these rural development programs involves creating new townships by relocating villagers and intervening in the existing villages' built environment by introducing new elements or modifying existing ones, such as alley expansion, clearing certain buildings, and introducing squares, etc., partly given by the ease of tourist traffic flow and creating visual appeal.

A certain degree of mismatch between the real space needs of inhabitants and the newly built rural community is evident, which ultimately wrecks inhabitants' satisfaction with the new space construction [30]. Researchers encounter significant spatial behavioral discrepancies between those who relocate to the new countryside and those who continue living in their original villages [31]. Rural planning affects both the sustainable development of villages [32] and the sustenance of their continuing existence as social and ecological entities and carriers of history and heritage.

The external space of ancient villages, as defined in this research, is the space constituting areas between residential buildings. A village's external space is not extended to the infinite extension of nature, such as forests and farmland. It is a domain of a meaningful social space rather than a natural environment beyond daily social interactions [33]. This external space constitutes the core of rural land use design, which involves various types of spaces and structures within the boundaries of a village's socially constructed spatial entity.

This culturally rich, traditionally vibrant, socially interactive, and eco-environmentally stable local external space has essential research value these days [9,19], especially in China [34,35]. The need to study village spaces emanates from their essential role in residents' daily societal lives and their contributions to the livability and vitality of a settlement [18,36]. Comfortable external spaces improve residents' quality of life by accommodating encounters with fellow residents, offering recreational opportunities and considerable social values [17] and flourishing the development of daily life and rural culture [37]. Elsewhere, ancient villages in other countries are conservation sites, museums of cultural values, and historical chronicles of ancestral generations [38]. The value of ancient villages would probably be substantial in China, where 8169 villages have already been designated as cultural and historic carriers of the country's five millennia legacy, and more numbers are expected soon [8].

We wanted to verify whether the spatial elements of newly established rural communities are modularized across different regions. So, we investigated the space designs of eight freshly built rural communities sampled from eight provinces, representing different administrative, geographic (coastal versus inland), and macro development environment (modern city areas versus predominantly rural hinterland) regions (Figure 1). The villages were also selected based on eight different planning firms. The data show that the design of new rural areas mirrors city space elements (Table 2). Since contemporary rural communities in China are designed as per table works of planning institutions and the developers build according to these drawings, the external spatial elements of contemporary rural communities can be obtained by analyzing the design drawings.

Figure 1. Locations of eight newly built rural communities (the map also includes the locations of three ancient villages and one newly built rural community included in the follow-up study).

Table 2. Categories of external spatial elements in eight cases of newly built rural communities in different regions.

External Spatial Elements	Village A Shanghai Municipality	Village B Jiangsu Province	Village C Hainan Province	Village D Zhejiang Province	Village E Henan Province	Village F Liaoning Province	Village G Shanxi Province	Village H Anhui Province
Piazza	•	•	•	•	•	•	•	•
Lawn	•	•	•	•	•	•	•	•
Carriageway	•	•	•	•	•	•	•	•
Pavement	•	•	•	•	•	•	•	•
Car parks	•	•	•	•	•	•	•	•
Planting Pond	•	•	•	•	•	•	•	•
Basketball court				•		•		
Drainage	•	•	•	•	•	•	•	•
Guard house	•	•	•	•	•	•	•	•
Pavilion	•	•		•	•			
Stream				•				•
Pond	•	•	•	•				•
Bridge				•				•
Open-air stage	•	•					•	•

"•" in the table indicates that the village contains this element.

As indicated in the above table, 81% of the external spatial elements in the eight cases were identical, reflecting that contemporary rural communities across the country are designed using modular design elements. The seriousness of the problem lies in the fact that the spatial plans completely ignored the rich and diverse spatial elements of the lo-

cal ancient villages [39] that must have transferred regional characteristics in terms of the village's external spatial elements and architectural styles and meanings to the next generations. These modular plans also ignore interpreting the need to transplant villagers' daily lives to the new planning movement [40–42].

Changes in external spatial elements have an impact, or even a complete change, on the lifestyle and spatial behavior of villagers [43]. The functional space elements in ancient villages support the basic spatial needs of the inhabitants, including the storage of firewood and farm tools, the growing of vegetables, and the raising of livestock. For example, a courtyard may be used to store firewood and agricultural tools; vegetable plots can meet the villagers' vegetable supply needs; pens can meet the villager's needs to raise livestock. These kinds of space utility functions have entirely been ignored in newly built rural community design, depriving the behavioral and functional space needs of villagers. This deprivation has been reflected by inhabitants' spontaneous transformation of the external space of newly built rural communities into vegetable plots or pens.

Villagers often remain unchanged with their rural economic mode of production and agricultural lifestyle, although they might be moved physically, voluntarily, or involuntarily to their new settlement. It is difficult for villagers to find jobs that are compatible with the latest urbanized settlements. Rural agricultural production cannot be fully performed in accordance with the urban model. Production is more accessible to guarantee when there is space for farm tools and livestock. This fact has been well-recognized and is discussed with due diligence in several important documents, such as ref. [44]. Consequently, conflicts often occur between inhabitants and managers, because managers favor visual scenery over the necessities of inhabitants. Very often, such conflicts are resolved through compulsory regulations that back the managers.

2.2. The Reference Value of the External Spatial Elements of the Ancient Village

The unique defining feature of an ancient village's external space is that it is an outcome of the long-term adaptive development of man to nature. This wisdom of adaptation to nature generates the spatial behavior of inhabitants and evolves over generations. The spatial behavior of inhabitants is not adventurous, but it connected to their daily production and living modes responding to the local natural elements, including climatic and topographic conditions. The harmonious relationship between the space and behavior of ancient villages is a wisdom that invites quest and learning to provide a reference for contemporary village spatial planning in particular and rural development planning in general.

In fact, some studies regarding village space exist but need to be more coherent, and the general endeavor needs more scientific methodological problems. Generally, ancient village space classification studies can be divided into spatial-type-oriented and constituent-element-oriented studies.

Conventionally, spatial type classification research categorizes space into historical, cultural, alley, and building spaces as four subsystems [45]. The village space is also divided into the interior and courtyard space (building unit level), alley space, public space, and surrounding landscape space. The public space may be divided into squares, wells, water streets [46], and green spaces [47]. Some scholars classify ancient village public spaces as explicit and invisible spaces based on their scope of accessibility. The former includes ancestral halls, streets, open educational facilities, and public service facilities, etc., while the latter consists of wells, riverbank beaches, spaces between houses, village shops, teahouses, and entertainment venues, etc. [48].

Among the few constituent-oriented studies in China, Peng Yigang proposed typical landscape elements from the perspective of landscape analysis. His prototype of external spatial environments constitutes 13 elements, including alleys, water streets, bridges, and Chinese memorial arches, etc. [49] Based on an ancient map, Pei Yifei's analysis of the spatial structure of ancient villages identifies eight components, including roads, residences, cemeteries, and landmarks, but also extends beyond to consider mountains, rivers, fields,

and forests that are not parts of the socially generated space [50]. For those who look at a village within a macro environment, mountains, forests, water, farmland, buildings, roads, and production and living elements are parts of the landscape design practice [51]. Monographs of village and national annals also contain references to the elements that make up the external spatial environment of ancient villages. However, these works are not special studies with the theme of categorizing these elements [52].

The classification of village space by space type facilitates a quick understanding of the overall spatial structure of a village. However, the multiple attributed nature of spatial type affects the interpretation of the results of the nexus between space and behavior. More concretely, attributes such as open space, private space, historical space, cultural space, and so on are redundant subsystems that appear in different classifications. For example, the square in front of the ancestral hall belongs to both open and cultural spaces.

To make the spatial element categorization study robust, we believe the spatial-entity-oriented spatial element categorization study is more plausible, in particular regarding the local spatial elements of villages in different regions.

2.3. Research on the Spatial Behavior of Villages Associated with Spatial Elements Will Provide Specific References for Village Planning

The core of settlement building is coordinating relationships between people and the environment, and external space is a key aspect [16]. Some researchers argue that incomplete external space design, gauged from the spatial behavior of inhabitants, is mainly the outcome of relatively weak theoretical research that requires due consideration and urgent intervention in the rural planning movement [2,53].

With the development of rural tourism in recent years, research on the spatial behavior of ancient villages includes the spatial behavior of both local villagers and tourists. However, our interest is in the spatial behavior of local villagers because we want to evaluate the effect of modularization on the daily life of these villagers in newly built rural communities. In addition, most ancient villages and newly built rural communities in China do not have tourism attraction resources; thus, they would continue their natural function of habitation and support their local villagers' natural means of living. Therefore, we can only provide accurate references for village spatial design by understanding the spatial behavior of local villagers and the rules of using space elements.

Some scholars have conducted descriptive analyses of villagers' daily lives and behavioral characteristics. Zhang Guangri puts forward the concept of living space pattern that focuses on the study of the typical representative patterns of human living space characterizing the early human era, the agricultural era, the industrial era, and the post-industrial era, making plain the evolution of the pattern of the living space in connection to the evolution of social civilization [54]. Fei Xiaotong describes the daily production life of ancient villages from a sociological point of view, taking Jiangcun as an example. The main feature of the study is to record the sociological characteristics of the production life of villages through prolonged observation and interviews [15]. Ren Yan describes ancient villages' lifestyles and spatial behavior using fixed-point observation and household interviews. The study analyzes villagers' space behaviors in terms of the use of public facilities, the spatial characteristics of senior activity centers, and the spatial behavioral characteristics of living spaces [55]. A study on the daily lives of aging community residents by Li Dongjun identified housing, public spaces, supporting facilities, and space use laws and suggested applications while constructing new rural communities [56].

As for research on the spatial behavior of ancient villages, the existing studies are mainly based on field observations, map marking, questionnaires, and interviews, aiming to describe and summarize the characteristics and laws of the spatial behavior of ancient villages and provide references for design practice [6,14,15,57–61]. Nonetheless, the literature on the connection between spatial behavior and spatial elements is rare in China and globally. The current study addresses this specific gap.

The usefulness of investigating the relationship between spatial behavior and external spaces in ancient villages lies in identifying the types of activities most closely related to the daily lives of villagers and their relationship with external spaces, which may provide planners with references. Such studies may help planners and development practitioners to understand villagers' spatial behaviors related to production, recreation, socialization, philosophy, and spirituality, etc. It may also help to obtain insights into whether certain space functionalities may be enhanced or substituted with alternatives that better foster life in these villages. This view is especially crucial when villagers' space value is considered rather than trapped by the materialist functionality view of spatial behavior. Furthermore, the academic value of exploring the spatial behavior of ancient villages includes diversifying the scope of village spatial studies in content and method and drawing knowledge that can be transplanted to urban space design based on logic and analogy.

3. Research Methods

3.1. Selection of Cases

The Huangshan hinterland area, Anhui Province, has many well-preserved ancient villages with peculiar regional characteristics. These ancient villages exemplify Huizhou's regional characteristics, such as clan concept, academy culture, and garden scenery.

There are 270 ancient villages in the hinterland of Huangshan City. Some of them have been changed into tourist hotspots, such as Xidi village and Hongcun village, which have been registered as UNESCO Intangible Heritage Sites. The tourism hotspot nature of the area, although the income of this tourism supports village residents economically, is a threat to the original spatial setup that evolved according to local philosophy and culture unless care is taken. The massive volume of tourism also negatively affects the size of rural populations. The Xidi and Hongcun villages were not selected as study cases because they have vigorously developed tourism after being designated as World Heritage sites, and public government data show that the two villages received more than 3.5 million tourists in 2023. Due to tourism, many indigenous people have moved out of these villages. At present, the villages are dominated by traders and tourists, which is outside the purpose of this research.

Our study subjects constitute samples from planned newly built rural communities and non-tourist-hotspot ancient villages. The former are the subjects of the modular plan problem already discussed in Section 2.1. Samples from the latter category are subjects of the space element and spatial behavior correlational study. We selected the Guanlu, Wucun, and Guxi villages for the reason that the villagers' original morphology and daily lives have not undergone notable changes, except for the renovation of a few buildings.

In addition, we included a research-based new planned village, Maotian, in the Huangshan hinterland. The village was a transplantation of the same community for which renovation intervention was technically infeasible, and the fund was not defensible. This village transplantation is included to substantiate whether claims against the blueprint of newly built rural communities can be justified otherwise.

Guanlu Village is under Biyang Town, Huangshan City's jurisdiction, at the foot of Xiwu Xiongguan Mountain. Its history traces 1000 years back to the later Tang Dynasty. It is a typical village of the Huizhou merchant society generation. The 7.8 ha area is home to a 230 permanent population. Wucun is located on the bank of the Fengxi River, 5.5 km away from the county seat, hosting 200 permanent residents within its 5.5 ha area. Yiqi Highway passes through this village, which is the only way to access the mountainous villages and towns. Located 2.5 km east of the county seat, Guxi's 3.4 ha area hosts 120 permanent residents. The village is located at the southern end of Hongcun Town. Maotian village is a home for 56 households and covers an area of about 55 acres. It is located in the same area as the above three villages.

3.2. Identification, Categorization, and Mapping of Space Elements

Unlike newly built rural community construction, which involves sorting out the classification of space elements according to planning drawings, the construction of ancient villages is bottom–up, as they are spontaneous evolutions of their inhabitants' generations. Thus, the classification of space elements requires on-site exploration. Based on this logic, our classification involved a three-step process.

First, we enumerated and categorized space elements by involving three local elders' consultations in each village through interviews and team discussions (Figure 2). The preference for older people over others was to ensure the capture of the basic history of the village and the local names of the space elements captured; otherwise, younger generations might forget some. Because of the social responsibility where local chiefs are regarded as trusts of their respective village legacies, each chief knows more about the village's history than the younger generations and ordinary villagers.

Figure 2. Villagers interviewed.

Second, each of the space elements identified based on the in-depth interviews was determined on the aerial photo and then placed in its appropriate position on the digital map produced by integrating drone-aerial maps, GPS, and ArcGIS. Mapping the key space elements identified based on the interviews with the village chief and the other three elders in each village enabled us to identify the spatial categories of unclassified areas.

Third, the categories of the space elements of the ancient villages were further supplemented by reviewing the local literature, including county records, essays, monographs, and scientific research papers. Furthermore, the review facilitated the interviews with the local chief and elders during the identification of the space elements.

The distribution map of the space elements of the ancient villages will serve as the basis for a spatial and behavioral correlation analysis, enabling GPS-collected spatial behavior data to be mapped to spatial elements using ArcGIS 10.3. Since there are no pre-existing spatial maps for the villages, we produced our high-resolution aerial map using drone technology.

The identification and mapping of the space elements involved six activities (Figure 3). The process of drawing space elements diagrams was as follows: (1) we scanned the village by drone; (2) generated the aerial map; (3) marked the boundary of space elements on the map; (4) transformed the boundary into a CAD file; (5) went back to the site and supplemented lacked information; and (6) exported the space element diagrams into categories.

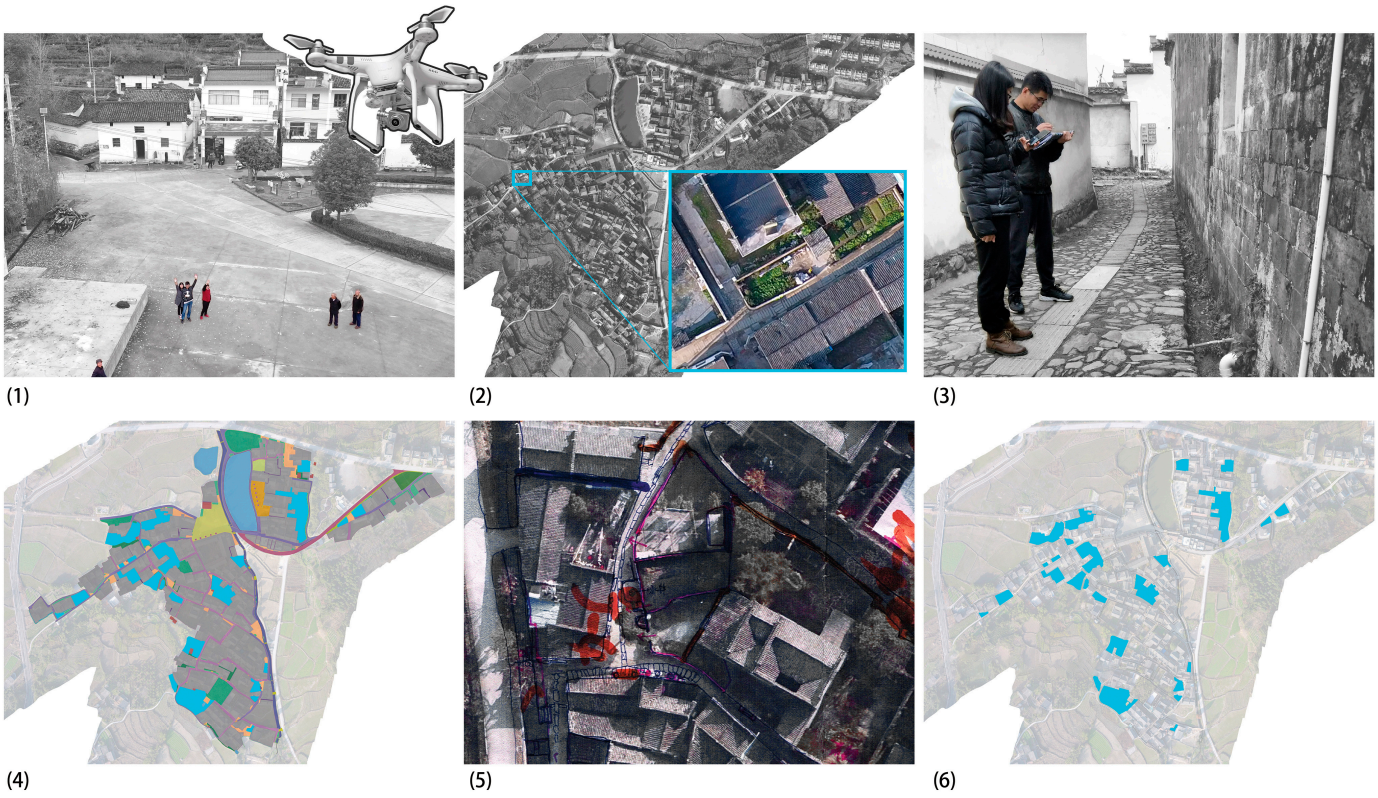


Figure 3. The process of drawing space elements.

The purpose of steps (1) and (2) was to draw high-resolution map of the villages, which is the basis of element boundary determination. We used a drone (DJI Mini 4 Pro) to take photos and Agisoft PhotoScan to synthesize the maps to create aerial maps with a sampling distance of 5 cm. Although Google Earth satellite maps are often used in spatial studies, we opted not to use them because of the high-resolution requirements of small-scale spatial elements. Step (3) refers to printing the village maps in color on the A2 drawing on a 1:200 scale for field investigation and ground truthing-based demarcation. The number of drawings depended on the area of the village, and then the boundaries of the elements on the map were marked through field research. Step (4) refers to converting the marked element boundaries into AutoCAD files. Step (5) filled in information missed during the AutoCAD conversion; a usual encounter in some spatial element boundary information might be missed otherwise. Then, it was necessary to return to the field to redraw the boundary, so the work needed to be completed at the village site. Step (6) refers to exporting the spatial elements into feature class categories (the blue tiles in the diagram represent the vegetable plots).

3.3. Collection of Villagers' Spatial Behavior Data

Conventionally, spatial behavioral studies depend on on-site observations, photo analysis, and quantitative analysis based on point-of-interest data [62,63]. The advantage of observation and map marking is the possibility of documenting details of behavior, such as events, people's expressions, weather, and temperature, etc. [64]. However, time and labor costs, mainly when applied to village studies, are enormous, because village study areas are wider. The numerous space elements generate more complex behaviors than squares and street corners [65,66]. On-site observation and counting are suitable for small areas of the site, such as squares and street parks, etc.; the area of the village is much larger, and alleys may be obstructed by the line of sight, which may affect data accuracy.

The use of anonymized mobile positioning is another common approach for spatial behavior studies [67]. This data collection method is suitable for a large spatial scale, say

a city scale. However, we realized that obtaining Point of Interest data from villagers' mobiles was problematic for two reasons—the unwillingness of communication companies because of the privacy of their customers and villagers' resisting installing mobile applications they do not know/use and sharing mobile phone data.

Alternatively, the Geographic Positioning System (GPS) provides an objective and precise record of pedestrian activities, with details such as accurate time–space information, walking route, time spent on a specific route or activity, and walking speed, which can be widely applied to collect information about the spatial distribution data of tourists [68,69]. In urban park studies, GPS devices are widely utilized. Furthermore, GPS is not affected by the spatial scale of the study area. Regarding quality, the error of GPS data is about one meter.

Given the limitations of other data collection methods and the advantages of GPS, we preferred to use it to collect the villagers' spatial behavior in this study. Among the three positioning modes (10 s/times, 20 s/times, and 30 s/times), we preferred the highest data accuracy mode (10 s/times) setting. The one-meter error was tested to simulate the villagers' travel displacement in curved parts of the route-based movement in a sports field.

In the interest of quality, we involved 25% of each village's residents, making up 130 villagers. Details of the samples are presented in Table A1. The samples were volunteers, and the village chief of each village built trust in the residents by introducing the research team's identity and the purpose of the study and asking residents for their consent to participate. All the survey participants were residents, 34% of which were men. Given China's aging population, particularly the rural population, 95 (70.3%) participants were above 60.

The data collection hours of the day were determined previously based on advanced on-site observation and through consultation with the three elders who participated in identifying the space elements. Commonly, villagers leave for work or any other activity around 7:00 in the morning and return home around 5:00 p.m. Evening leaving is seldom, so it was not considered. GPS data were collected for 13 days. In favor of accuracy, we determined to dispatch 10 GPS devices per day (September 2021). We also excluded uncomfortable weather days and special event days such as market days.

3.4. Correlation Analysis of the Relationship between Space Elements and Spatial Behavior

We used Arc GIS 10.3 to synthesize the villagers' spatial distribution of activities, collected using a GPS device from which we established the correlation between space elements and spatial patterns that synthesized the characteristics of villagers' use of space elements in ancient villages. The activities were (Figure 4):

- Loading the georeferenced drone aerial map of a village and the space element distribution map onto ArcMap and then matching the space element distribution map with the aerial photograph through the geographic alignment function.
- Adding space behavior GPS data—we loaded the GPS data onto ArcMap and set the coordinate system to the same coordinate system of the aerial photograph so that the spatial features and the activity points (and routs) were aligned.
- Spatial linking—linking GPS data to space element distribution maps using the Spatial Link function of ArcGIS.

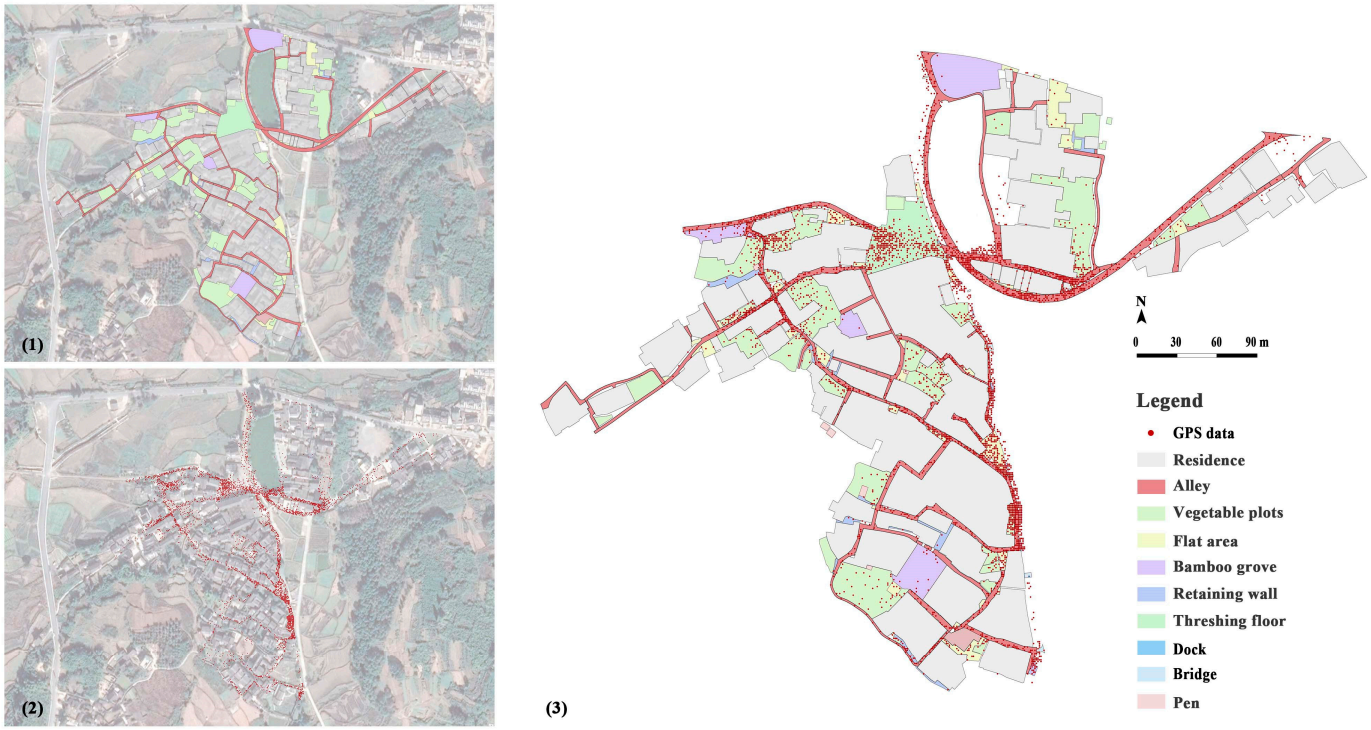


Figure 4. Methods of associating GPS data with village space elements: (**1**) associating village aerial map with space element distribution map; (**2**) associating village aerial map with GPS data; and (**3**) associating GPS data with space elements.

4. Results

4.1. Categories of Space Elements of Ancient Villages and Their Distribution

We identified 16 space elements in the ancient villages of the region. Table 3 lists their names along with corresponding meanings and depicts pictorial views. Figures 5–7 portray the space element maps of the three villages.

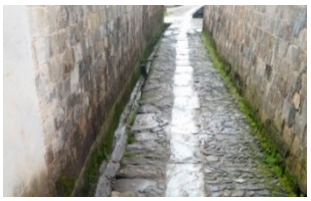
Table 3. External spatial elements of ancient villages of Huangshan hinterland.

No.	Name	Description	Photo	Applied to Newly Built Rural Communities Surveyed or Not
1	Vegetable plots	Sites used for growing vegetables. These plots are either spaces between mansions or sites of abandoned buildings converted to vegetable farms. The inhabitants mainly support their vegetable needs from these small plots.		No
2	Pen	The vegetable plots usually place the livestock pens near where the livestock are fed with vegetable leaves. At the same time, the livestock manure serves as organic fertilizer for the vegetables farming.		No

Table 3. *Cont.*

No.	Name	Description	Photo	Applied to Newly Built Rural Communities Surveyed or Not
3	Threshing floor	An extensive site used for drying grain and tea, but now also used for car parking.		Yes, developed into different forms
4	Flat area	Since the villages are often situated in mountainous areas with narrow lanes that are inconvenient for passage of crowds, the villagers set back their courtyard entrances and create small buffer spaces. Villagers usually get their grains dry here and often chat here.		No
5	Alley	It is not of equal width, as the boundaries are richly varied, thus forming many spatial nodes. It also has another form—the water street.		Yes, developed into different forms
6	Pond	It consists of the general impoundment and the feng shui pond located at the main gateway of the village. Feng shui pond is one that villagers believe can protect the village and brings them good luck.		Yes
7	Dock	Small platform beside the stream, usually used for washing clothes and vegetables.		No
8	Bridge	The dominant bridges in Hui area are stone slab; there also exist arch bridges and suspension bridges.		Yes, developed into different forms
9	Flowerbed	A small plot in front of a house or side /node/ of a street used for growing ornamental flowers.		Yes

Table 3. *Cont.*

No.	Name	Description	Photo	Applied to Newly Built Rural Communities Surveyed or Not
10	Bamboo grove	It is mainly used to regulate the microclimate and beautify the environment.		Yes
11	Dang	垱[dǎng], low-lying space behind the compound usually used for storing daily garbage.		No
12	Drainage channel	It is divided into open channels and culverts. The open channels are mostly distributed on the edge of the lanes, whereas the culverts are distributed below the main streets, covered by stone slabs.		Yes, developed into different forms
13	Drainage trench	It is an inaccessible gap between the houses, and it is only used for flood discharge.		No
14	Stream	Most of the ancient villages in the Hui area are built near water, and the streams are the main places for villagers to wash their clothes and vegetables.		Yes
15	Well	The wells abandoned after the villages installed piped water systems.		No
16	Arbor	The villagers use simple materials such as bamboo and wood to build an arbor usually used for growing climbing vegetables and fruits.		Yes, developed into different forms

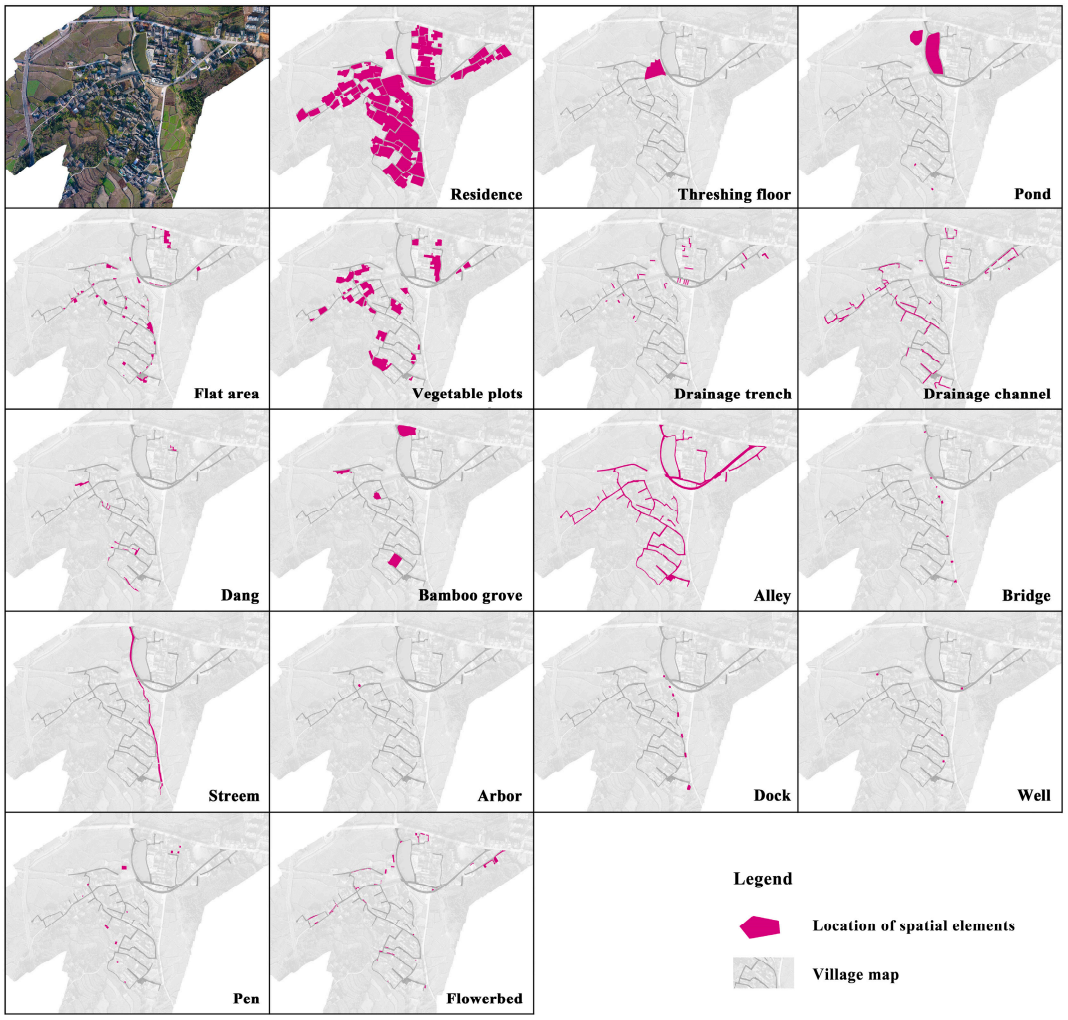


Figure 5. Aerial map and distribution of external spatial elements in Guanlu Village.

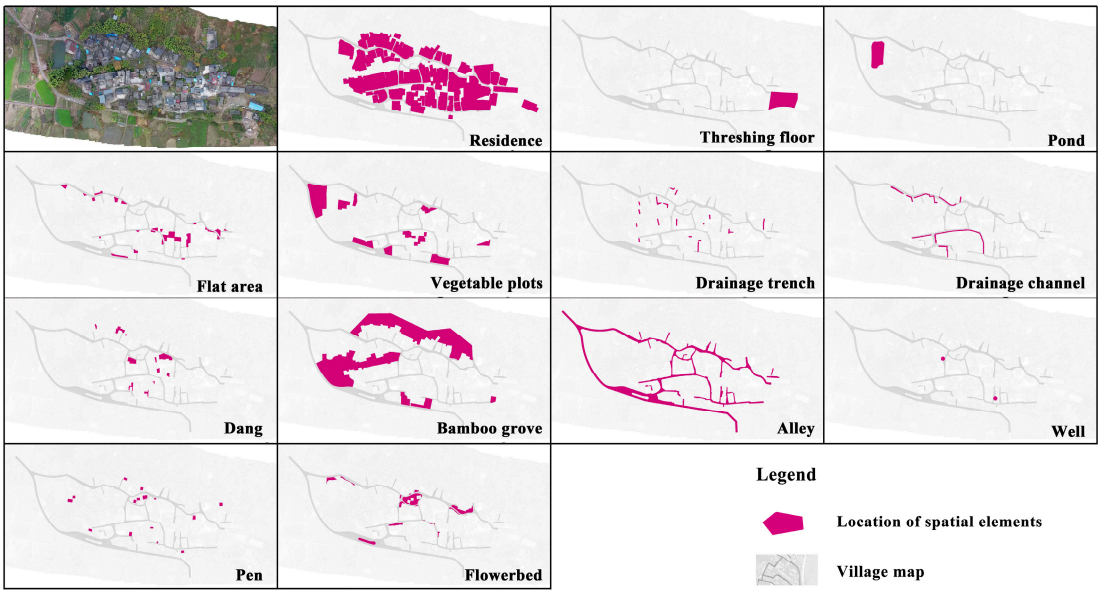


Figure 6. Aerial map and distribution of external spatial elements in Guxi Village.

Figure 7. Aerial map and distribution of external spatial elements in Wucun Village.

The villagers have fixed needs for each space. In addition, the village's relationship with the space elements is not only one function per element. A single element may serve multiple needs. Take the flat area (locally called tǎn) as an example. It is the concession space at the house's entrance near the street, is in daily use, and facilitates several family activities, including drying grains, communicating, and dining.

Some space elements are related to the local natural topographic setting and environment. The research area is a typical mountainous area, and the villages are built between mountains and rivers where the farmland spaces are smaller in order to accommodate construction. To fully use the flatter lands for farming, residential settlements are built densely and narrow streets and deep-narrow drains are installed. These narrow streets hinder short daily communications while carrying furniture and farming tools, etc. Therefore, the flat space supports almost all socializing transactions on a daily basis. Although this topographic nature limits size and its shape is often irregular, the flat area functions as an open spatial node inside the deep alley, enriching the spatial landscape with various living scenes.

The inhabitants' spatial behavior is supposed to reflect the topological correlation of the space elements. Villagers' behaviors and life needs determine what space elements should be available in the village and their distribution of space elements. For example, vegetable plots are cultivated between mansions, serving as buffer strips between the units, and the flat area is the transition space between the frontage of the mansion and the narrow alley.

Another typical example is the importance of the pond. The presence of ponds in every village is the result of traditional beliefs and rational function. Traditionally, the Chinese people, at least the older generations in rural areas, believe that water represents wealth. The half-moon shape of the pond reflects the wish of the people to increase their wealth through time and finally attain the peak. During its revolution, the moon first ap-

pears as a slight arc, and it gradually increases to become a full circle. From this perspective, the pond (water) is semi-circular in shape and is named the feng shui pond. It symbolizes that, currently, residents are not at the peak of prosperity but have some wealth and are thriving to attain a possible level of prosperity.

As a wealth wish representation, the pond is usually located at the main gateway of the village, reflecting the common aspirations of the village residents. Because of the risk of overflowing during heavy rain, it is usually placed at the lowest part of the settlements.

The rational existence of the pond water reflects the vulnerability of the dwellings to fire, because a major part of their construction component is wooden. Where the village area is large, instances of within-settlement ponds may also exist. Given the narrow and winding alleys in large villages, the remote placement of the pond makes it inaccessible in case of a fire emergency. In response, small ponds are usually set within the settlements targeted at fire emergencies.

4.2. Spatial Activities

We generated the villagers' activity distribution maps by importing the GPS coordinate data into ArcMaptivities. As depicted in Figures 8–10, the GPS data (walkways and nodes) clearly outline the village streets (travel routes) and spatial configuration activities in the village. The topological fit between the activity distribution and spatial structure of the village suggests that the GPS data meet the requirements of behavioral analysis in terms of accuracy.

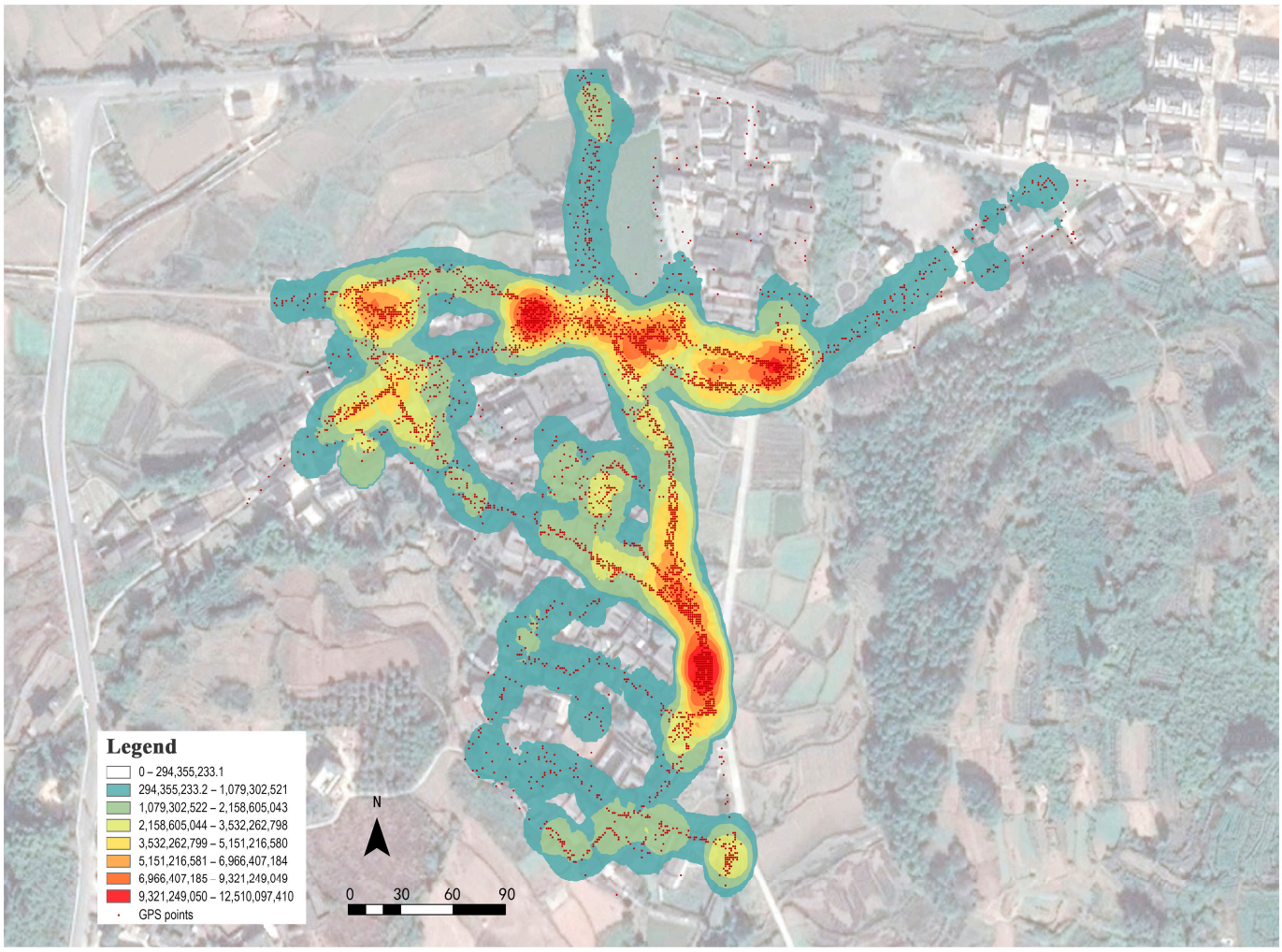


Figure 8. Heat map of villagers' activity distribution in Guanlu Village.

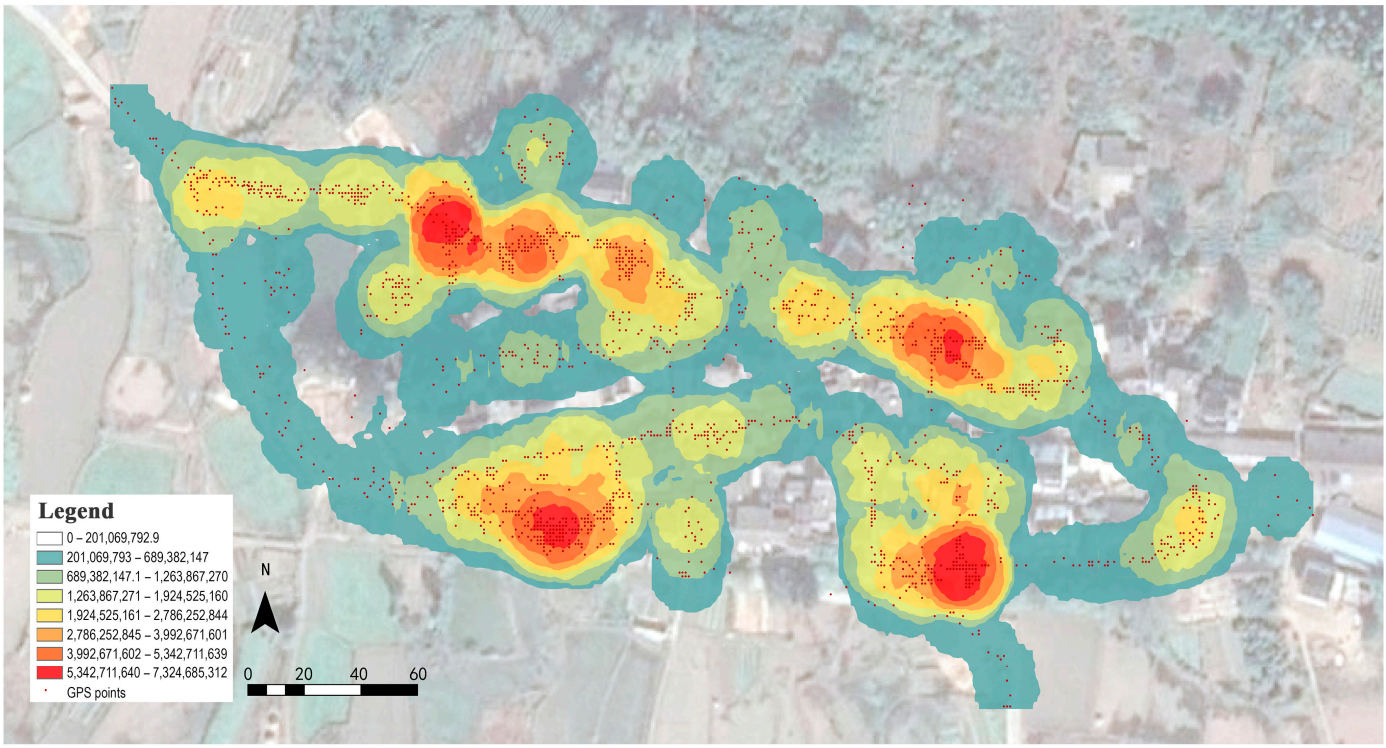


Figure 9. Heat map of villagers' activity distribution in Guxi Village.

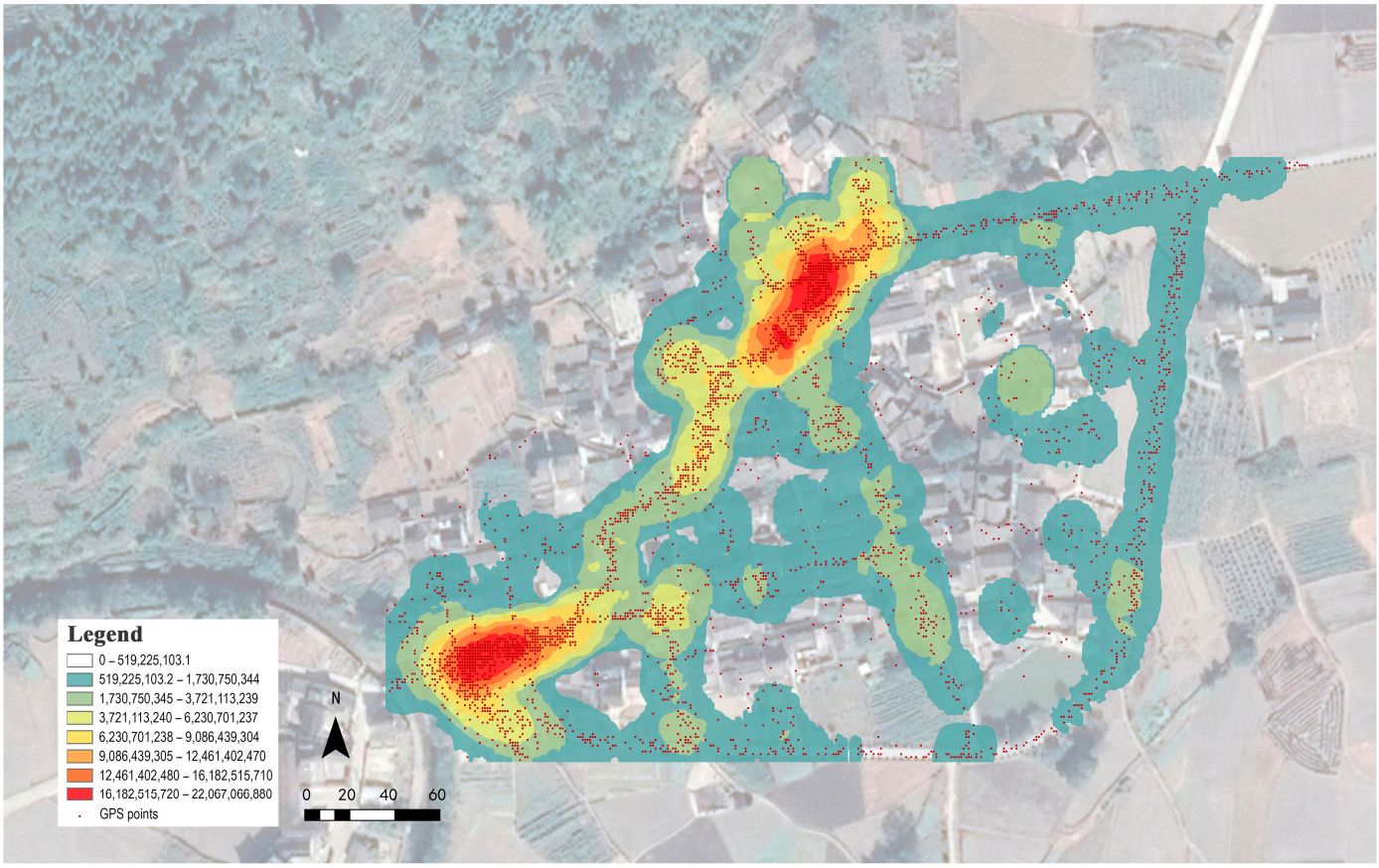


Figure 10. Heat map of villagers' activity distribution in Wucun Village.

The heat maps of the villagers' spatial behavior portray the distribution patterns (hotspots and cold spots), which show approximate ranges that need to clearly define the characteristics of villagers' use of specific space elements. However, the relationship between behavior and space was analyzed by associating space elements with GPS coordinates (Figure 11). Table A2 reports the time spent on each spatial element for each village.

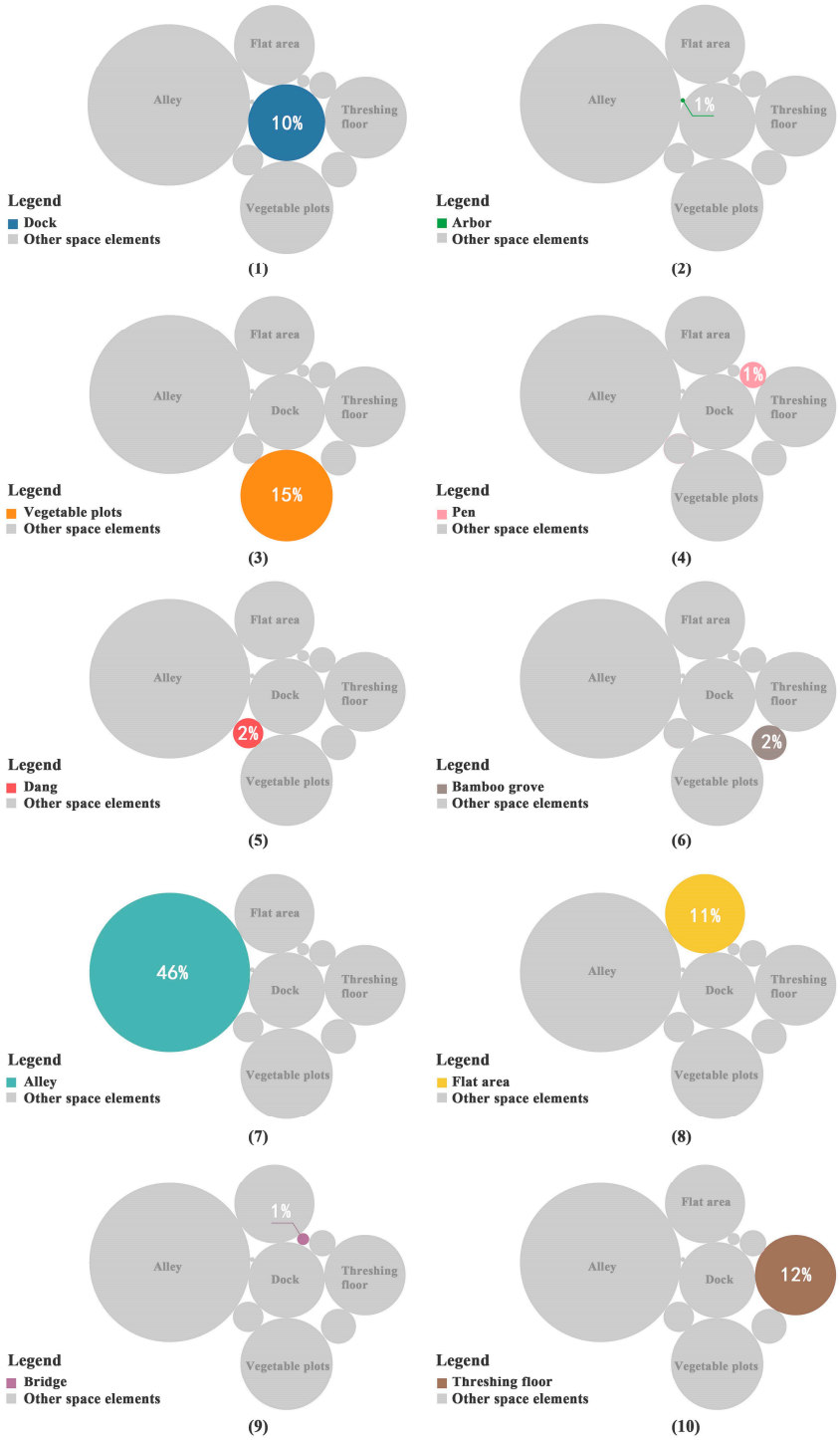


Figure 11. Percentage distribution of frequency of time spent on each space element in the villages. (**1**) Dock, (**2**) arbor, (**3**) vegetable plots, (**4**) pen, (**5**) dang, (**6**) bamboo grove, (**7**) alley, (**8**) flat area, (**9**) bridge, and (**10**) threshing floor.

Although the GPS data were associated with gender and age so that gender and the temporal disaggregated spatial behavior of the villagers could be obtained, a preliminary analysis suggests that age and gender have no significance. The reason for the exclusion of the age variable was that the participants were predominantly older, given an aging population. There were only a few young people (Table A2).

Ancient villages in the same region have the same space elements and similar lifestyles, so one may hold the presumption that they have the same spatial use characteristics. However, discrepancies in the data for specific elements indicate that external factors can influence the use of these space elements, not the spatial use of the behaviors. In contrast, the frequency of threshing floor space use and time duration in the Guxi village GPS was only 8% (sample weighted) out of the total in the three villages. The Guanlu and Wucun villages shared 58.3% and 33%, respectively (sample weighted). Through field research, it was found that the threshing floors in the Guanlu and Wucun villages have been treated with good ground hardening selected materials and were handled hygienically. Given the wetness of the village, many inhabitants use the space for various activities, including selling vegetables, repairing agricultural machinery, and even sunbathing.

Conversely, the threshing floor in Guxi village lacks ground-hardening treatment, and the site is muddy. Consequently, the data illustrated that fewer residents gather there even on sunny days, suggesting that the site is not exploited for extra functions other than its primary purpose of threshing. This feature can inform village regeneration for optimizing building materials when establishing village spaces to improve environmental quality rather than replacing existing spaces with other new space types.

Another significant discrepancy was in the bamboo grove. In Guxi village, the sampled individuals spent 8.6% of their time on the bamboo tree site; in the other two villages, they spent below 1.5%. The influencing factor, in this case, was the size of the space. In Guxi village, the bamboo grove area is 4100 square meters, 13.7 folds of the average of the other two villages (about 300 square meters). Given its large size, the inhabitants of Guxi use it for additional functions, such as poultry farming, microclimate regulation, and landscaping functions in the other two villages.

In general, the behavioral GPS data and field investigation symmetrically suggest that the size and quality of the space element determine the number and type of functions it supports.

5. Discussion

5.1. Ancient Village Key Space Elements and Topological Structure of Inhabitants' Spatial Behavior

In this subsection, we discuss three critical findings of the study: the essential spatial elements that support the lives of ancient village residents and their sociocultural meanings, the space utility behaviors of the residents during day hours, and the topological relation of their spatial behaviors. First, we discuss the details of the space use, and then we summarize the interpretations in the final paragraphs.

From our three cases, we identified 16 ancient village space elements. Five space elements, including alleys, vegetable plots, threshing floors, docks, and flat areas, contained 94.6% of the total amount of inhabitants' space use time, which new rural planning usually needs to include.

The alley was the most frequently used space by villagers, accounting for 42.3% to 56.4%. Villagers spend so much time in these alleys not only because they are the place they must pass through; another essential reason is the existence of many nodes at different intervals that are hotspots of concentrations. The alleys of the villages are irregular in both their shape and the span of their width (Figure A1) because of the multitudes of various logics, including family relations, feng shui geomancy, and topography, etc., that determine the arraignment of buildings. The appearance of these folded corners along the alleys makes a specific part of the alley relatively spacious—about 3–6 m compared to the 2 m span of the alley routes. These spaces are often paved with flat stones and are

equipped with rocks for a short breath sitting along the way. They are also places where the elders gather by coincidence because the alleys receive sufficient sunlight and fresh air compared to enclosed indoor spaces. Some nodes are joints of multiple residential buildings that gather to draw larger groups to chat, while others have only one or two villagers basking in the sun in the corners of the walls where they shield themselves from the wind. These nodes enrich the spatial hierarchy and provide activities for the villagers.

The alley, although a pass-through space, also hosts several behavioral activities. The main behaviors include purpose walking, observing, and trimming vegetables. The significant share of time spent in these alleys is not just trace passing time, but much activity time. An hourly disaggregated analysis of the use of this space element justifies this. In the morning, the time spent in the alley was less than 8%, and in the late afternoon, it was less than 2% in Guanlu and Wu. The peak time for using alleys, except in the morning in Guxi, was from 11:00 to 16:00 and from 13:00 to 14:00, suggesting two behavioral patterns in this particular space. One behavior is that spatial activities are arranged in a series of the hours of the day, where 12:00 to 13:00 turns from one activity to another. Second, 11:00 to 12:00 and 13:00 to 14:00 are activity-intensive hours; thus, much time in the alleys means trimming vegetables and sorting animal forage/feed. In Guxi, 50.8% of the alley use time was in the morning, indicating the effect of the area's wetness on the spatial use timing of the village, which followed a different pattern than the other two villages. The inhabitants of Guxi intensified their alley activity in the morning and gradually shifted to activities of other space elements.

Vegetable plots are where residents grow vegetables and fruits for self-consumption and earning. Spaces between residential buildings are intensively used for such purposes. Of the total, residents spent about 15% of their time in vegetable plots. The hotspot time for this particular element was from 10:00 to 11:00 (19.7%), followed by from 13:00 to 17:00 (14.2%).

The association of vegetable plots with the daily life of the villagers traces back a long time. The ancient villages were (and still are, in most cases) scattered and lived far from the towns. Due to inconvenient distance routes and sometimes risky hauling, the villagers could seldom travel to the distant vegetable and fruit markets. The option was, and is still, relying on themselves for most necessary vegetables. When walking along the deep alleys of the village, green spaces filled with different vegetables and fruits appear every 30 m interval or so, adding to the idyllic beauty of the landscape.

Although access to marketplaces is not a problem in newly built rural communities, their long-established habit of self-reliance on produce self-reliance motivates villagers to continue vegetable gardening. Furthermore, they exchange their labor and time for higher urban prices of vegetables and fruits. Both cases encourage them to continue their close attachment to small vegetable plots. Reportedly, they even convert lawns into vegetable plots on their own. It is worth mentioning that their engagement in producing vegetables within their vicinities is not just that they support their lives at ease. Instead, their labor contribution to the national GDP, though no objective study has been conducted on it, can be referred to and may serve as an argument to safeguard their interests and preferences in their original villages by letting them continue their living there or transplanting their vegetable gardens to the new settlements. The national ecological development programs [70–73] that have contributed to the displacement of ancient villagers, at least in part, have to consider compensatory programs integrated into the new settlement planning movement.

The threshing floor at the village entrance is the center of many activities, including drying grain, relaxation/open recreation/vegetable market, and temple fairs. The threshing floor accounted for 12% of the total GPS data. Its peak use time was between 14:00 and 16:00 because of the convenience of sunbathing, which is one of the favorite activities of older people in the villages. In autumn, villagers bring their harvested crops to the threshing floor to dry them, and there is a spectacular display of crops and straw bales (locally known as Sunshine Autumn).

The number of cars has increased in recent years, and the threshing floor has become a parking lot. In addition, commodity trading is an indispensable part of people's lives, and villages have replaced urban shopping malls with bazaars. The threshing floor is converted into an open-air bazaar, where villagers from neighboring villages converge, making it the liveliest place in the village. The village market usually runs for five days, say the 5th, 10th, 15th, 20th, 25th, and 30th of each month, on the threshing floor. The threshing floor is also a place for temple fairs and wedding celebrations; villagers hold folk performances such as dragon and lion dances and watch open-air films; and children play hide-and-seek, throw handkerchiefs, jump rope, draw gyros, and fly kites, etc. In general, the threshing floor is a stage for orchestrating most societal activities and business operations.

The dock is located by a stream or pond, and its primary function is not mooring but for villagers to wash clothes and vegetables and socialize. Even though the villages have installed water supply facilities, the majority of them still prefer the stream for such activities mainly because of its socializing value. Villagers gather here, where conversation is as meaningful as labor.

The flat area is a peculiar and featured space that accounts for 11% of the total spatial use time data. It is a transitional space between residences and narrow alleys. Much of the crowd was observed from 9:00 to 12:00 and from 13:00 to 14:00 h. Since the study villages are mountainous, buildings are densely populated in favor of the small, plain, arable fields. Alleys are narrow, and some are lower than building feet due to erosion. If villagers enter mansions directly from the alley, the small space will make people feel constricted, and it is not convenient for villagers to carry furniture and agricultural tools. Therefore, the residence gates in this area are not adjacent to the alley but give way to the flat area as a transition space between the residence and the alley. As a relatively open space in the deep alleys, it concentrates activities such as neighbors' conversations and daily sun-drying, enriching spatial variations and life scenes.

The meanings of the spatial behaviors discussed in the above paragraphs span implications for newly built rural community design and more interpretations of village space organization logic.

From the village design practice, these findings illustrate the degree of responsiveness of the new rural planning to the villagers' daily lives, including much of the production socializing activities. A loss of production and socialization would affect not only the villagers' quality of life by denying them skill-fit production activities and daily social interactions, but it would also effectively sweep away the regional identity embedded in the rural culture, philosophy, and local identity of societal structuring in space, such as family-tree-based settlement alignment, specificity of produce, and production means, etc. The new rural planning suggests that local/regional identity would be paper rhetoric narration, which, so far, is the objective reason for village preservation once it is lost.

While differences are natural among the villages, explained by the carrying capacity/area/ of the space elements, the space behaviors in aggregate illustrate robust features—timing and spatial configuration, as illustrated in Figure 9. In regard to time behavior, hotspot and cold spot times exist for the interactions of the inhabitants with each space element. The hotspot times for bamboo were from 9:00 to 10:00 and from 12:00 to 13:00; for Dang, from 11:00 to 12:00; for the flat area, from 8:00 to 10:00; for pen, from 13:00 to 14:00; for the threshing area, from 14:00 to 16:00; and for alleys, from 7:00 to 15:00.

From a space use behavior, the findings indicate logical space topological organization. First, the relatively even distribution of space use (aggregated average values) (Figure A2) suggests that the activity behaviors of the ancient villagers are not random, but patterned in topology and daytime dimensions. While considering the total activity time (thick purple line plot in Figure A2), the temporal behavior is relatively even between 7:00 and 15:00.

The second behavioral factor suggests an intense hour–space use arrangement. Vegetables, bamboo, and docks were more morning activities and were down at noon and rebounded towards late noon. Vegetable activity rebounded between 1:00 and 3:00 p.m.,

though at a lower peak than in the morning. Dock activity rose again towards late afternoon. These activities suggest that inhabitants primarily work in very localized sites close to their residential buildings in the morning and farther sites after lunch. Dong was, peculiarly, a lunchtime activity, but it was also notable at dusk. The flat area was more active from around 8:00 to 10:00 and at around 15:00, suggesting its users are mainly older people. Residents coming back from field activities and from somewhere where they spent their day also visit the space on their way home. The threshing area, as described above, was a typical activity in the afternoon from around 14:00 to 16:00.

In general, connecting the spatial configuration of the space elements and the dominant time of use, the topological configurations among the space elements in the villages are noticeable. The 12:00 to 13:00 period highlights the activity type and distance between the morning and afternoon hours. The implication of this temporal–topological behavioral relationship for newly built rural community design is not just what element be missing in the planning, but also that their topological alignment has a deep meaning that requires additional inquiry.

5.2. Ancient Village Residents' Test Preference Meaning of the Space Element and Space Use Correlation

While new rural areas mirror city space elements in their entirety, renovation interventions of ancient villages become threats to such tendencies. For example, the local government renovated buildings that were designated as having historical value in Guanlu Village and Hongcun Village, giving visitors visual attractions. The renovation process involved the maintenance of the historical buildings on the one hand and the transformation of the external space on the other. In terms of external space, the planners designed a large area to support extended squares, parks, and lawns at the cost of a loss of historic buildings, the cost of the preservation of the village's identity and history as a whole unit, and the cost of limited plain area available in hilly/mountainous villages.

From the field investigation of the Guanlu, Guxi, and Wucun villages and the project-based investigation of Hongcun village, the authors appreciate a straightforward negative test of the ancient village residents in these new spaces. The GPS data in Guanlu illustrate this. Villagers mainly gathered in the original spaces rather than on the squares and lawns. No GPS data were obtained for the newly built lawns and roads inside. From these data, it is possible to make a strong conjecture that the inhabitants may not have a positive reaction to the new elements.

Given that squares and lawns are created with tourists in mind, it is possible to easily judge that they are different from the daily activities of the villagers. Residents do not trim and sell vegetables and prepare forage in squares and lawns. This phenomenon suggests that village designers reflect on which kind of spaces villagers need and like. Many urban communities have been designed in the process of urbanization, and the elements of external space in these communities are almost the same, both in China and abroad [74]. Urban design logic has been applied to the external space of the village, which incorporates the space elements of urban parks and CBD without detailed research about the spatial behavior of villagers, which will inevitably lead to the problem of newly built spaces in the village not being able to meet the actual needs of its inhabitants.

Even from a tourism development point of view, the importance of the richness of space elements is suggested. A better understanding of what influences tourism experiences will help to optimize tourism destinations' supply and further development [75]. Spatial richness facilitates meaning and knowledge exploration and is among the factors that create antecedents [76]. Obviously, the rich composition of a destination's space element is one of the most important.

5.3. Design Practice as an Example of Application

In the context of rural revitalization, the local government is willing to create a better living environment and improve the quality of villagers' daily lives. The main problem in

Maotian Village is the need for more sewage and rainwater drainage systems. The water system is polluted because of the decay of toilets and drainages. Its built area and supporting surroundings are dilapidated, too. Significant icons of its historic value buildings, such as the temple and the ancestral hall, have been ruined. Literally, no reason could mention any value of renovating the built environment and its immediate surroundings. If any mystery was suggested for renovation, the renovation cost would be double that of constructing a new one. To avoid the problem of new settlements being far away from farmland due to "Village Consolidation" and the high cost and rugged construction caused by in situ renewal, we replaced the nearby land with Maotian Village. We planned a new settlement based on the spatial elements of local villages (Figure 12).

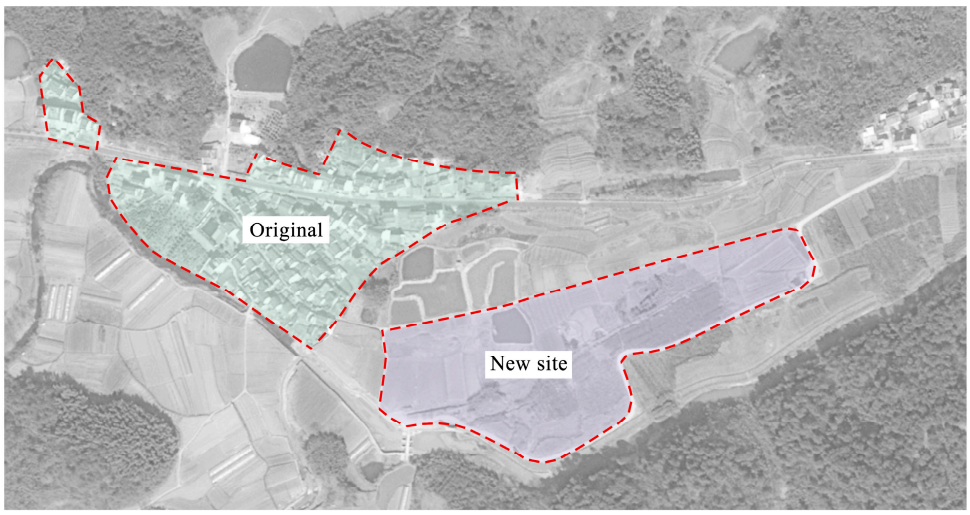


Figure 12. The planning area of Maotian new settlement.

It is important to note that we are advocating for something other than the design of contemporary rural communities through the exact replication of ancient and vernacular spaces. Arguments for the necessity of developing spatial planning based on the innovative categorization of forms of the physical morphology of ancient villages are tough [77], so we opted to take advantage of current knowledge. However, lifestyles are changing, too. Understanding that the complete replication of existing elements is neither possible nor feasible, a rational approach was required to accommodate today's necessary components.

Before the design, we thoroughly investigated the daily habits of the 130 local villagers and how they used the village space during the research process. We also asked the villagers for their suggestions on the village's transformation and optimized some spatial elements in the context of contemporary living needs, such as the renovation of the street width and the transformation of the threshing floor to meet the parking demands.

- Motorways on the village outskirts. A two-way carriageway was included as a ring access bordering the village to meet the villagers' demand for motor vehicles. Within the interior parts of the site, pedestrian walkways were separated from the vehicle lanes. Considering a quiet living atmosphere, carriageways were five minutes' walking distance from residential buildings.
- Emergency fire lanes. Although only the periphery of the village was open to traffic, a 4 m wide lane was installed within the site to ensure that rescue vehicles could access it easily. Fast-tracked emergency rescue is significant for villages with aging residents.
- Parking. Two parking options were made available. One option was roadside parking spaces on the village's exterior driveway. The second was the use of the threshing floor. The threshing floor was compacted with selected materials to support parking needs during crowd events. It could serve as a parking space during festive days,

such as the Ching Ming Festival and Chinese New Year, during which, young people flee back with vehicles to the villages for family reunification.

- Ancestral halls (social and traditional worth value), temples (spiritual worth value), and other cultural buildings were installed on the new site.

On the other hand, creating a stream is not a rational decision. Although it is an essential spatial element of the native village, there is no river in its vicinity, and the creation of streams and their daily maintenance will put a substantial economic burden on the village. The water supply facilities we planned can replace streams to meet the villagers' water needs. After clarifying which spatial elements are included in the village plan, the designer also needs to consider which elements are most needed in the villagers' daily lives. These elements should be emphasized in the design process. At the same time, the spatial location characteristics of the spatial elements should not be ignored, and this information can be obtained from Table 3 and Figures 5–7.

Compared with the eight cases of newly built rural communities we investigated, the research-informed design of the Maotian village community has a richer and more diverse design vocabulary (Table 1 and Figures 13 and 14), which continues the regional characteristics and meets the current actual demand of the villagers for the spatial environment.

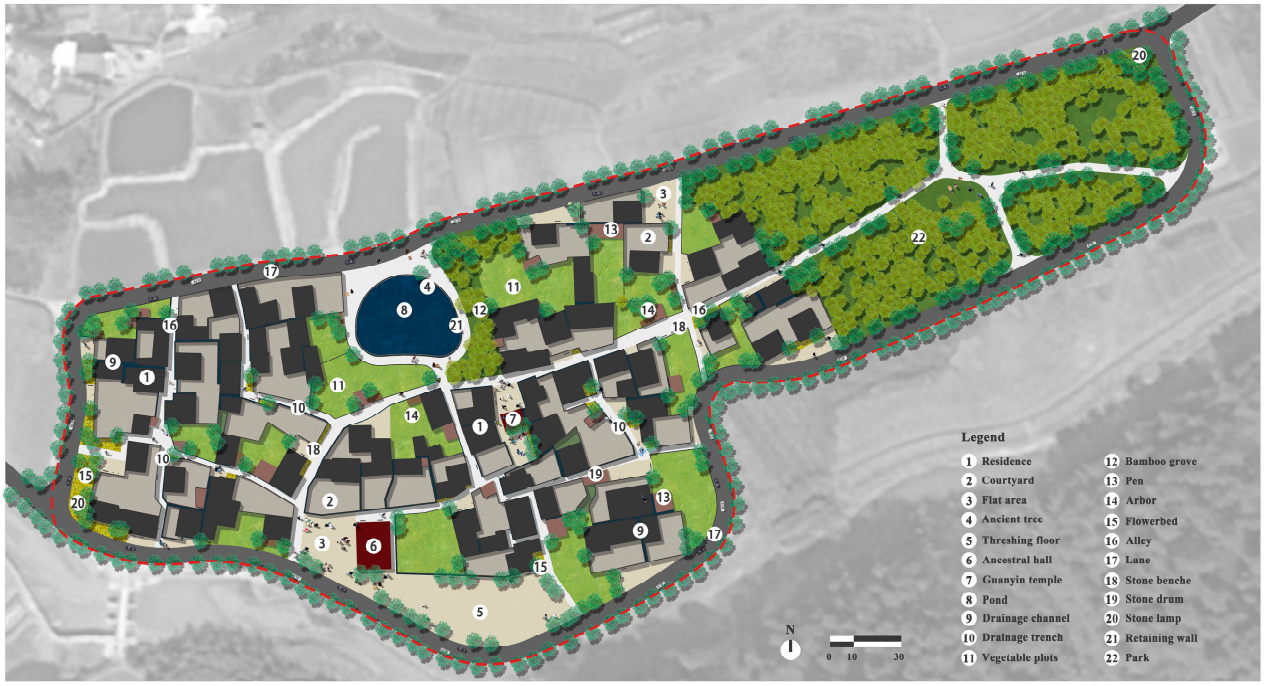


Figure 13. Maotian new settlement planning based on the external spatial elements in native villages.

The design benefited from spatial element and spatial behavior correlation studies conducted in the Guanulu, Guxi, and Wucun villages. The response of the spatial element and spatial behavior correlation study to the needs of this particular ancient village community was highly suggested by the full consent and cooperation of residents of Maotian village throughout the planning processes. During the planning process, the villagers not only provided their subjective suggestions for the design, but also helped us to collect the spatial elements of three villages and the daily behavior data of 130 villagers, providing an accurate and objective basis for the design.

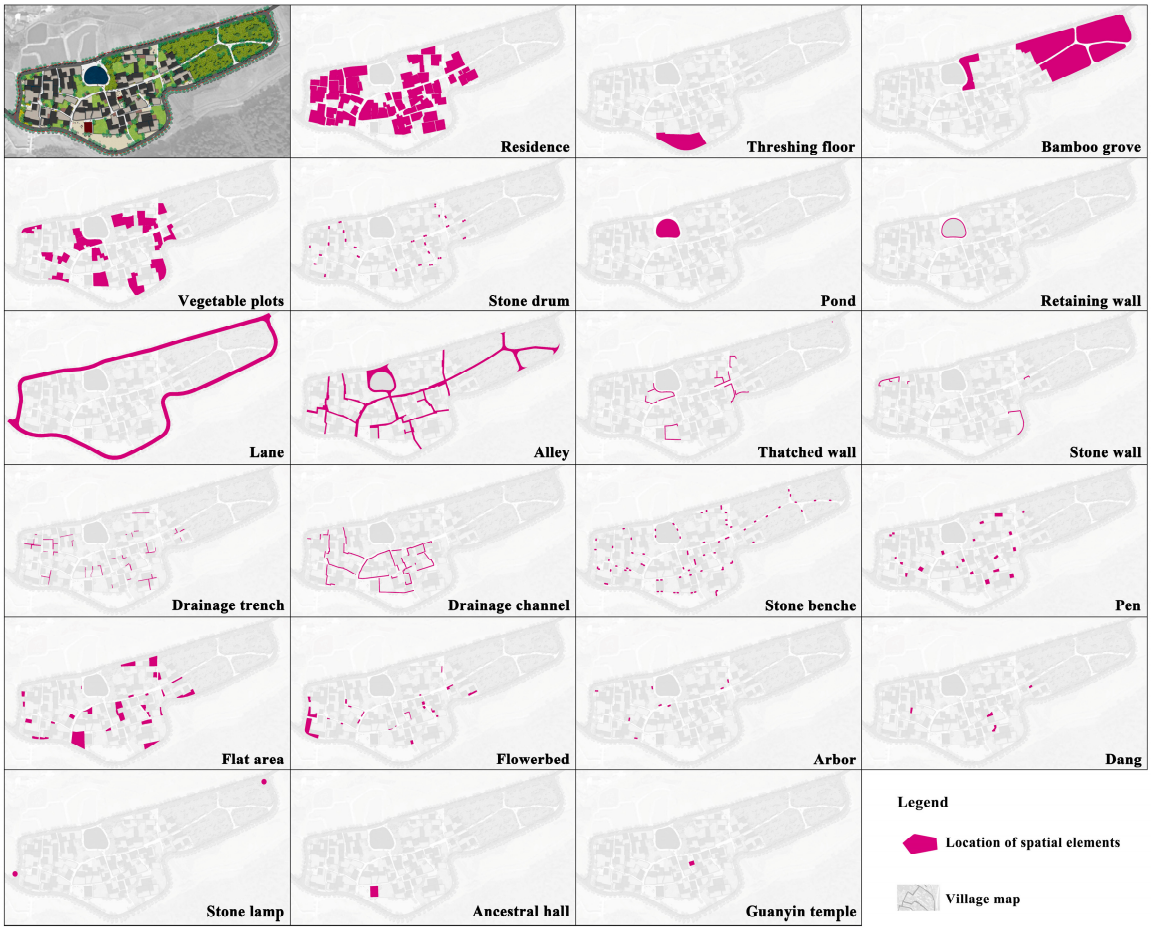


Figure 14. The external spatial elements in Mia Tian new settlement.

6. Conclusions

This paper was developed to reflect on village spatial design practice in China as part of the government's rural development planning movement, but with a broader implication globally both in terms of planning practice and academic relevance.

The core problem that initiated this paper is the establishment of newly built rural communities without genuine research regarding the spatial elements and spatial behavior of village residents. Village spatial design is modularized across the board and disregards local identity. Sociocultural values and processes have been ignored and replaced by a space of modern urbanized consumption. On the other hand, the new plan elements disregard the actual needs of the target residents—aging rural people.

To reflect on the limitations of the village design as a process and product and to produce academic value of learning regarding village space understanding, this paper creates nuanced learning from (1) a fresh investigation of the spatial element–spatial behavior correlation of ancient village residents, (2) lessons from research-based new rural community building, and (3) an assessment of the intuitive newly built rural community design. The critical values of the findings are as follows:

- The research identified 16 spatial elements that support ancient village residents' daily life and sociocultural processes. These elements are quite different from those introduced by village planning in newly built rural communities. The type (functional) variation is explained by the sociocultural context of the ancient villages and partly the variation in means of earning a living. Topography and geography are typical of both village types. Where a few common space elements of the new and ancient villages exist, their sociocultural values differ. The distinct nature of the ancient vil-

lage space elements could be easily understood from the space behavior load of the villagers.

- The study is precise in spatial and behavioral research on specific elements rather than in a particular spatial range. Five space elements, including alleys, vegetable plots, threshing floors, docks, and flat areas, satisfy 94.6% of villagers' needs for external space. From this finding, it becomes evident that the space behavior of the ancient villagers is quite different from that of the urban-oriented modern plan. The situation suggests that newly built rural community planning contradicts the preservation and modernization of villages. The research method on the relationship between space and behavior proposed in this study significantly improves the accuracy of the research. It relates the daily activities of villagers to specific spatial elements rather than spatial scope. Its value lies in the fact that designers can more accurately design corresponding space elements in the face of the villagers' different space needs.
- The investigation of ancient village spatial elements and their spatial behavior indicates the logic of using a use-time-based topological structure of spatial elements quite distinct from the modern urban literature. In the urban literature, distance is a function of time cost. In the ancient village, the language is quite different—space is organized according to hours of the day activity. Another key feature of the spatial behavior of ancient villagers inferred from the three cases is that, regarding the spatial behavioral load, on average, the distribution between 7:00 and 15:00, is balanced. Although it is premature to provide a conclusive interpretation regarding the time–space philosophy wisdom of ancient villagers, the finding suggests a new direction for investigating the spatial behavior of ancient villagers.
- The study proposes and practices a design methodology for a newly built rural community based on the spatial elements and their relationship with the behavior of local ancient villages. It solves the problems of the modularity of spatial elements and the mismatch between space and villagers' behavioral habits, which are common in newly built rural communities. From the research-informed newly built rural community design of the Maotian newly built rural community in Huangshan hinterland, based on the research results, updating the external spatial elements of ancient villages under the demands of contemporary life makes the application of spatial elements not only continue the villagers' rudimentary way of life, but also satisfy the demands of the contemporary way of life on the external space.

The critical value of this paper is underscoring the man–space relationship of ancient villages. Urban space is well theorized from the sociological class structure and land rent. The village space structure has no such explicit theories. The space generation from specific empirical knowledge, such as the feng shui in oriental countries and the sociocultural process, seems to define the space organization of ancient villages in China, as illustrated in this paper. The empirical wisdom and sociocultural processes produce a distinctive topological arrangement of external space elements supporting daily life earnings and social relations instead of economic maximization rationality and the legal protection of such economic relations. This suggests the importance of transplanting the basic principle of the space generation mechanisms into a new community planning system. The process requires thorough research. Studies have claimed that designers lack an understanding of the relationship between spatial behavior and external spaces within ancient village establishments [55], as elsewhere in other countries such as Australia, this has manifested in a blurred distinction between small town and rural planning [2]. At the core, there is a need for more thorough theoretical research.

Given China's vast geographic territory, distinctive regional cultures reflecting the multi-ethnicity of China, etc., the need for research-based village planning has been suggested. In fact, the international experience suggests that early addressing the issue related to spatial transformation would be worth the value of rescuing the loss of space concept of the village society and its values. In response to the high-quality requirements for urban-

ization in the context of rural revitalization, the following recommendations are proposed based on our current research:

- Avoid rural areas following the urban community construction pattern and modular design elements such as squares and lawns.
- Policies need to explore a new people-centered approach to urbanization. One of the main problems of the last round of urbanization was the mismatch between the newly built rural communities and the needs of villagers in their daily lives, resulting in the failure of these villagers, as "new citizens", to integrate into the new environment, the first thing to be clarified in high-quality urbanization is the villagers' natural habits and needs in their daily lives.
- The government should support the establishment of a database for research on the association between external spatial elements and the behavior of ancient villages in different regions. In China, there are clusters of ancient villages with different regional styles, such as Anhui, Fujian, and Shanxi, with very different architectural styles and folk cultures. The establishment of a database not only protects cultural heritage but also contributes to the sustainable development of the villages' villages' regional characteristics.

Although this paper comes up with lessons on the value of learning for planning practice and the worth of engaging in further academic value elaboration both in depth and breadth, we note the following limitations, the study is a one-time-packed investigation. Generalization about village space elements and behaviors needs more cases representing different regional cultures. Although the amount of research data is huge, it contains 130 villagers, 5 days of GPS data, and nearly 1000 spatial distributions of 16 spatial elements, we hope to research more ancient villages in Anhui Province, China in the future to further improve the accuracy of the results.

In addition, ancient villages in different regions possess different external spatial elements. For future research, we plan to compare and contrast the external spatial elements and the spatial behaviors of ancient villages in different regions. Through comparative analysis, clarifying the specificity of the external spatial elements of ancient villages in specific regions will be beneficial to the formation of rural communities with significant regional styles, and related research will lead to interesting new findings.

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Appendix A

Table A1. List of villagers who participated in the survey.

GPS Code	Name	Age	Gender	Name	Age	Gender	Name	Age	Gender
1	Cheng Chaoying	58	Male	Wang Zhiguo	64	Male	Wang Xiuyun	70	Female
	Wang Chaoli	64	Male	Wang Jianying	66	Female	Xu Xiaoyuan	85	Female
	Wang Yuexin	66	Male	Wang Jingxian	67	Female	Ye Yinfeng	72	Female
	Tao Jigen	61	Male	Xu Yinggui	65	Male	Jiang Xinyun	30	Female
	Wang Liansheng	65	Male						
2	Wang Liansheng	68	Male	Fang Baoyi	63	Male	Li Chunzhi	82	Female
	Cheng Yuehong	37	Female	Chu Shuisong	62	Male	Zhang Yinghao	66	Female
	Deng Wanqiong	55	Female	Wang Chang'e	62	Female	Wang Ruyi	40	Male
	Zhou Jiying	67	Male	Wang Shishuang	76	Male	Su Xinling	54	Female
	Jin Guanglin	70	Male						
3	Wang Dawei	67	Male	Wang Jianjing	67	Male	Yang Sanliu	56	Male
	Zhu Guoying	54	Male	Cheng Xiaoxiang	58	Female	Zhan Yuzhen	70	Female
	Shao Huifen	65	Female	Wang Zaohong	52	Female	Lee Do-kwon	70	Male
	Ye Heling	48	Female	Zhou Yongmei	51	Female	Huang Xiuzhen	79	Female
	Shao Cuiying	69	Female						
4	Jiang Hui	62	Male	Wang Jinqian	76	Male	Jiang chang	55	Male
	Ye Qisun	65	Female	Yu Rongju	59	Female	Jin Zirui	70	Male
	Xu Huali	54	Female	Cheng Xianying	62	Female	Jiang Lianyuan	80	Male
	Zhou Yongmei	51	Female	Wang Hengyu	63	Male	Sheng Ruizhen	57	Female
	Sun Ping'an	70	Female						
5	Shao Lihua	63	Female	Yao Jialie	73	Male	Jin Zuhe	67	Male
	Liu Hualin	71	Male	Wang Jinyao	71	Female	Cheng Gaisu	76	Female
	Hu Xiaolan	55	Female	Wang Xiuyun	70	Female	Wang Shisun	62	Male
	Wang Jingheng	70	Male	Ding Yihua	51	Female	Wang Haichun	65	Male
	Wu Tianci	71	Male						
6	Cheng Lianhua	67	Female	Sun Ping'an	69	Female	Ding Xiansun	46	Male
	Jiang Bin	29	Male	Yu Yunmei	56	Female	Wang Ruiling	62	Female
	Yu Shuijiao	82	Female	Zhang Tianlin	63	Male	Zhang Bosong	71	Male
	Wang Haining	71	Male	Wang Chang'e	62	Female	Wang Jianfei	70	Male
	Wu San'nai	83	Female						
7	Huang Shuimin	56	Male	Cheng Xianyou	61	Male	Wang Zaogui	72	Male
	Wang Lizhen	74	Female	Wu Yuxian	64	Female	Xu Yinggui	65	Male
	Jiang Shangren	76	Male	Huang Shunli	68	Male	Cheng Guobin	65	Male
	Sun Aizhu	63	Female	Sun Yiwen	65	Female	Wang Aiyun	57	Female
	Jin Jianzhong	54	Male						
8	Cheng Xianxiang	55	Male	Sheng Ruizhen	57	Female	Zhu Rongfeng	73	Female
	Tao Ainan	72	Female	Jiang Songbing	72	Male	Wang Xiaoying	46	Female
	Zhu Zhuannan	66	Female	Zhan Yuzhen	70	Female	Wang Aihong	44	Female
	Wang Liling	62	Female	Wang Yunzhen	56	Female	Han Ronghong	67	Male
	Ching-ying	49	Female						
9	Zhou Liying	64	Male	Wang Yongfang	62	Female	Su Chang'e	28	Female
	Cheng Guangzheng	68	Male	Wu Tianci	70	Male	Jin Qinglin	72	Male
	Zhu Jianglai	72	Male	Li Yueping	63	Male	Ye Shanyun	66	Female
	Jiang Zhenmei	61	Male	Huang Xuanmin	65	Male	Li Shunqiao	58	Female
	Zhan Yuzhen	70	Female						
10	Wang Yongfang	71	Female	Liu Haian	58	Male	Wang fang	68	Female
	Wang Guozhi	71	Male	Wang Yiliang	70	Male	Wang Guozhi	71	Male
	Zhu Zhuanmei	74	Female	Li Chengfa	80	Male	Cheng Juhua	71	Female
	Fang Meixiu	73	Female	Cai Juan	36	Female	Yao Jialie	73	Male
	Wang Guangfa	67	Male						

Table A2. Number of GPS points contained in the space elements.

Spatial Elements	Total	Male	Female	Time Period										
				7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18
B-1 of Guanlu Village														
Dock	704	101	603	50	108	63	82	107	57	40	34	87	65	11
Vegetable plots	1302	528	774	127	170	117	419	144	72	174	57	0	0	22
Dang	58	44	14	5	0	1	0	1	8	26	6	0	11	0
Alley	3348	915	2433	128	264	454	203	923	261	427	463	22	147	56
Pen	12	9	3	0	7	0	0	0	4	0	1	0	0	0
Arbor	8	8	0	0	0	0	0	0	8	0	0	0	0	0
Flat area	890	411	479	0	321	67	36	208	27	129	2	9	74	17
Bridge	57	35	22	0	0	0	0	27	11	17	0	0	2	0
Threshing floor	1425	513	912	26	49	87	145	95	53	134	453	325	50	8
Bamboo grove	116	99	17	0	38	0	0	0	78	0	0	0	0	0
B-2 of Guxi Village														
Vegetable plots	604	401	203	233	4	80	0	70	0	0	0	0	0	217
Dang	95	38	57	0	0	4	19	19	6	0	0	0	0	47
Alley	2203	2127	76	682	437	49	80	445	142	164	12	31	142	19
Pen	107	54	53	7	19	19	2	16	3	41	0	0	0	0
Flat area	458	395	63	55	64	287	4	6	18	15	0	0	0	9
Threshing floor	105	105	0	0	0	0	0	0	0	0	0	0	0	105
Bamboo grove	334	201	133	0	0	173	75	0	0	59	0	0	0	27
B-3 of Wucun Village														
Dock	1504	263	1241	50	108	163	382	157	57	70	134	187	185	11
Vegetable plots	1326	561	765	38	103	148	217	118	67	227	167	88	144	9
Dang	198	54	144	0	27	5	6	89	12	6	8	45	0	0
Alley	4253	2009	2244	229	287	555	797	389	169	897	334	121	395	80
Pen	150	47	103	9	27	4	2	9	23	26	9	24	13	4
Flat area	1080	665	415	10	30	102	17	160	2	50	525	181	3	0
Threshing floor	968	302	666	18	54	24	58	23	12	133	333	206	89	18
Bamboo grove	21	3	18	0	0	4	5	0	12	0	0	0	0	0

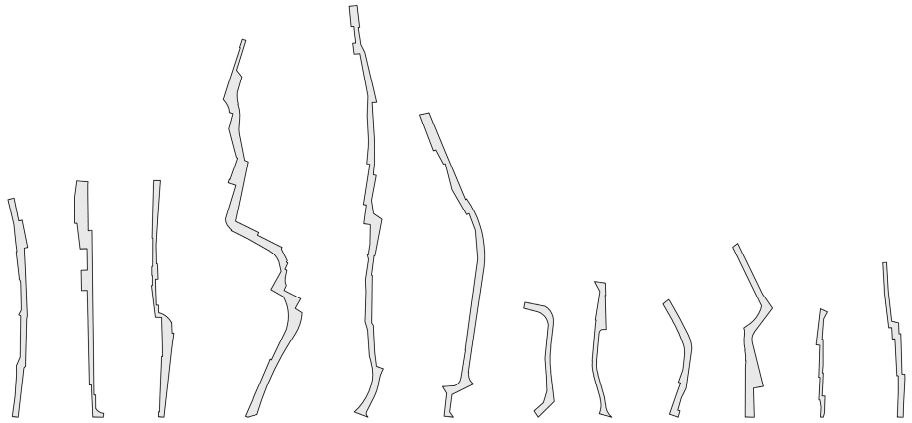

Figure A1. Shape of alley in ancient villages.

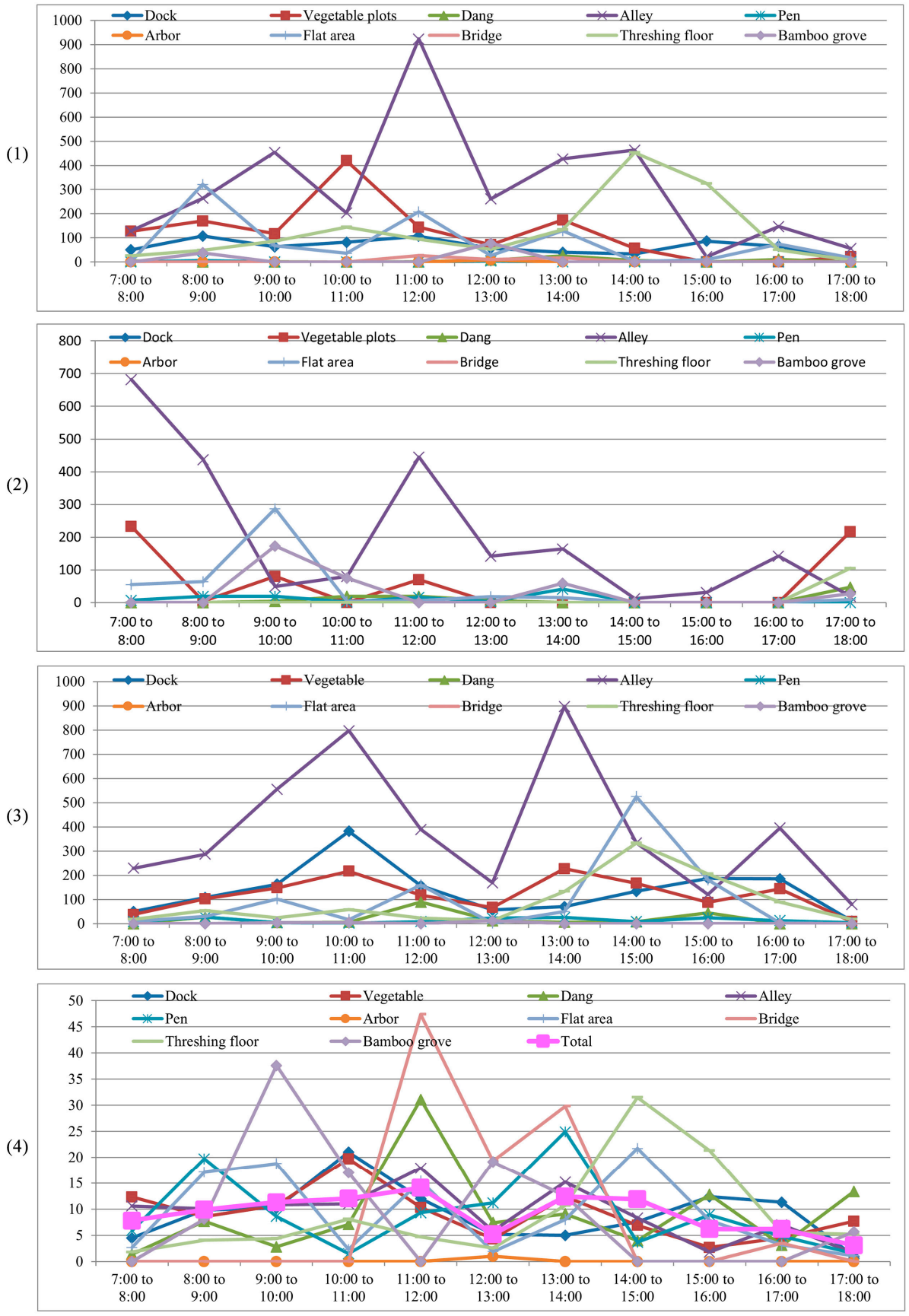

Figure A2. Space use time distribution: (**1**) Guanlu village, (**2**) Guxi village, (**3**) Wu village, and (**4**) distribution of total time spent on each element in all villages.

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