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Influencing factors and mechanisms on self-governed rural public open space quality: a conceptual social-ecological system (SES) framework

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Self-governed public open spaces (POSs) face challenges related to collective action dilemmas, specifically the Hardinian tragedy of the commons and underinvestment. Despite extensive research on social-ecological systems (SES) addressing human-environment issues, there has been no quantitative empirical investigation into the determinants of governance in rural POSs. This study, operationalizing McGinnis and Ostrom's SES framework and incorporating collective action theories, identifies institutional-social-ecological factors affecting the quality of self-governed POSs in rural China. Questionnaires were distributed to 594 households in 198 villages in Taigu via random sampling. The study employed PLS-SEM and mediation models to identify 15 key SES factors, including 4 institutional factors, 7 social factors, and 4 ecological factors. These variables impact the perceived quality of POSs either directly or through mediation by incentive activities, collective investment, and self-organizing activities. Based on the research findings, the study proposes five policy implications for the self-governance of rural POSs in China. The study not only contributes to the development of an SES-based POS governance framework, but it also offers policy insights into the significance of SES factors and ways to incentivize collective action for effective self-governance of rural public open spaces in China.

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Introduction

Public open space (POS) is an important resource located within the human social-ecological system that is closely intertwined with the sustainability of human society, the economy, and the environment (Dietsch, 2018). There is no consensus on the definition of POS, such that a given definition of POS is typically a response to the specific functions and characteristics it serves (Ling et al., 2019). Based on China's rural land system and the relationship between POSs and residents' activities, for present purposes, rural POSs in China refer to open spaces located within the built-up regions of villages. Such spaces are primarily intended for residential use, artificially constructed, not covered by buildings or structures, and serve multiple purposes, including providing venues for residents' public leisure, social activities, sports activities, ecological landscapes, agricultural and sideline production, and offering functions related to disaster prevention and reduction. To phrase this another way, China's rural POSs can be described as "open spaces within villages for residents' public activities" (Liu et al., 2014).

To address the supply and demand challenges associated with various products that occur against the backdrop of its large population, China has implemented a dual land ownership system, combining urban state ownership and rural collective ownership. Unlike state-owned POSs, rural POSs in China, which operate under a common property regime, are collectively owned and managed by village collectives. According to type of goods (Buchanan and Tullock, 1965), from the perspective of property rights, rural POSs in China can be considered club goods due to their excludability and non-rivalry. That is, rural POSs are collectively invested in and maintained by the villagers, who have the right to restrict the use of these spaces to non-members. Similar to golf clubs and cinemas, the use of these resources by members does not diminish their availability to other members. However, the dual land ownership system has somewhat constrained village development. These constraints include the disparity between industrial and agricultural product prices (known as the 'scissors difference'), restrictions on industrial and commercial activities in rural areas, inadequate government investment in rural development resulting in poor rural economic conditions, and the ongoing brain drain from rural areas. Consequently, rural POSs in China often face challenges related to insufficient resource management capabilities. As a result, villages struggle to effectively exercise their management rights, leading to collective action problems such as over-consumption, underinvestment, and resource depletion, known as the 'tragedy of the commons' (Hardin, 1968). Poorly managed rural POSs in China often fail to identify and exclude free-riders, as well as provide timely maintenance for the POSs. These issues result in resource degradation and an inability to reasonably allocate the limited resources among villagers. Consequently, villagers have to compete for the use of POSs. For instance, when a POS used for daily life and production activities has an uneven surface due to long-term lack of management and maintenance, villagers who need to dry grains are forced to compete with those playing badminton for access to the flat areas of the POS. Therefore, in practice, poorly managed rural POSs in China more closely resemble or inevitably transform into common-pool resources, characterized by significant rivalrousness and non-excludability among resource users (Webster, 2007).

To tackle the 'tragedy of the commons,' Ostrom (2007) proposed moving beyond the limitations of the property rights system in an effort to secure the sustainable development of commons through self-organization or self-governance. Although the dual land ownership system in China somewhat limits the self-governance capacity of rural POSs, it also provides institutional support for such self-governance in rural areas. Ostrom's collective action theory posits that the factors influencing the self-governance of actors are complex and numerous (Ostrom, 2007). In an effort to explain and analyze the cooperative conditions necessary for actors to participate in self-organization and maintain related institutions in the collective action process, Ostrom developed the social-ecological system (SES) framework (Ostrom, 2007). The development of the SES framework is based on extensive research from various commons self-governance contexts and collective action theories (Anderies et al., 2004; Baland and Platteau, 1996; Olson, 1965; Ostrom, 1990; Pinkerton, 1989; Pinkerton and Weinstein, 1995; Wade, 1989). The SES framework serves as a concrete manifestation of Ostrom's collective action theory, distinguished by its multi-disciplinary and multi-level characteristics. Specifically, it can diagnose complex resource management problems and system interactions across institutional, social, and ecological dimensions whilst also offering micro-level guidance to navigate specific issues (McGinnis and Ostrom, 2014). Therefore, as a type of common-pool resource, Ostrom's collective action theory and SES framework provide valuable and comprehensive insights into the challenges of self-governance for rural POSs in China. However, most POS self-governance studies have failed to systematically address all SES components (Francis et al., 2012), and only a few have applied the SES framework to the field of POS self-governance (Schmitt-Harsh and Mincey, 2020).

Although Ling et al. (2019) applied the SES framework to study the impact of property rights on rural POS management through qualitative analysis, to date, no empirical studies using the SES framework that provide robust quantitative evidence have been published. It is worth noting that most studies using the SES framework in POS management merely identify the relevant SES factors without analyzing the interactions (mediating roles) between them. Such an approach may result in errors and incomplete understanding and interpretations of the impact effects (path analysis), which in turn impacts the robustness of the analysis results (Shi and Ling, 2023). Shi and Ling (2024) developed a conceptual SES framework for POS self-governance through a systematic literature review. This framework offers a comprehensive foundation for SES research in POS self-governance context. However, to date, there is no empirical evidence supporting this framework. Furthermore, even though rural POS management in China faces significant challenges, there is scant research specifically probing rural POS management in China.

In light of the above background and gaps in the existing literature, this article adopts the SES framework as a theoretical framework to identify significant institutional-social-ecological factors affecting the POS self-governance ability (collective action) of villagers in rural China and to explore how these key institutional-social-ecological factors operate. This study will be the first to quantitatively operationalize McGinnis and Ostrom's SES framework in the self-governed POS context (McGinnis and Ostrom, 2014). Specifically, the study takes 198 villages in Taigu, China as the study area, and uses the PLS-SEM model and mediation effect models to identify the institutional-social-ecological factors that influence rural POS quality. Subsequently, the impact paths of SES factors are determined to analyze the mediating effects of interaction variables. Compared to the existing literature, the novelty of this study lies in its pioneering use of the systematic and multidimensional SES framework offering robust statistical evidence of factors that matter to rural POS management in China. To be precise, the study makes two primary contributions: Firstly, it bridges the knowledge gaps in the limited research on the SES framework in the field of POS management by understanding what and how SES factors and the

mediating roles of interaction variables influence POS quality. Secondly, the research findings hold empirical values for future sustainable rural POS planning and management in China.

Literature review: SES framework and collective action theories

Ostrom (2007) developed the social-ecological system (SES) framework to study the sustainability of common-pool resources. The SES framework offers the advantages of comprehensiveness, systematicity, and multi-disciplinarity, whilst also informing and guiding the in-depth analysis of micro-level issues (McGinnis and Ostrom, 2014). Although the SES framework includes highly detailed content, it cannot be directly applied to empirical research. The reason for this is that the specific research background needs to be accounted for, which necessitates appropriate adjustments to the variables. With the above in mind, this study developed a conceptual SES framework for POS management in rural China through a literature review, considering the background of rural China.

Outcomes (O). For present purposes, outcomes pertain to the villagers' ability to participate in rural POS self-governance, as reflected in villagers' self-perceived POS quality. Moreover, villagers' self-perceived POS quality is assessed by reference to five variables: number of human-constructed facilities, maintenance of human-constructed facilities, hygiene, landscape, and usability.

It should be stressed that the supply level of public facilities affects users' experience of POSs. Management performance of public facilities encompasses two aspects: the number of human-constructed facilities and the maintenance of human-constructed facilities (Shi and Ling, 2024). Some studies have found that the absence of signage and seating in POSs impacts users' experience and that the deficiency of public facilities was viewed as depriving users of their right to engage in daily leisure activities (Adjei Mensah, 2015). Damaged facilities that are rendered unusable also signify insufficient facility supply, further affecting the user experience. In this study, public facilities refer to seats and fitness equipment used for leisure purposes in POSs. Moreover, hygiene not only affects the attractiveness of POSs, but poor hygiene conditions can also negatively impact users' health (Adjei Mensah, 2015; Shi and Ling, 2024). The landscape of POS is another factor that affects the attractiveness of POS; as Liu et al. (2014) argued, one of the functions of rural POSs in China is to offer an ecological landscape. Finally, POS usability is a critical measure of POS quality: when POSs are difficult to use, users are likely to visit POSs less frequently, whilst unattractive POSs typically are of lower quality (Adjei Mensah, 2015; Chen and Tu, 2024).

Resource systems and units (RSU). The management of large POSs typically entails higher costs, making the management of large POS more challenging (Ling et al., 2018). Wade's conditions for successful commons management, as a collective action theory, suggest that smaller resource systems are more effectively managed under common property arrangements. Larger rural POSs generally require greater human and financial resources for maintenance, and monitoring user behaviors becomes more difficult. Nevertheless, larger POSs are often more attractive to users (Biernacka and Kronenberg, 2018). These larger spaces typically feature more facilities and offer a broader range of services, which enhances their usability. When a rural POS holds historical and cultural value, the government and relevant policymakers typically take appropriate measures for its development. For example, in Zhejiang Province, the government provides specific financial subsidies to villages with historical and cultural heritage (Zhou

et al., 2019). Meanwhile, Zhou et al. have provided insights into the policies for protecting rural historical and cultural heritage in China (Zhou et al., 2019). These implications include clearly defining the property rights of historical and cultural heritage, cultivating local talent to provide resources and opportunities for management participation, and promoting collaboration among different stakeholders. These measures can enhance the village collective's ability for self-governance of rural POSs.

The location of POSs influences their accessibility. In comparison to POSs located in mountainous or hilly areas, POSs located on plains are more readily accessible. This is critical as the accessibility of POSs impacts the motivation of actors to participate in self-organizing activities (Nordin et al., 2020). Rural POSs in China serve as important sites for agricultural production and processing (Liu, 2012). However, due to transportation challenges, the costs of grain drying and processing in mountainous areas are often high. Moreover, farmland marginalization is prevalent in mountainous and hilly villages across China, leading to a decreased economic reliance on POS among villagers (Huang and Tan, 2023; Shao et al., 2015; Wang et al., 2021), which in turn reduces their motivation to participate in POS self-governance. In rural areas where POSs are located near urban regions, villages may attract a portion of the population due to their affordable housing and low-cost commercial environment. This can place greater pressure on the management of rural POSs, potentially leading to a decline in their quality (Oostrum, 2022). However, the proximity to urban areas also offers the advantage of accessing urban resources (Wang et al., 2009), which can alleviate some negative effects of the dual land ownership system on rural development and potentially enhance the self-governance of rural POSs.

Governance systems (GS). Many studies have demonstrated that government assistance can enhance the management performance of POSs (Agrawal and Gibson, 1999). Although the property rights of rural POSs belong to the village collective, when a village has significant economic value and development potential, the government may become involved as an operator, investor, facilitator, coordinator, promoter, and educator in self-governance of rural POSs (Ying and Zhou, 2007). For example, in Daye County, China, the local government has invested substantial funds to improve rural POSs and infrastructure in order to develop rural tourism (Liu et al., 2020). Additionally, the local government assists villagers in coordinating with private investors and provides training in self-governance (Liu et al., 2020). These measures have a positive impact on the quality of rural POSs. In the study, government assistance is measured by whether the village has specific investment for rural POSs.

Non-government organizations serve as platforms to facilitate collective action among community members (Amelia, 2007). While these non-government organizations may not directly govern POSs, they can cultivate villagers' collective action capabilities and build social capital, which in turn facilitates POS governance. Amelia (2007) reached a similar finding in the study on public participation in green space management in Birmingham. Although the agendas of community non-government organizations were not directly related to green space management, these organizations established networks for information exchange and built social capital both within and outside the community. These networks and social capital have been shown to benefit citizens' self-governance of green spaces. The non-government organizations in this study include farmers' professional cooperatives and farmers' cultural organizations. The farmers' professional cooperatives are organizations based on rural household contract management, aiming to achieve mutual

assistance among members by providing services related to the sale, processing, transportation, and storage of agricultural products, as well as agricultural production and management-related technologies and information. Farmers' professional cooperatives require that farmers constitute at least 80% of the total membership (Song et al., 2014). Farmers' cultural organizations are spontaneously formed by local farmers who are passionate about arts and culture, with the main goals of improving rural cultural levels, enriching farmers' lives, promoting cultural exchange, and protecting and inheriting rural cultural heritage (Wu, 2012). Both of these non-government organizations are self-organized by farmers. Although they are not directly related to the self-governance of POSs, they can develop villagers' self-governance skills and accumulate social capital among villagers (Liang et al., 2018; Song et al., 2014; Wu, 2012). Lehavi (2004) argued that social capital will be depleted if there is no long-term participation in self-governance activities.

POS management regulations in villages stipulate the rights of POS-related actors. These regulations assist in establishing a system for promptly identifying and resolving POS management issues (den Boer, 2022). In rural China, the management regulations for POSs are typically included in village rules and agreements. These regulations specify the rights of villagers to use the rural POSs and the obligations they must fulfill (Teng, 2018). Rural management regulations are typically displayed in the most prominent places within a village, such as the central POS or at the entrance of the village committee office. Wade (1989), Ostrom (1990), Baland and Platteau (1996) all argue that locally devised access and management rules are one of the conditions for facilitating successful commons management. Participation of monitors is an integral component of rural POS monitoring systems; monitors can observe the behavior of users to prevent opportunistic misuse of POSs (Ling et al., 2018). In rural China, monitors are referred to as 'grid members.' Grid members are publicly elected by villagers in each village. One of their responsibilities is to act as monitors, overseeing and correcting villagers' violations according to rural management regulations (Mittelstaedt, 2022). This includes monitoring rural POS hygiene, facility quality in rural POSs, and other related aspects. The role of monitors in successful commons management is affirmed by the collective action theories of Ostrom (1990), Baland and Platteau (1996).

Actors (A). The transaction costs of collective action in the self-governance of POSs increase with the size of the group. Accordingly, larger groups may face more challenges in reaching a consensus among individuals, and the cost of monitoring actors is higher (Lehavi, 2004; Ling, 2019; Ling et al., 2014). As early as 1965, Olson's collective action theory posited that small groups facilitate successful commons management (Olson, 1965). Similarly, Wade (1989), Baland and Platteau (1996) identified small groups as one of the conditions for successful commons management. However, studies on commons in China have also found that more actors can positively impact commons management performance (Shi and Ling, 2022; Wang et al., 2016). This is because a greater number of actors can reduce the individual management costs associated with common property resources (Shi and Ling, 2023). In this study, the number of relevant actors is measured as the number of permanent residents in a village.

The socio-economic attributes of these actors influence their participation in the self-governance of POSs. Agrawal (2001) referenced multiple cases of commons management and identified that low levels of poverty among actors are one of the conditions for facilitating successful commons management.

In this study, the villagers' income level and the proportion of the village population that was impoverished were taken as the SES variables to study the impact of villagers' economic attributes on POS quality. In rural China villages, homesteads serve as the residential land for each household (Gu et al., 2020). As villagers with larger homestead areas typically tend to have access to more extensive private activity spaces, they tend to be less dependent on POSs, which in turn translates to diminished enthusiasm for participating in POS self-governance (Ling et al., 2019; Madden, 2010). Wade's collective action theory posits that a high level of dependence by group members on a resource system is a condition for facilitating successful commons management (Wade, 1989).

Compared to other participants, leaders have access to a wealth of POS governance-related knowledge, experience, and social networks (George, 2018), which cumulatively contribute to the success of self-governance in POSs. Baland and Platteau (1996) argued that leaders who are familiar with the external environment, educated, and connected to local traditional elites is the condition for facilitating successful commons management. In rural China, village leaders are elected by villagers, with each village having two primary leaders: party branch secretary and village committee director (Tan and Xin, 2007). Some villages also elect additional cadres, such as the deputy party branch secretary, deputy village committee director, village accountant (Zhang et al., 2012). Having more village cadres can lead to more effective handling of self-governance affairs, as they can share responsibilities and alleviate the workload of the party branch secretary and village committee director (Zhang et al., 2012). The educational level of village leaders has been shown to be an indicator of their capacity to manage village affairs, such as addressing villagers' poverty (Zhang et al., 2024). Additionally, the age of village leaders also reflects their management capacity. Kung et al. (2009) found that older leaders in China tend to have lower educational levels, making it more difficult for them to identify development opportunities for the village. However, some studies suggest that older village leaders in China tend to have more extensive experience in managing village collective affairs (Perry and Goldman, 2009). Therefore, the study specifically examined three variables related to leadership: number of village cadres, education level of village leaders, and age of village leaders. The village leaders in the study include the village party branch secretary and the village committee director.

Interactions (I). Bowles and Polania-Reyes (2012) and Vatn (2009) found that cash incentives sometimes interfere with or crowd out intrinsic sources of motivation. Although most rural areas in China do not offer specific rewards for villagers' participation in POS self-governance, many village committees distribute bonuses to villagers. These bonuses partly come from the revenues generated by villagers' collective actions, such as the operation of collective enterprises and collective farmland (Tang, 2015). The more benefits a group obtains through collective action, the more likely they are to aspire to successful self-governance (Ling et al., 2016; Tang, 2015). Therefore, although there is no direct relationship, higher bonuses may increase villagers' confidence and motivation to participate in POS self-governance, as they anticipate benefits from their involvement. Generally, increased financial investment benefits POS management; conversely, when investment exceeds returns, actors' enthusiasm for participating in POS management decreases, which in turn diminishes POS quality (Ling et al., 2021). In rural China, the self-governance of POSs is primarily funded through village collective income, personal investments, and donations. Maintaining facilities within these POSs requires continuous

financial support. Moreover, investment in rural POSs requires the consent of villagers. If a significant portion of the villagers do not agree with the village committee's decision to invest in the construction and maintenance of rural POSs, the management of rural POSs cannot proceed, and there may also be challenges in organizing related collective actions (Xu and Yao, 2015). Self-organizing activities for rural POS management include village meetings and collective actions among villagers to maintain the POS, such as cleaning and routine maintenance. A higher frequency of self-organizing activities can enhance the collective action ability of actors, especially their problem-solving abilities (Reed et al., 2018). Some studies use the frequency of villagers' participation in rural commons self-governance activities as a measure of the level of collective action in commons management (Wang et al., 2016).

In addition to the institutional-social-ecological variables studied here, this research also includes two demographic profile variables, 'age of respondent' and 'gender of respondent'-as control variables.

This study proposes a conceptual SES framework based on the potential mechanisms through which variables impact POS quality, as well as the SES framework. Table 1 presents the detailed definitions of the research variables, the corresponding hypotheses, and their sources. The conceptual SES framework is depicted in Fig. 1.

Based on the above research variables and conceptual framework, the study proposed 15 hypotheses related to institutional-social-ecological factors. They are:

H1: 'Size of public open space' has a positive or negative impact on the quality of public open space.

H2: 'Historical and cultural value' has a negative impact on the quality of public open space.

H3: 'Location' has a negative impact on the quality of public open space.

H4: 'Proximity to urban area' has a positive or negative impact on the quality of public open space.

H5: 'Government assistance' has a negative impact on the quality of public open space.

H6: 'Nongovernment organizations' have a positive impact on the quality of public open space.

H7: 'Public open space management regulations' have a negative impact on the quality of public open space.

H8: 'Monitoring system' has a negative impact on the quality of public open space.

H9: 'Number of relevant actors' has a positive or negative impact on the quality of public open space.

H10: 'Income level of villagers' has a positive impact on the quality of public open space.

H11: 'Proportion of impoverished villagers' has a negative impact on the quality of public open space.

H12: 'Per capita homestead area' has a negative impact on the quality of public open space.

H13: 'Number of village cadres' has a positive impact on the quality of public open space.

H14: 'Education level of village leaders' has a positive impact on the quality of public open space.

H15: 'Age of village leaders' has a positive or negative impact on the quality of public open space.

Moreover, the study proposed three hypotheses related to interaction factors. They are:

H16: 'Incentive activities' play a positive mediating role between the institutional-social-ecological variables and the quality of public open space.

H17: 'Collective investment' plays a positive or negative mediating role between the institutional-social-ecological variables and the quality of public open space.

H18: 'Self-organizing activities' play a positive mediating role between the institutional-social-ecological variables and the quality of public open space.

Research methodology
Study area. This study specifically selected villages in Taigu District, Jinzhong City, Shanxi Province as the study area. The location of Taigu District is shown in Fig. 2.

As is the case in other rural areas in China, rural POS self-governance in Taigu is frustrated by the impact of dual land ownership. In response, it is necessary to develop sustainable POS management strategies through scientific methods. The total area of Taigu District is 1050 square kilometers. According to the seventh population census of China, the permanent population of Taigu District was 322,099, 42.77% of which is constituted by the rural population. According to data from the Statistics Bureau of Taigu District, as of 2023, there are 198 administrative villages in Taigu District. The locations of the 198 administrative villages are shown in Fig. 3.

This study will investigate and examine the self-governance of central POSs in these 198 administrative villages. In this paper, 'central POS' refers to public open spaces arranged for communal and productive activities within the village that serve the entire village. Typically, central POSs are located next to ancestral halls, temples, and opera stages, and they are used for gathering crowds and hosting commercial and recreational activities during festivals. At other times, central POSs are used for drying agricultural produce, hanging clothes, and recreational and leisure activities. Examples of central POSs and related facilities are shown in Fig. 4. In the study area, a total of 198 central POSs were surveyed from the 198 administrative villages.

Data collection. The data in this study was collected through questionnaires. Based on the SES framework, the questionnaire can be divided into six parts: What are the characteristics of the central POS in the village? (Resource systems and units); What system has been adopted to manage the central POS in the village? (Governance systems); What are the characteristics of the villagers? (Actors); How do institutional-social-ecological factors interact with each other? (Interactions); What is the quality of the central POS in the village? (Outcomes); What is the demographic profile of the respondents? (Demographic profile of respondents) The research questionnaire is available in the supplementary materials.

Although the unit of analysis is central POSs in villages, random sampling was employed to minimize sample data bias. To ensure the reliability and consistency of data, three sets of data were collected from each village through questionnaire surveys. Specifically, the study considered the central POS as the core of a village, and each household in a village was assigned a number based on its distance from the central POS, with smaller numbers indicating closer proximity. Subsequently, three households were randomly sampled from the numbered household list for each village, and questionnaires were distributed to them. If the sampled households were unfamiliar with matters related to the self-governance of POSs, conditions, and quality of POSs, or declined to respond, the random sampling process was repeated until three valid datasets were collected from each village. According to the sampling strategy, a total of 765 questionnaires were distributed, with 594 datasets collected, representing 198 villages. According to data from the seventh population census of China, the number of rural households in the 198 villages involved is approximately 53,392. Following Krejcie and Morgan (1970), the margin of error for the sample size is less than 0.05,

Table 1 Definition of variables.

	Name of Latent variables	Name of observed variables	Measurement Level	Variables' Assignment	Expected Sign of Hypothesis	Source
Demographic profile of respondents	Age of respondent (control variable) (CV1)	Age of respondent	Interval-ratio level of measurement			
	Gender of respondent (control variable) (CV2)	Gender of respondent	Nominal level of measurement	Male = 1; Female = 2	H1: ±	Wade (1989); Biernacka and Kronenberg (2018)
Resource systems and units (RSU)	Size of public open space (RSU1)	Size of public open space	Interval-ratio level of measurement		H2: -	Zhou et al. (2019)
	Historical and cultural value (RSU2)	Historical and cultural protection public open space	Nominal level of measurement	Public open space with historical and cultural protection units = 1; Public open space without historical and cultural protection units = 2		
	Location (RSU3)	Location of public open space	Nominal level of measurement	Public open space located on plain = 1; Public open space located on hilly = 2; Public open space located on mountain = 3	H3: -	Nordin et al. (2020); Huang and Tan (2023); Wang et al. (2021)
	Proximity to urban area (RSU4)	Distance between urban CBD and rural public open space	Interval-ratio level of measurement		H4: ±	Oostrum (2022); Wang et al. (2009)
Governance systems (GS)	Government assistance (GS1)	Government investment projects	Nominal level of measurement	Public open space with government investment projects = 1; Public open space without government investment projects = 2	H5: -	Ying and Zhou (2007); Liu et al. (2020)
	Nongovernment organizations (GS2)	Number of farmers' professional cooperatives	Interval-ratio level of measurement		H6: +	Amelia (2007); Song et al. (2014); Wu (2012); Liang et al. (2018); Lehavi (2004)
		Number of farmers' cultural organizations	Interval-ratio level of measurement			
	Public open space management regulations (GS3)	Public open space management regulations	Nominal level of measurement	Public open space with public management regulations = 1; Public open space without public management regulations = 2	H7: -	Teng (2018); Wade (1989); Baland and Platteau (1996); Ostrom (1990)

Table 1 (continued)

Name of Latent variables	Name of observed variables	Measurement Level	Variables' Assignment	Expected Sign of Hypothesis	Source
Monitoring system (GS4)	Participation of monitors	Nominal level of measurement	The village have designated monitors for public open spaces = 1; The village have not designated monitors for public open spaces = 2	H8: -	Mittelstaedt (2022); Baland and Platteau (1996); Ostrom (1990)
Actors (A)					
Number of relevant actors (A1)	Number of permanent residents	Interval-ratio level of measurement		H9: ±	Lehavi (2004); Ling (2019); Ling et al. (2014); Olson (1965); Wade (1989); Baland and Platteau (1996); Shi and Ling (2023); Shi and Ling (2022); Wang et al. (2016)
Income level of villagers (A2)	Per capita income of villagers	Interval-ratio level of measurement		H10: +	Agrawal (2001)
Proportion of impoverished villagers (A3)	Proportion of impoverished villagers	Interval-ratio level of measurement		H11: -	Agrawal (2001)
Per capita homestead area (A4)	Per capita homestead area	Interval-ratio level of measurement		H12: -	Ling et al. (2019); Wade (1989); Madden (2010)
Number of village cadres (A5)	Number of village cadres	Interval-ratio level of measurement		H13: +	Zhang et al. (2012)
Education level of village leaders (A6)	Education level of party branch secretary	Nominal level of measurement	Junior high school = 1; Senior high school = 2; Junior college = 3; Bachelor = 4; Postgraduate = 5	H14: +	Zhang et al. (2024)
	Education level of village committee director	Nominal level of measurement	Junior high school = 1; Senior high school = 2; Junior college = 3; Bachelor = 4; Postgraduate = 5		
Age of village leaders (A7)	Age of party branch secretary	Interval-ratio level of measurement		H15: ±	Kung et al. (2009)
	Age of village committee director	Interval-ratio level of measurement			
Interactions (I)	Incentive activities (I1)	Annual per capital collective bonus of villagers	Interval-ratio level of measurement	H16: +	Tang (2015); Ling et al. (2016)

Table 1 (continued)

Name of Latent variables	Name of observed variables	Measurement Level	Variables' Assignment	Expected Sign of Hypothesis	Source
Collective investment (I2)	Collective investment for public open space	Interval-ratio level of measurement		H17: ±	Ling et al. (2021); Xu and Yao (2015)
Self-organizing activities (I3)	Number of public meetings and activities	Interval-ratio level of measurement		H18: +	Reed et al. (2018)
Outcomes (O)	Quality of public open space (O)				
	Number of human-constructed facilities	Ordinal level of measurement	Low = 1; Medium = 2; High = 3		
	Maintenance of human-constructed facilities	Ordinal level of measurement	Low = 1; Medium = 2; High = 3		
	Hygiene	Ordinal level of measurement	Low = 1; Medium = 2; High = 3		
	Landscape	Ordinal level of measurement	Low = 1; Medium = 2; High = 3		
	Usability	Ordinal level of measurement	Low = 1; Medium = 2; High = 3		

In the Expected Sign of Hypothesis column, a '+' indicates that the variable may have a positive impact on the quality of POS, a '−' indicates a potential negative impact, and '±' suggests that the variable may have either a positive or negative impact on the quality of POS.

with a confidence interval of 95%. Based on this, the sample size is both sufficient and representative.

Data analysis. The study involved a single-item measurement structure, non-normally distributed data, formative model, and mediation effect model. Therefore, the analysis was carried out using PLS-SEM and mediation effect model. Partial Least Squares (PLS), a second-generation Structural Equation Modeling (SEM) technique developed by Wold (1982) and elaborated on by Chin (1998a).

The PLS-SEM and mediation effect model of this study determined the interactions among institutional-social-ecological variables by analyzing the multiple mediating effects of the interaction variables. Although PLS-SEM is capable of repeating the traditional causal steps (three-step) method to determine the mediating effects of interaction variables, this introduces significant errors (Gefen et al., 2000; Shi and Ling, 2023). In response, the bootstrapping procedure was employed to test the significance of the mediating effect of interaction variables in SmartPLS 4. Crucially, compared to the traditional causal step approach, the bootstrapping test can handle competitive partial mediation (Zhao et al., 2010). Additionally, it does not require the normality assumption of sampling distribution to test mediation, nor is it affected by sample size (Chin, 2010; Preacher and Hayes, 2008). Regarding the present bootstrapping procedure, the number of bootstrap subsamples was set to 5000, the test type was set to two tailed, and the significance level was set to 0.05.

Results and discussion
Descriptive statistics. Table 2 details the descriptive statistics for all items (observed variables) based on the 594 samples. The higher the standard deviation values in the data, the greater the spread of the data. Based on the mean values and standard deviations presented in Table 2, most variable data values exhibit relatively low dispersion around the mean. However, the variables such as the size of public open space, distance between urban CBD and rural public open space, number of permanent residents, per capita income of villagers, per capita homestead area, annual per capita collective bonus of villagers, and collective investment for public open space have higher standard deviations. This indicates significant differences among the villages for these variables. The measurement scale is equal to the observed scale across all items, indicating that the variable design in this study is reasonable. Excess kurtosis reflects the difference between the tails and peaks of a distribution compared to a normal distribution. When excess kurtosis is greater than 0, it means that the distribution has sharper peaks and heavier tails compared to a normal distribution. Examination of the excess kurtosis values reveals that for the binary variables historical and cultural protection public open space and government investment projects, the higher excess kurtosis indicates significant differences between a few villages and the others for these two variables. For numerical variables, the number of farmers' cultural organizations, proportion of impoverished villagers, annual per capita collective bonus of villagers, and collective investment for public open space exhibit higher excess kurtosis values. This suggests that for these variables, a few villages are significantly higher or lower than the others. Skewness indicates the non-symmetrical pattern of data: when the skewness is zero, the data has a symmetric distribution. Furthermore, negative skewness indicates a left-skewed distribution (most of the data is greater than the median), whilst positive skewness indicates a right-skewed distribution (most of the data is less than the median). Compared to other variables,
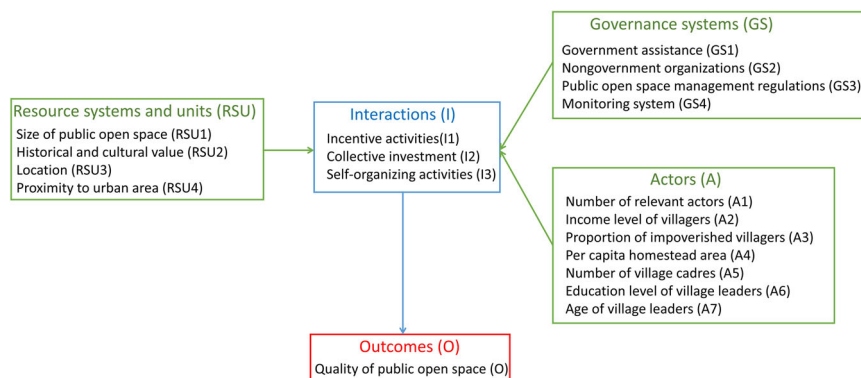
Fig. 1 Conceptual SES framework. The green boxes represent the three core subsystems in the conceptual SES framework: resource systems and units (RSU), which include ecological factors; governance systems (GS), which include institutional factors; and actors (A), which include social factors. The blue boxes represent the interaction factors that may emerge from the interaction between factors within the three core subsystems. These interaction factors may play a mediating role in the process where institutional-social-ecological factors influence the quality of public open space. The green arrows represent the pathways through which institutional-social-ecological factors influence interaction factors, while the bule arrow represents the pathway through which interaction factors influence the quality of public open space. The red box represents the quality of public open spaces, which is the dependent variable in this study. It is used to measure the self-governance performance of rural POSs in China.
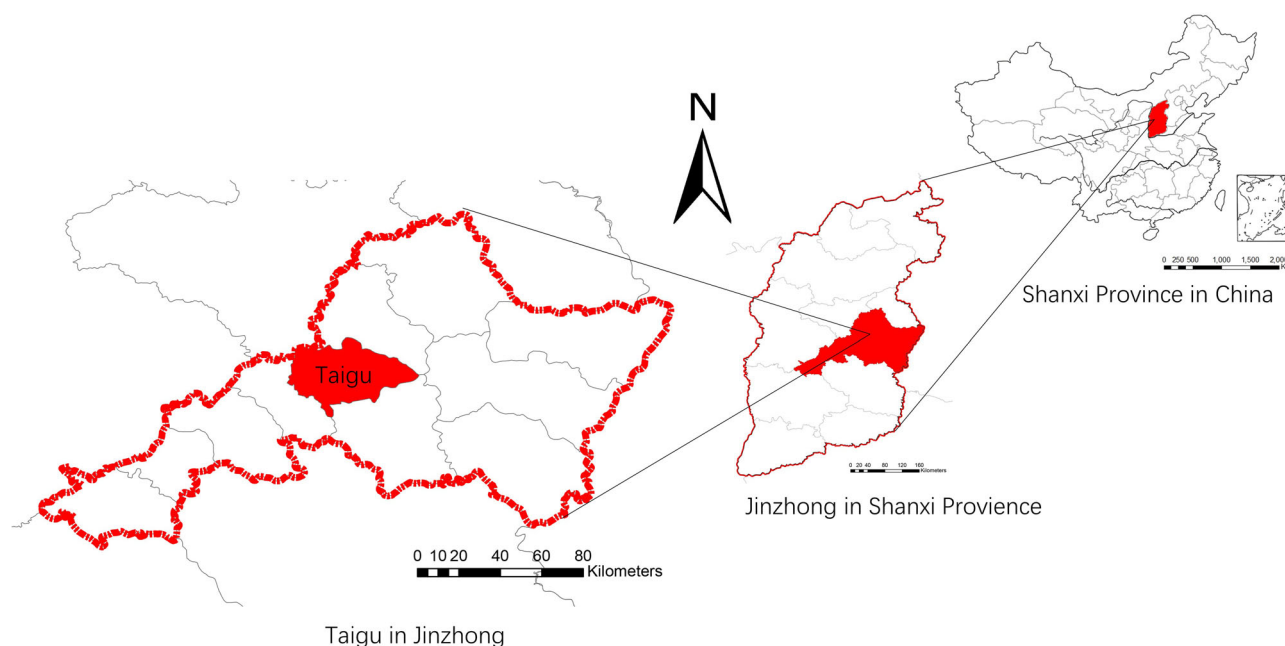

Fig. 2 Location of Taigu District. The Figure step-by-step illustrates the specific location of Taigu District. The first step, 'Shanxi Province in China' shows the location of Shanxi Province within China, represented by the red area on the map of China. The second step, 'Jinzhong in Shanxi Province,' shows the location of Jinzhong City within Shanxi Province; the red boundary line represents the regions of Shanxi Province, while the red area represents Jinzhong City. The third step, 'Taigu in Jinzhong,' shows the location of Taigu within Jinzhong City; the red boundary line represents the region of Jinzhong City, while the red area represents Taigu District.

historical and cultural protection public open space, government investment projects, proportion of impoverished villagers, and annual per capita collective bonus of villagers have higher skewness values. Specifically, historical and cultural protection public open space and government investment projects exhibit negative skewness (left-skewed), indicating that only a few villages' POSs have historical or cultural protection value and only a few villages' POSs receive government investment. On the other hand, the proportion of impoverished villagers and annual per capita collective bonus of villagers exhibit positive skewness (right-skewed), indicating that a few villages have a higher proportion of impoverished population and a few villages offer higher collective bonuses to villagers. According to the excess

kurtosis and skewness values, none of the variables follow a normal distribution.

Assessment of measurement model. The validity of the measurement model was assessed in the present research by evaluating indicator weights, variance inflation factors (VIF), and inter-construct correlations.

When a construct was composed of more than one indicator, equal weights were assigned to each indicator. As shown in Table 3, the outer weights of each indicator were greater than 0.2 and the p-values were less than 0.05, demonstrating that the indicators were relevant for the formative index. Thus, it can be
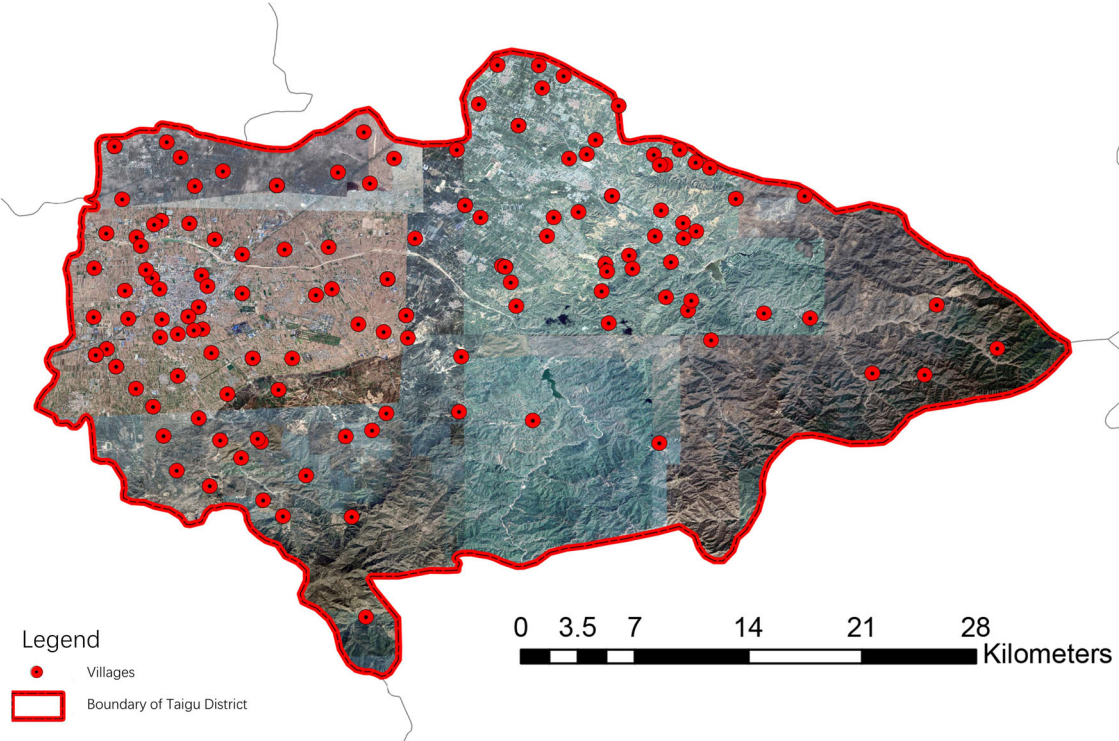
Fig. 3 The locations of 198 administrative villages in Taigu. The red boundary line represents the boundaries of Taigu District. The red dots indicate the locations of the 198 administrative villages within Taigu District.

Fig. 4 Example of central POSs in villages. a Central POS located next to village committee office. **b** Central POS located next to historical protection buildings. **c** Central POS located next to opera stage. **d** Small central POS. **e** Greening central POS. **f** Facilities in POS.

concluded that the constructs exhibited a sufficient level of validity (Chin, 1998b). The study also assessed the multicollinearity of formative indicators by calculating the variance inflation factor (VIF). Table 3 shows that the VIF values of formative indicators were less than 3.3, indicating excellent values and multicollinearity between formative indicators was not an issue (Diamantopoulos and Siguaw, 2006). Finally, the study examined the inter-construct correlations, as shown in Fig. 5, the correlations between constructs were less than 0.7, indicating sufficient discriminative validity among constructs (MacKenzie et al., 2005).

In summary, the validity of the measurement model in the study was demonstrated by assessing indicator validity (outer

Table 2 Descriptive statistics for the items (observed variables).

	Mean	Median	Scale min	Scale max	Observed min	Observed max	Standard deviation	Excess Kurtosis	Skewness
Age of respondent	51.689	54	20	77	20	77	16.095	−1.159	−0.327
Gender of respondent	1.519	2	1	2	1	2	0.5	−2.001	−0.074
Size of public open space	1886.753	1175	82	11352	82	11352	2002.674	5.36	2.173
Historical and cultural protection public open space	1.949	2	1	2	1	2	0.219	14.989	−4.116
Location of public open space	1.677	1	1	3	1	3	0.851	−1.289	0.671
Distance between urban CBD and rural public open space	17333.94	14300	920	57000	920	57000	12135.874	0.468	0.935
Government investment projects	1.97	2	1	2	1	2	0.171	28.279	−5.494
Number of farmers' professional cooperatives	2.909	2	0	21	0	21	3.94	5.322	2.18
Number of farmers' cultural organizations	0.778	1	0	8	0	8	1.074	13.229	2.98
Public open space management regulations	1.227	1	1	2	1	2	0.419	−0.298	1.305
Participation of monitors	1.566	2	1	2	1	2	0.496	−1.936	−0.266
Number of permanent residents	1094.399	668	6	6000	6	6000	1249.33	2.527	1.663
Per capita income of villagers	39444.44	40000	20000	60000	20000	60000	12110.37	−1.176	−0.167
Proportion of impoverished villagers	0.01	0.006	0	0.133	0	0.133	0.015	24.106	3.979
Per capita homestead area	174.424	150	30	650	30	650	93.307	2.965	1.24
Number of village cadres	5.732	6	1	16	1	16	2.658	1.232	0.689
Education level of party branch secretary	3.374	3	1	5	1	5	0.683	0.843	0.702
Education level of village committee director	3.288	3	1	5	1	5	0.605	1.652	0.72
Age of party branch secretary	52.328	53	30	72	30	72	8.087	−0.287	−0.15
Age of village committee director	49.278	50	27	65	27	65	7.636	−0.201	−0.367
Annual per capital collective bonus of villagers	31.111	0	0	620	0	620	101.274	15.959	3.982
Collective investment for public open space	17252.53	7000	0	160000	0	160000	25969.618	8.997	2.86
Number of public meetings and activities	5.389	5	1	15	1	15	2.976	−0.866	0.256
Number of human-constructed facilities	1.359	1	1	3	1	3	0.609	1.092	1.493
Maintenance of human-constructed facilities	2.232	2	1	3	1	3	0.489	−0.134	0.457
Hygiene	2.268	2	1	3	1	3	0.714	−0.959	−0.443
Landscape	1.636	2	1	3	1	3	0.703	−0.777	0.645
Usability	1.864	2	1	3	1	3	0.783	−1.333	0.244

Table 3 Indicator validity of the measurement model.

Indicator	Outer weights	P values	Variance inflation factor (VIF)
Age of respondent	1.000	0.000	1.000
Gender of respondent	1.000	0.000	1.000
Size of public open space	1.000	0.000	1.000
Historical and cultural protection public open space	1.000	0.000	1.000
Location of public open space	1.000	0.000	1.000
Distance between urban CBD and rural public open space	1.000	0.000	1.000
Government investment projects	1.000	0.000	1.000
Number of farmers' professional cooperatives	0.618	0.000	1.106
Number of farmers' cultural organizations	0.618	0.000	1.106
Public open space management regulations	1.000	0.000	1.000
Participation of monitors	1.000	0.000	1.000
Number of permanent residents	1.000	0.000	1.000
Per capita income of villagers	1.000	0.000	1.000
Proportion of impoverished villagers	1.000	0.000	1.000
Per capita homestead area	1.000	0.000	1.000
Number of village cadres	1.000	0.000	1.000
Education level of party branch secretary	0.611	0.000	1.129
Education level of village committee director	0.611	0.000	1.129
Age of party branch secretary	0.615	0.000	1.117
Age of village committee director	0.615	0.000	1.117
Annual per capital collective bonus of villagers	1.000	0.000	1.000
Collective investment for public open space	1.000	0.000	1.000
Number of public meetings and activities	1.000	0.000	1.000
Number of human-constructed facilities	0.295	0.000	1.171
Maintenance of human-constructed facilities	0.295	0.000	1.185
Hygiene	0.295	0.000	1.301
Landscape	0.295	0.000	1.636
Usability	0.295	0.000	1.824

Notes. *p<0.05, **p<0.01, ***p<0.001
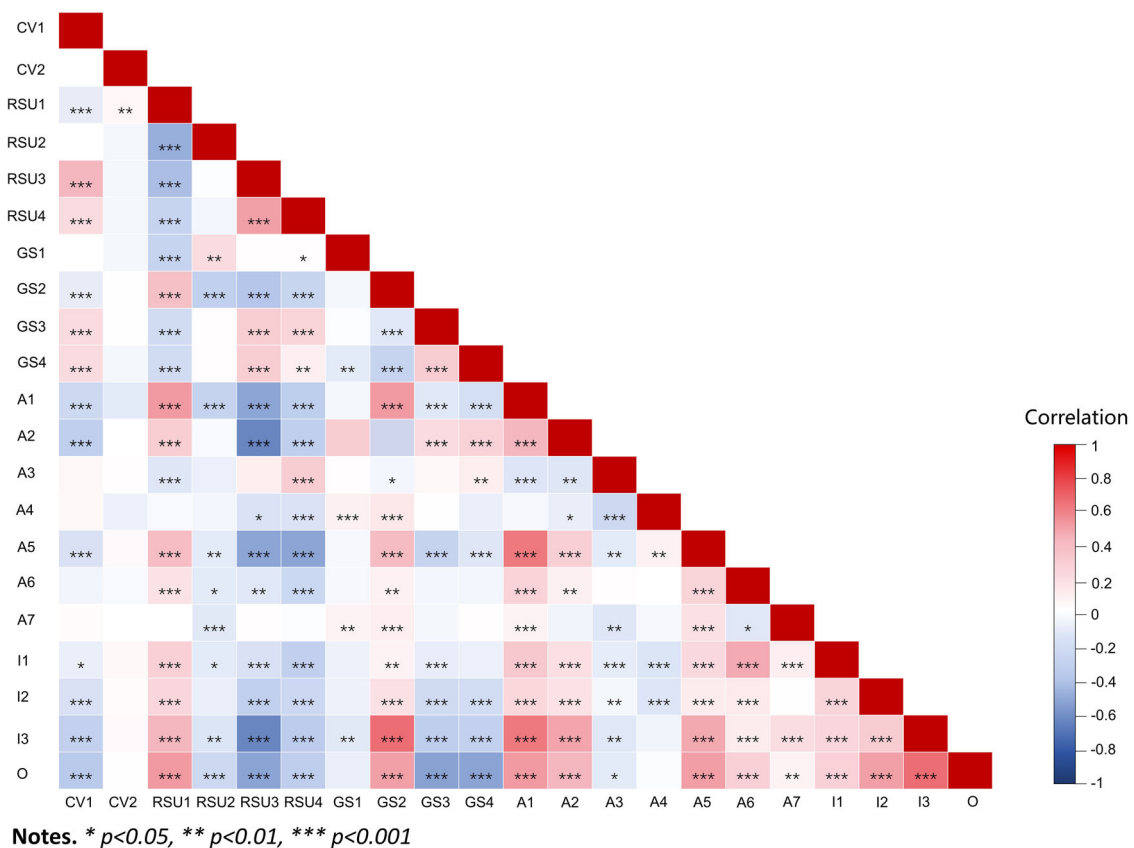
Fig. 5 Construct validity of the measurement model (Inter-construct correlations). This Figure represents the correlations between latent variables (constructs). The closer the color block is to white, the weaker the correlation between the two variables. Darker red blocks indicate a stronger positive correlation, while darker blue blocks indicate a stronger negative correlation. *** indicates a p-value less than 0.001, ** indicates a p-value less than 0.01, and * indicates a p-value less than 0.05. Color blocks without any marks, except those comparing the same variable, indicate no correlation between the two variables.

Table 4 Assessment of the structural model validity.

	R-square	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values	SSO	SSE	Q-square
Incentive activities	0.378	0.043	8.762	0.000	594.000	504.346	0.151
Collective investment	0.208	0.029	7.087	0.000	594.000	511.721	0.139
Self-organizing activities	0.670	0.020	34.126	0.000	594.000	304.121	0.488
Quality of public open space	0.769	0.018	42.681	0.000	2970.000	2581.118	0.131

weights and variance inflation factor (VIF)) as well as construct validity (inter-construct correlations).

Assessment of structural model. The study assessed the validity of structural model by evaluating the coefficient of determination (R^2), predictive relevance (Q^2), and path coefficients.

As detailed in Table 4, the R^2 for incentive activities was 0.378, indicating that 37.8% of the variation in incentive activities can be explained by the significant institutional-social-ecological variables featured in the research model. Moreover, the R^2 of collective investment is 0.208, which can explain 20.8% of the variation in collective investment that forms part of the significant institutional-social-ecological variables in the research model. Meanwhile, the R^2 of self-organizing activities is 0.670, indicating that 67.0% of the variation in self-organizing activities can be explained by the significant institutional-social-ecological variables included in the research model. Finally, the R^2 of POS quality is 0.769, which is indicative of the fact that 76.9% of the variation in self-organizing activities can be explained by the significant institutional-social-ecological variables in the PLS-SEM model. Based on the above, it can be concluded that the PLS-SEM model demonstrated substantial explanatory power (Chin, 1998b). Additionally, the study assessed the predictive relevance of the PLS-SEM model through Q^2. As shown in Table 4, the Q^2 values of incentive activities, collective investment, self-organizing activities, and quality of POS are greater than zero, indicating that the tested model has predictive relevance. Specifically, according to the Q^2 values, the model demonstrates medium predictive relevance for incentive activities, collective investment, and the quality of public open space, and large predictive relevance for self-organizing activities. Considering both Q^2 and R^2 values, the research model is valid and well-suited to meet the study's objective (Sarstedt et al., 2022).

According to the results of the PLS-SEM Algorithm and Bootstrapping approach, the tested model demonstrated that a total of 15 institutional-social-ecological variables influence POS quality through both direct effects and the mediating effects of incentive activities, collective investment, and self-organizing activities (see Table 5).

In the resource systems and units, factors such as the size of public open spaces, historical and cultural value, location, and proximity to urban areas are significantly associated with POS quality. Additionally, POS size has a significant direct effect on POS quality, as well as an indirect effect through the mediating role of collective investment. According to the VAF value, the indirect effect mediated by collective investment accounts for 19.8% of the total effect.

Previous studies have suggested that managing larger-sized POS is more challenging and such POSs are more prone to succumbing to the tragedy of the commons (Ling, et al., 2018). By way of contrast, the present research findings indicate that larger POSs tend to offer better POS quality, as their ample space for diverse facilities and landscapes enhances the user experience. Although the research findings demonstrate that larger POSs require more financial investment, this increased investment significantly improves their quality. In the context of POS self-

governance in rural China, the additional costs associated with managing larger POSs did not have a negative impact. This alleviates concerns raised in some studies about the potential adverse effects of excessive financial investment on POS self-governance (Ling et al., 2021).

Although POSs with high historical and cultural value may not necessarily prompt villagers' investment and participation in POS management, historical and cultural value is directly associated with POS quality. This is primarily because such POSs tend to attract external funding and technology for investment, construction, and maintenance (Zhou et al., 2019). Furthermore, out of respect for local history and culture, and to protect their economic interests, local villagers are also careful in maintaining and utilizing rural POSs.

Whilst location is not directly associated with POS quality, it indirectly affects POS quality through the full mediating effects of incentive activities and self-organizing activities. Notably, location positively influences POS quality through the mediating effect of incentive activities, while it exerts a stronger negative influence on POS quality through the mediating effect of self-organizing activities. POSs located in mountainous and hilly areas typically suffer from inconvenient transportation, which may not meet some of the villagers' production and living needs. As a result, villagers are less motivated to participate in POS self-governance, a finding consistent with the results of other studies (Huang and Tan, 2023; Shao et al., 2015; Wang et al., 2021). Moreover, villages located in mountainous and hilly areas, due to limited interaction with the outside world, may have villagers whose income more heavily dependent on village collective economic organizations, such as collective farmland and forests. As a result, these villages tend to have higher bonuses compared to those in plains, and villagers' production and daily lives are more reliant on the self-governance of village collectives. This, to some extent, has a positive impact on villagers' participation in POS self-governance, although the effect is minimal.

Proximity to urban areas exerts indirect negative effects on POS quality through the mediating effect of incentive activities. Villages closer to urban areas often engage in a wider range of urban industries, resulting in better economic development conditions. Consequently, village collectives near urban areas can provide higher bonuses to villagers. This type of incentive activity positively impacts the self-governance of rural POSs. The findings of this study demonstrate that villages near cities can mitigate the negative effects of the dual land ownership system on the self-governance of rural POSs (Wang et al., 2009).

In governance systems, government assistance, nongovernment organizations, public open space management regulations, and monitoring systems exhibit significant associations with POS quality. Government assistance indirectly influences the POS quality through the full mediating effect of self-organizing activities. These investment funds are directly applied by the local government or contractors to the construction and maintenance of rural POSs, and therefore, they do not impact the variable 'collective investment.' As previous studies have shown, government assistance is not limited to financial investment but also enhances villagers' collective action

Table 5 The impact of institutional-social-ecological variables on quality of POS.

		Effect	Estimate	P-value	Standard deviation (STDEV)	T statistics (|O/STDEV|)	Lower 2.5%	Upper 2.5%
Resource systems and units (RSU)	Size of Public open space	Direct effect	0.154	0.000	0.033	4.699		
		Indirect effect (Collective investment)	0.038	0.047	0.019	1.988	0.002	0.077
		Total effect	0.192					
		Variance accounted for (VAF) value	0.198					
	Historical and cultural value	Direct effect	−0.363	0.002	0.115	3.146		
		Total effect	−0.363					
	Location	Indirect effect (Incentive activities)	0.012	0.024	0.005	2.260	0.003	0.024
		Indirect effect (Self-organizing activities)	−0.041	0.004	0.014	2.885	−0.071	−0.016
		Total effect	−0.029					
		Variance accounted for (VAF) value	1.000					
	Proximity to urban area	Indirect effect (Incentive activities)	−0.014	0.008	0.005	2.639	−0.025	−0.004
		Total effect	−0.014					
		Variance accounted for (VAF) value	1.000					
Governance systems (GS)	Government assistance	Indirect effect (Self-organizing activities)	−0.052	0.008	0.019	2.671	−0.095	−0.018
		Total effect	−0.052					
		Variance accounted for (VAF) value	1.000					
	Nongovernment organizations	Direct effect	0.077	0.006	0.028	2.758		
		Indirect effect (Self-organizing activities)	0.053	0.002	0.017	3.132	0.021	0.087
		Total effect	0.130					
		Variance accounted for (VAF) value	0.408					
	Public open space management regulations	Direct effect	−0.554	0.000	0.058	9.591		
		Indirect effect (Self-organizing activities)	−0.027	0.015	0.011	2.442	−0.052	−0.008
		Total effect	−0.581					
		Variance accounted for (VAF) value	0.046					
	Monitoring system	Direct effect	−0.464	0.000	0.045	10.348		
		Indirect effect (Self-organizing activities)	−0.022	0.020	0.009	2.326	−0.043	−0.006
		Total effect	−0.486					
		Variance accounted for (VAF) value	0.045					
Actors (A)	Number of relevant actors	Indirect effect (Incentive activities)	0.016	0.040	0.008	2.053	0.003	0.033
		Indirect effect (Self-organizing activities)	0.023	0.009	0.009	2.597	0.008	0.042
		Total effect	0.039					
		Variance accounted for (VAF) value	1.000					
	Income level of villagers	Indirect effect (Incentive activities)	0.006	0.042	0.003	2.033	0.001	0.012
		Indirect effect (Self-organizing activities)	0.011	0.047	0.006	1.991	0.002	0.023
		Total effect	0.017					
		Variance accounted for (VAF) value	1.000					

Table 5 (continued)

	Effect	Estimate	P-value	Standard deviation (STDEV)	T statistics (|O/STDEV|)	Lower 2.5%	Upper 2.5%
Proportion of impoverished villagers	Indirect effect (Collective investment)	−0.011	0.035	0.005	2.110	−0.023	−0.001
	Total effect	−0.011					
	Variance accounted for (VAF) value	1.000					
Per capita homestead area	Indirect effect (Incentive activities)	−0.009	0.025	0.004	2.237	−0.018	−0.002
	Indirect effect (Collective investment)	−0.047	0.000	0.009	5.258	−0.065	−0.030
	Indirect effect (Self-organizing activities)	−0.010	0.025	0.005	2.247	−0.020	−0.003
	Total effect	−0.066					
	Variance accounted for (VAF) value	1.000					
Number of village cadres	Direct effect	0.146	0.000	0.028	5.234		
	Total effect	0.146					
Education level of village leaders	Indirect effect (Incentive activities)	0.022	0.009	0.008	2.601	0.005	0.039
	Indirect effect (Collective investment)	0.023	0.049	0.012	1.968	0.002	0.047
	Total effect	0.045					
	Variance accounted for (VAF) value	1.000					
Age of village leaders	Indirect effect (Incentive activities)	0.008	0.013	0.003	2.475	0.002	0.016
	Indirect effect (Self-organizing activities)	0.024	0.002	0.008	3.059	0.010	0.041
	Total effect	0.032					
	Variance accounted for (VAF) value	1.000					

capabilities, which has been proven effective in the self-governance of rural POSs (Liu et al., 2020; Ying and Zhou, 2007).

Non-government organizations have a direct positive association with POS quality. Additionally, they positively impact POS quality through the mediating effect of self-organizing activities. The VAF value indicates that indirect effects account for 40.8% of the total effect. This finding indicates that even if non-government organizations in villages are not specifically established to promote POS self-governance, they can still cultivate social capital and enhance villagers' collective action capabilities. The accumulation of social capital among villagers and the improvement in collective action skills facilitate the organization of self-organizing activities for POS management. The findings of this study are consistent with those of other related studies (Liang et al., 2018; Song et al., 2014; Wu, 2012). Furthermore, POS management regulations directly affect POS quality and also influence it indirectly through the mediating effect of self-organizing activities. The VAF value shows that indirect effects account for 4.6% of the total effect. Locally devised access and management rules are widely recognized by scholars in the field of commons management as crucial for the successful management of commons (Baland and Platteau, 1996; Ostrom, 1990; Wade, 1989). In this research context, POS management regulations have been shown to effectively improve POS management performance by clarifying the rights of relevant actors, preventing the misuse of POSs, and providing guidance for resolving management issues. Additionally, POS management regulations facilitate the organization of self-organizing activities by preventing some villagers from shirking their management responsibilities.

The presence of a monitoring system is directly associated with POS quality. In addition, it has an indirect effect on POS quality through the mediating effect of self-organizing activities. The VAF value indicates that the indirect effect accounts for 4.5% of the total effect. Ostrom (1990), Baland and Platteau (1996) argued that monitors are one of the conditions for facilitating successful commons management. Ling et al. (2018) found that monitors can oversee the use of POSs by actors, preventing misuse. Furthermore, monitors can ensure that actors participate in POS self-organizing activities and discourage them from shirking their management responsibilities.

With regard to actors, the number of relevant actors, income level of villagers, proportion of impoverished villagers, per capita homestead area, number of village cadres, education level of village leaders, and age of village leaders are significantly associated with POS quality. The number of relevant actors has a positive and indirect impact on the POS quality through incentive activities and self-organizing activities. Prior research has demonstrated that the management costs for self-governance increase with a larger number of actors (Olson, 1965). However, the study found that villages only possess the requisite conditions for POS self-governance when there are a sufficient number of residents within the village. Rural POSs are large commons, and a lack of individual actors increases the cost of each actor's participation in POS self-governance. Therefore, in villages with smaller populations, the frequency of villagers' participation in POS self-organizing activities tends to be lower. Villages with larger populations often indicate better local economic development environment, which allows villagers to avoid seeking livelihoods elsewhere. A supportive local economic development environment establishes the conditions necessary for the efficient operation of rural collective economic organizations. Consequently, these villages are able to provide higher bonuses to villagers. Part of these bonuses comes from villagers' collective actions, and higher bonuses can enhance villagers' confidence in successful self-governance (Tang, 2015). As a result, villagers are

more likely to actively participate in the construction and maintenance of rural POSs.

The income level of villagers shows a positive association with POS quality, though this association is mediated by the effects of incentive activities and self-organizing activities. As suggested by Agrawal's collective action theory, low levels of poverty among actors are a condition for facilitating successful commons management (Agrawal, 2001). Wealthier actors are better positioned to engage in POS self-organizing activities, as they have a greater capacity to bear the costs of rural POS self-governance. Additionally, in villages where villagers have higher incomes, this typically indicates a favorable local economic environment. A strong economic environment supports the operation and revenue generation of rural collective economic organizations, enabling village collectives to distribute higher bonuses to villagers. Villagers perceive that collective actions can bring personal benefits, which motivates them to actively engage in POS self-organizing activities. Conversely, a higher proportion of impoverished villagers negatively impacts POS quality, with this effect being fully mediated by collective investment. In villages with a high proportion of impoverished populations, the primary focus is not on maintaining rural POSs but on addressing the issues of poverty, especially in the context of China's comprehensive efforts to achieve moderate prosperity. Moreover, impoverished populations often lack the capacity to participate in POS self-governance (Agrawal, 2001).

The per capita homestead area is negatively associated with POS quality and mediated by the effects of incentive activities, collective investment, and self-organizing activities. Firstly, land resources in a village are limited. Allocating more residential land per capita results in reduced area of collective production land. Consequently, such villages often experience lower collective income and lack the capacity to provide villagers with higher bonuses or invest more funds in rural POSs. Furthermore, when villagers have larger private spaces, their reliance on POSs decreases, leading to lower enthusiasm for participating in POS self-organizing activities. This finding is consistent with research by Ling et al. (2019) and Madden (2010) on the impact of resource dependence on POS self-governance performance.

The number of village cadres forms a positive and direct association with POS quality. Villages with more cadre members tend to put in place a clearer division of responsibilities for collective action affairs (Zhang et al., 2012). This leads to more efficient self-governance of POS, ultimately enhancing its quality. Meanwhile, the education level of village leaders positively impacts POS quality, though it is mediated through the impact of incentive activities and collective investment. Well-educated village leaders have the ability to generate more collective income for the village (Kung et al., 2009), which allows them to provide higher bonuses to incentivize villagers' participation and cooperation in POS self-governance. Increased collective income also enables greater investment in POS self-governance, positively impacting the management of rural POSs. Moreover, the age of village leaders is positively correlated with POS quality through the full mediating effects of incentive activities and self-organizing activities. Older leaders generally have more management experience and a broader social network (Perry and Goldman, 2009). They can use their experience to secure more collective benefits for villagers and employ bonuses to promote their participation and cooperation in POS self-governance. Additionally, their extensive social networks often result in greater prestige and organizational capacity within the village, enhancing their ability to effectively organize villagers for POS self-

organizing activities. These results validate the importance of leadership in successful commons management as proposed by Baland and Platteau (1996).
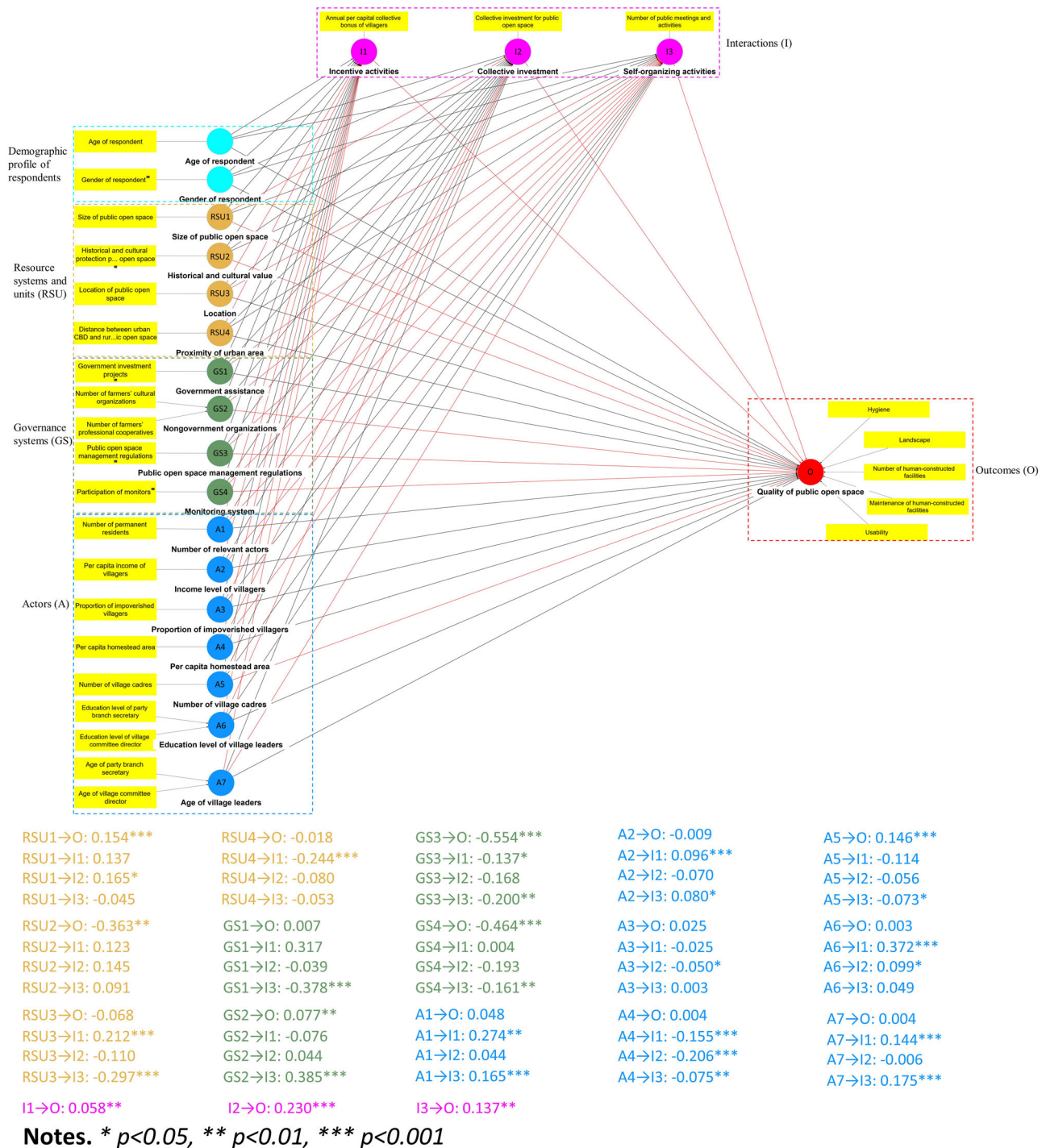
In summary, based on the descending total effect size, 15 variables were identified from the research results: Public open space management regulations, Monitoring system, Historical and cultural value, Size of Public open space, Number of village cadres, Nongovernment organizations, Per capita homestead area, Government assistance, Education level of village leaders, Number of relevant actors, Age of village leaders, Location, Income level of villagers, Proximity to urban area, and Proportion of impoverished villagers. The impact mechanisms of these institutional-social-ecological factors on the quality of POSs are shown in Fig. 6, with significant paths marked in red.

Conclusion

To bridge the research gap in the self-governance of rural POSs and address the challenges posed by the dual land ownership system on POS self-governance in rural China, this study employs the SES framework and PLS-SEM to identify the institutional-social-ecological factors influencing villagers' ability for POS self-governance, as well as the mechanisms by which these factors exert their influence. The study identified 15 institutional-social-ecological factors that influence villagers' self-perceived rural POS quality in Taigu, China. It delineated the pathways through which these factors influencing POS quality, both through the direct effects of institutional-social-ecological factors and the multiple mediating effects of three interaction variables. Specifically, historical and cultural value and the number of village cadres were found to directly affect POS quality. Factors such as location, proximity to an urban area, government assistance, number of relevant actors, income level of villagers, proportion of impoverished villagers, per capita homestead area, education level of village leaders, and age of village leaders indirectly affected POS quality through incentive activities, collective investment, and self-organizing activities. Moreover, size of public open space, nongovernment organizations, public open space management regulations, and monitoring systems directly impacted POS quality and exerted indirect effects on POS quality through the mediating effects of collective investment and self-organizing activities. Among the significant factors, institutional factors exert a stronger influence on POS quality and are more amenable to adjustments in the context of rural POS self-governance. Therefore, priority should be given to improving the institutions for rural POS self-governance. However, it is also essential to consider the local social and ecological context and the roles of various actors in the reform and implementation of self-governance institutions. This study is noteworthy as it provides novel, comprehensive insights into the self-governance of POSs in rural China.

Building on the research results and related discussion, five policy implications are proposed for the management of POSs in rural China. Firstly, villages located in mountainous and hilly areas should focus on the construction and maintenance of road and transportation infrastructure alongside the maintenance of POSs. Inconvenient transportation can negatively impact the usability of rural POSs and hinder their self-governance. Secondly, the government should actively assist in the development of those POSs with historical and cultural value, such as by improving their quality or enhancing the self-organizing management capacity of villagers. Moreover, these historical and cultural POS can attract external tourists, thereby increasing local visibility and driving economic prosperity. Thirdly, villages should implement public open space management regulations and monitoring systems. The development of these management

RSU1→O: 0.154***	RSU4→O: -0.018	GS3→O: -0.554***	A2→O: -0.009	A5→O: 0.146***
RSU1→I1: 0.137	RSU4→I1: -0.244***	GS3→I1: -0.137*	A2→I1: 0.096***	A5→I1: -0.114
RSU1→I2: 0.165*	RSU4→I2: -0.080	GS3→I2: -0.168	A2→I2: -0.070	A5→I2: -0.056
RSU1→I3: -0.045	RSU4→I3: -0.053	GS3→I3: -0.200**	A2→I3: 0.080*	A5→I3: -0.073*
RSU2→O: -0.363**	GS1→O: 0.007	GS4→O: -0.464***	A3→O: 0.025	A6→O: 0.003
RSU2→I1: 0.123	GS1→I1: 0.317	GS4→I1: 0.004	A3→I1: -0.025	A6→I1: 0.372***
RSU2→I2: 0.145	GS1→I2: -0.039	GS4→I2: -0.193	A3→I2: -0.050*	A6→I2: 0.099*
RSU2→I3: 0.091	GS1→I3: -0.378***	GS4→I3: -0.161**	A3→I3: 0.003	A6→I3: 0.049
RSU3→O: -0.068	GS2→O: 0.077**	A1→O: 0.048	A4→O: 0.004	A7→O: 0.004
RSU3→I1: 0.212***	GS2→I1: -0.076	A1→I1: 0.274**	A4→I1: -0.155***	A7→I1: 0.144***
RSU3→I2: -0.110	GS2→I2: 0.044	A1→I2: 0.044	A4→I2: -0.206***	A7→I2: -0.006
RSU3→I3: -0.297***	GS2→I3: 0.385***	A1→I3: 0.165***	A4→I3: -0.075**	A7→I3: 0.175***
I1→O: 0.058**	I2→O: 0.230***	I3→O: 0.137**		

Notes. *p<0.05, ** p<0.01, *** p<0.001*

Fig. 6 Impact mechanisms of institutional-social-ecological factors on the quality of POS. The circles in the Figure represent the latent variables (constructs). Light blue circles represent control variables, tan circles represent ecological variables, green circles represent institutional variables, dark blue circles represent social variables, pink circles represent interaction variables, and a red circle represents the dependent variable. The yellow boxes in the Figure represent observed variables (indicators). The arrows represent all potential influence paths, with red arrows representing significant influence paths. At the bottom of the Figure, the tan, green, and blue text respectively represent the coefficients of institutional-social-ecological variables on interaction variables and the dependent variable. Pink text represents the coefficients of interaction variables on the dependent variable. *** indicates a *p*-value less than 0.001, ** indicates a *p*-value less than 0.01, and * indicates a *p*-value less than 0.05. Paths without any '*' indicate non-significant influence.

systems can improve both the quality of POSs and villagers' collective action efficiency. Fourthly, the management experience and knowledge of village leaders and cadres play crucial roles in village management. In cases where village leaders lack experience, the local government can arrange for a first secretary to guide and support their work in the villages. Fifthly, local governments should encourage villages to establish non-governmental organizations that can cultivate social capital among villagers and improve their collective action ability for POS management.

In the context of China's dual land ownership system, the self-governance of POSs faces various challenges. Working from the perspective of the SES, this study identified the relevant SES factors that impact the villagers' self-perceived POS quality, with a particular focus on the multiple mediating effects of three interaction variables. This approach provides a robust method that yields more precise and detailed findings on rural POS management in China. In contrast, most quantitative studies utilizing the SES framework exclusively identify SES factors or the mediating effects of single interaction variables. Therefore, the findings of this study can assist local governments and village collectives in formulating more effective strategies for rural development and villagers' self-governance, ultimately contributing to the broader push for sustainable development in rural China. This study aligns with the values of Sustainable Development Goals 11.3 and 11.A, which promote the sustainable development of human settlements.

Although this study makes significant contributions, it has two limitations that could be addressed in future research. First, the variables and impact mechanisms identified in this study are only validated within the context of rural POS management in Taigu District. Given that China has 34 provincial-level administrative regions, with rural areas differing in ecological environment, economic development, and social culture, the findings of this study may not necessarily apply to rural POS self-governance in other regions of China. Additionally, while the study model demonstrates a high level of fit, it cannot guarantee that all potential influencing variables are included; the addition of further variables might yield different results. Future research could encompass a broader range of study areas and SES factors to provide more precise guidance for the development of POSs in rural regions.

Data availability

The data analyzed and reported in this study are available from the corresponding author on reasonable request.

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Author contributions
Xuerui Shi: conceptualization, methodology, investigation, data curation, formal analysis, visualization, writing-original draft. Gabriel Hoh Teck Ling: conceptualization, methodology, validation, supervision, write-review & editing.

Competing interests
The authors declare no competing interests.

Ethical approval
The study was conducted in accordance with the Declaration of Helsinki. Ethical approval (UTMREC-2024-78) was granted by the Research Ethics Committee (UTM REC) of Universiti Teknologi Malaysia, to which the authors are affiliated. The study did not involve the collection of data that could identify participants. All information was anonymized and did not contain any personally identifiable details.

Informed consent
Informed consent was obtained from all participants involved in this study. The informed consent form explained the purpose of the study, the research process, potential risks and benefits, data confidentiality measures, and the contact information of the researchers and the Research Ethics Committee (UTM REC) of Universiti Teknologi Malaysia. Participants were informed in the consent form that the survey was anonymous, their participation was entirely voluntary, and they had the right to withdraw from the survey at any time without providing any reason. Additionally, all information provided would be stored anonymously and securely.

Additional information

Supplementary information The online version contains supplementary material available at https://doi.org/10.1057/s41599-024-04049-3.

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