Testing the stakeholders' partnership in a tourism waste management network: An ERGM approach

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Research Article

Keywords: tourism waste management, stakeholder networks, ERGM, network configurations, Motuo County

Posted Date: April 1st, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1456848/v1

Abstract

The exponential random graph model (ERGM) is an effective approach for testing the dynamic and local processes of a network. This paper explores the structure of stakeholders' partnerships in a tourism waste management network using high-order dependency ERGMs based on relational data obtained from a field survey in Motuo County, China. The results reveal that (1) many edges have been formed in the observed network, which indicates the network is relatively tight; (2) the parameter of "Geometrically Weighted Edge Distribution" shows a high transitive effect of the network; (3) the structural effect is more significant than the attribute effect; and (4) the simulation model well fits the observed data, which reflects that the tourism waste network governance structure with close connection and collaborative division of labor has been formed in the case. These findings indicate that different groups of stakeholders have been extensively involved in tourism waste management in Motuo County. The edgewise shared partners formed by stakeholders of different groups increase the information transmission efficiency of the network. The results have implications for tourism waste management, specifically for promoting sustainability transitions via network governance.

1. Introduction

Tourism waste has attracted widespread attention from scenic area managers and researchers. Tourism waste management is essential for preventing environmental pollution in tourist destinations. Moreover, the tourism industry can be seen as a test site for waste management and recycling within the scope of its products and services (Tansel et al., 2019). Some tourist destinations have focused on creating "garbage-free scenic areas"; moreover, plans for waste classification and recycling management have been developed, and intelligent technologies for waste monitoring have been introduced.

An increasing number of studies have been conducted on waste management and recycling; however, we have limited insight into the effect of co-operative intervention on the tourism industry. Tourism waste management should focus on prevention and collaborative actions with residents and tourism stakeholders (Hayati et al., 2020). In other words, the management of tourism waste cannot be performed by a single interested party. Instead, this work involves various stakeholders with different responsibilities to formulate tourism waste management policies and coordinate, communicate, and allocate waste management tasks. Since different stakeholders have different interests, their participation in tourism waste management takes different forms, influencing the effectiveness of waste management. Therefore, researchers must conduct a systematic review of the network structure of tourism waste management to obtain a holistic understanding of the current situation and to diagnose problems.

Generally, the stakeholders of tourism destinations include local residents, tourists, managers of tourism enterprises, government departments, and other non-governmental organizations (Byrd, 2007). Evaluating the efficiency of waste management from the perspective of stakeholders involved in tourism waste is required due to the comprehensive nature of the tourism industry and tourism economic activities. In addition, network governance theory provides essential theoretical support for urban waste management analysis (e.g., Wang, 2015; Tan & Sun, 2019). Moreover, the exponential random graph model (ERGM), which has emerged in recent years, has attracted increasing interest from scholars because it considers the impact of multiple internal structural factors and external drivers on network generation (Xu et al., 2021). This model assumes that network relationships are generated by stochastic processes. Thus, the impact of various levels of network structural parameters on the network can be modeled (Wang et al., 2016; Shi & Li, 2019). However, there is a lack of studies on using ERGM for analyzing the governance of multiplex networks, especially in tourism waste management.

Therefore, this paper analyzes the partnership of stakeholders in tourism waste management using ERGM to propose suitable countermeasures that improve the efficiency of tourism waste management.

The rest of the paper is organized as follows. Section 2 briefly reviews the research on tourism waste management, ERGM, and network waste management. Section 3 describes the methodology and data, including the study site, the investigation, data source, hypotheses, and establishment of ERGMs. Section 4 describes the quantitative results and discusses the findings of this study. Section 5 concludes the paper and provides suggestions for achieving long-term sustainable tourism.

2. Literature Review

Scholars have explored the socio-economic and environmental impacts of tourism waste and the unsustainability of tourism areas resulting from tourism waste from different perspectives using interdisciplinary research. Previous studies on tourism waste in scenic areas have primarily focused on qualitative descriptive analyses of measures or plans for waste collection and treatment (e.g., Little, 2017; Abbas et al., 2021). Moreover, the majority of published studies on tourism waste have mainly considered the environmental impact of tourism waste (e.g., Barber et al., 2014; Murava & Korobeinykova, 2016; Abdulredha et al., 2017; Greco et al., 2018; Kularatne et al., 2019; Paiano et al., 2020; Diaz-Farina et al., 2020) and used summary statements to describe the experiences and methods of tourism waste management (Liu et al., 2019). Furthermore, existing studies have focused primarily on a single subject (e.g., Giurea et al., 2018; Hu et al., 2018; Wijanarko., 2020). Nevertheless, few studies considered tourism waste management in scenic areas from different stakeholders' perspectives (e.g., del Mar Alonso-Almeida, 2012; Kariminia et al., 2012; Ezeah et al., 2015; Phu et al., 2018).

The topic of stakeholders has received some attention in municipal waste management (e.g., Yukalang et al., 2018; McNicholas & Cotton, 2019; Tonini et al., 2020). However, most published papers concentrated on initiatives, planning, and design (e.g., Fuldauer et al., 2019; Ikhwan et al., 2019). To date, several quantitative methods have been used in empirical studies, such as social network analysis (SNA) and ERGM (e.g., Dietrich et al., 2018; Schulz et al., 2018; Zhang et al., 2021). However, ERGM is more advantageous for evaluating complex network structures formed by multiple Stakeholders.

ERGM emphasizes the self-organization of relationships and the connectedness of individuals, i.e., the probability of a relationship depends on the existence of other relationships. Typically, researchers apply social theory to develop hypotheses utilizing primarily relational, quantitative representations and use

ERGM as an analytical framework for the subsequent analyses using parameter estimation and hypothesis testing (Wang et al., 2016). Moreover, the ERGM can infer the generative mechanisms of the network by examining structures and processes rather than merely the integral network structure (Sharifnia & Saghaei, 2020). Therefore, the ERGM enables the integration of micro and macro scales using simulations. Therefore, these advantages of the ERGM for analyzing complex networks make it highly suitable for studying the partnerships of stakeholders in tourism waste management.

The ERGM was initially applied in environmental public management and waste management. For example, Tan and Sun (2019) analyzed the network structure of urban household waste separation and recycling using ERGMs and proposed resolving the stakeholder conflicts according to their results. Ghinoi et al. (2020) applied the ERGM to evaluate the drivers of stakeholders' interactions in a food waste management system. Nevertheless, the number of published papers is extremely small, so it can be asserted that the application of ERGM in the field of waste management research is still in the exploratory stage.

Tourism waste management is still government-led in China, especially in the less economically developed regions of western China. This management type may lead to inefficient waste management. Unlike the traditional authoritative and hierarchical model of policy making and management, waste governance emphasizes a collaborative approach to the management of public affairs by all stakeholders. In a highly efficient waste governance model, stakeholders share the benefits, resources, and power, achieving a win-win situation through communication, negotiation, sharing, and cooperation. Empirical work as part of network studies has shown how specific endogenous network characteristics and exogenous organizational attributes drive the networking behavior of stakeholders (Ghinoi et al., 2020). However, to the best of our knowledge, this issue has not been explored in applied studies focused on qualifying the stakeholder's partnership structure in a tourism waste management network based on ERGM.

Therefore, inspired by the ERGM, this paper aims to fill this gap by investigating the configurations to test the characteristics of the stakeholders' partnership in the tourism waste management network and identify the factors influencing the network structure. Motuo County, China, has ended the ticket-free mechanism in 2020 and is exploring how to use part of the ticket income for waste disposal in scenic spots. Our focus on Motuo County as a case study is also motivated by its representativeness of Yarlung Zangbo National Park.

3. Methodology

3.1 Study area and case study overview

Motuo County (27° 33' N–29° 55' N, 93° 45' E–96° 05' E) is located in southeastern Tibet, China, at the lower reaches of the Yarlung Tsangpo River and covers an area of 31394.67 km^2. The average elevation is 1200 m, the lowest altitude in Tibet, and the region receives abundant rainfall (Tang, 2020). Motuo is located at the eastern end of the Himalayas, where extensive movement of the earth's crust has created a topography dominated by high mountain valleys, resulting in world-famous ecotourism resources. This area has attracted a wide range of tourists. As a result, the tour route from Milin to Motuo is currently one of the more popular routes for tourist groups (Zhu et al., 2021).

In 2000, the State Council of China approved the establishment of the Yarlung Zangbo Grand Canyon Nature Reserve with Motuo as the core area. The Yarlung Zangbo Grand Canyon National Park was established in 2010 in the Tibet Autonomous Region of China. The area of Motuo County is about two-thirds of the total area of the Yarlung Zangbo Grand Canyon National Nature Reserve, representing an important part of the Yarlung Zangbo Grand Canyon National Park. In recent years, the problem of tourism waste in the southeast Tibetan ecotourism area has attracted widespread attention from people from all walks of life. Therefore, it is representative to study tourism waste management in the Motuo region. The location of the study area and representative landscapes are shown in Fig. 1.

3.2 Stakeholders involved in tourism waste management

The stakeholders' network analyzed in this paper consists of stakeholders involved in tourism waste management. The tourism stakeholders are typically divided into four main groups: government, community, enterprise, and advocacy groups (e.g., Byrd, 2007; Saito & Ruhanen, 2017). Similarly, the main stakeholders involved in waste management are classified as government, enterprise, community, and advocacy groups (e.g., Joseph, 2006; Caniato et al., 2014; Kim & Nguyen, 2020). Based on the information obtained from the field surveym the main stakeholders involved in tourism waste management are listed in Table 1.

Table 1
Major stakeholders and their classification.

Major type	Stakeholder	No.
Local government departments	Cultural and Tourism Bureau	A
	Urban Management Bureau	B
	Housing and Construction Bureau	C
	Environmental Protection Bureau	D
	Damu Township	E
	Motuo Township	F
	Dexing Township	G
	Bengbei Township	H
Enterprises	Tourism development & management companies	I
	Restaurants/accommodation	J
Local communities	Individuals not involved in tourism development	K
	Individuals involved in tourism development	L
advocacy Groups	NGO environmental organizations	M
	Research institutions or experts	N
	Media	O
	Tourists	P

3.3 Survey and data

The data for this study were obtained from a combination of questionnaires and interviews. The questionnaire was designed based on the authors' previous study and field survey in the study area and drawing on ideas from the published literature on the design of network analysis (e.g., Dredge, 2006; Baggio et al., 2010; Van der Zee & Vanneste, 2015; Rao et al., 2016; Shi & Li, 2019; Tan & Sun, 2019; Zhang, 2020). The questionnaire consisted of two aspects. The first part was a survey of the respondents' familiarity with and participation in tourism waste management. Five questions (see Table 2) were used to assess the level of knowledge and contribution of the respondents to tourism waste management. A total of 42 respondents were interviewed; their information is presented in Appendix A (see Table A1). These stakeholders included the main stakeholders in the 4 main categories and 16 sub-categories (No. A - P). We assigned weights to the respondents based on their responses to these five questions. Table A2 in Appendix A lists the details of the survey content and findings.

Table 2
Stakeholder weight assignment.

No.	Questions	Assignment criteria							
▯	Have you made suggestions for tourism waste management?	Several times	2	Once	1	None	0		
▯	Have you participated in the policy formulation of tourism waste management?	Yes	1	No	0				
▯	Do you know the stakeholders of tourism waste management?	Very well	3	Relatively well	2	Generally	1	Not well	0
▯	Have you ever communicated with other stakeholders?	Regular	2	Occasional	1	None	0		
▯	Have you participated in tourism waste management?	Lead	2	Participate in	1	No	0		

The aim of the second part of the questionnaire was to investigate the existence of a relationship between two stakeholders in tourism waste management. The values “0” and “1” represent no association/no coordination and association/coordination, respectively. The raw data were weighted and averaged based on the results of the first part of the weight assignment to the respondents.

Then, the weighted relational data matrix was binarized using the average value (0.00772) as the cut-off value (or the threshold). The relational data reflecting the stakeholders’ cooperation or association in the existing local tourism waste management network is shown in Table 3.

Table 3
Relationship matrix of stakeholders' network

Stakeholders	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
A	—	1	1	1	1	1	1	1	1	1	0	1	0	0	0	1
B	1	—	1	1	0	1	0	0	0	0	0	0	0	0	0	1
C	1	1	—	0	0	0	0	0	1	0	1	0	1	0	0	0
D	1	1	1	—	1	1	0	0	1	1	0	0	1	1	0	0
E	1	1	1	1	—	0	0	0	1	1	1	1	0	1	1	0
F	0	1	1	1	0	—	0	0	0	0	0	1	0	0	0	1
G	0	0	0	0	0	0	—	0	0	0	0	0	0	0	0	1
H	0	0	1	1	0	0	0	—	0	0	0	0	1	0	0	0
I	1	0	1	1	1	0	0	0	—	1	0	0	0	1	1	0
J	0	0	1	1	1	0	0	0	1	—	1	0	1	1	1	0
K	0	0	0	0	1	0	0	0	1	1	—	1	0	0	1	0
L	0	0	0	0	1	0	0	0	1	0	1	—	0	0	1	0
M	0	0	1	1	0	0	0	1	0	1	0	0	—	1	0	0
N	0	0	0	0	1	0	0	0	1	1	0	0	0	—	1	0
O	0	0	0	0	1	0	0	0	0	0	0	0	0	0	—	0
P	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	—

3.4 Hypotheses

Our initial observations of the stakeholders were developed based on fieldwork and the questionnaire collation. The relational data in Table 3 indicate that a network governance model for tourism waste management has already been developed among different groups of stakeholders.

Realizing the fact that an information exchange occurs between two stakeholders in combination with resource sharing with third parties in the observed network, we propose the following three hypotheses reflecting the partnership among stakeholders with different structures in tourism waste management.

H1 The clusters in our network consist of several triads and edges with multiple shared partners.

H2 The clusters in our observed network consist of several dyads and edges with multiple shared partners.

H3 The identity effect between dyads, i.e., two actors, results in multiplex ties between different groups.

3.5 Method

Unlike most linear and nonlinear analysis methods, the ERGM is theory-driven and emphasizes the structure of the network (Desmarais & Cranmer, 2012). A critical theoretical assumption of the ERGM is that networks are self-organizing, i.e., local relationships are interdependent. These local relationship patterns are considered as the network configurations (Wang et al., 2013; Stephens et al., 2016). Researchers use multiple network configurations to predict the emergence of networks. Accordingly, the model parameters describe the significance of the network configurations in the observed relationships. Therefore, the ERGM models a given network based on the local relationship structures, such as dyads and triads (Ulibarri & Scott, 2017; Felmlee et al., 2021). Moreover, these network configurations are considered to arise from local social processes in which network actors form links corresponding to their living environment.

The following four model types represent four key milestones in the development of the ERGM: the simple random graph model, dyadic independence model, dyadic dependence model, and high-order dependence model (Snijders et al., 2006; Robins et al., 2007; Stephens et al., 2016). The expressions and explanations of these four models are listed in Table A3, Appendix A.

Erdös & Rényi (1959) proposed a statistical model for obtaining simple random graph features based on Bernoulli's assumption that the "relationships between network members are generated randomly and independently of the relationships between other members". The model compares relational network data with an assumed zero distribution with only one network configuration, the edge. Therefore, the model cannot provide useful information on the network structure. On this basis, the p1 model that reveals the model's out-links, in-links, and mutual relationships was proposed (Holland & Leinhardt, 1981). Subsequently, this model evolved into another expression that could integrate covariates; this model is known as the p* model (Wasserman & Patrision, 1996).

However, the p* model has certain limitations, such as an inability to fully capture the structural characteristics of the observed network. Thus, researchers (e.g., Hunter, 2007) improved curved exponential family (CEF) models and modified the p* model by introducing statistical terms, such as the geometrically weighted degree distribution (GWD), geometrically weighted edgewise distribution (GWESP), and geometrically weighted dyadwise shared partners (GWDSP). Correspondingly, the Markov Chain Monte Carlo (MCMC) estimation method was proposed. It has a realization-dependent conditional assumption and relatively high simulation accuracy (Geyer & Thompson, 1992). Typically, a parameter estimate of more than twice the standard error indicates significance (Snijders et al., 2006; Robins et al., 2007).

Based on the above comparison of the analytical models generated by ERGM theory at different stages, the high-order dependence models were applied to our study. Structural and attribute effects are incorporated into the modeling process in this paper to describe the intra- and cross-organizational relationships in the network of tourism waste governance. Specifically, the GWESP and GWDSP are used to determine pure structural effects, including the information transmission and intermediary effect of the network, respectively. The established models are defined in Equations (1)−(2), and the information related to the model configurations is provided in Table 4.

$$P_r(\mathrm{Y} = y) = \frac{1}{c}\exp\{\theta L(y) + \eta Esp(y) + \zeta M(y)\}$$

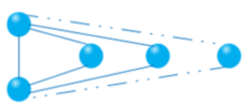
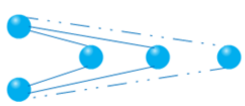
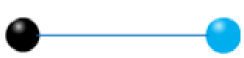
1

$$P_r(Y = y) = \frac{1}{c}\exp\{\theta L(y) + \delta Dsp(y) + \zeta M(y)\}$$

2

where c is a constant; θ, η, and δ are the parameters of the network's edge, GWESP, and GWDSP, respectively; *M(y)* is used to estimate the impact of the identity attributes of different groups of stakeholders on the network structure, and ζ is its parameter.

Table 4
Parameters and estimators of the ERGM used in this paper

Configuration/ estimator	Visualization	Parameter	Hypothesis	Effect types
Edge / *L(y)*		θ	——	Structural effects: network density (constant term, generally unexplained)
Geometrically Weighted Edgewise Shared Partners (GWESP) / *Esp(y)*		η	**H1**	Structural effects: the transmissive character of the network.
Geometrically Weighted Dyadwise Shared Partners (GWDSP) / *Dsp(y)*		δ	**H2**	Structural effects: the extent to which relationships in a network are controlled or constrained by intermediaries.
Main effect (identity) / *M(y)*		ζ	**H3**	Attribute effects: the influence of the identity attributes of the network members.

4. Results And Discussion

4.1 Results

4.1.1 Model estimation and fit

The R Statnet toolkit was used to estimate the parameters and determine of the goodness of fit (GOF) of the proposed model. In addition, the step-by-step model (including Model 01 - Model 05) based on R Statnet is shown in Appendix A (Table A4). Table 5 report the results of the ERGMs, including the high-order dependence models defined in Equations (1)-(2).

Based on the information provided by Goodreau et al. (2008) and Zhang (2020) for determining the value of the decay parameter α, α = 0.1 was used as the initial condition. The value of α was gradually increased until the log-likelihood estimate of the model no longer increased. In this paper, α was 0.25. The significant parameter estimates of Model 04 (in Table A4) have more than two times of its standard errors, and the Z-values and P-values are significant. Therefore, it can be tentatively concluded that Model 04 has a better fit than Model 05 (in Table A4) for the observed relational data.

Furthermore, Model 04 has the lowest values of the Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), and log-likelihood. The results of the last iteration the MCMC model are shown in Fig. 2. The left side of Fig. 2 shows the statistical terms for each configuration, and the right side of Fig. 2 shows the histograms of the densities of the configurations. The statistical time series of Model 04 exhibits random fluctuations around 0, indicating that Model 04 has high stability and does not exhibit approximate degradation.

Table 5
Estimated values of coefficients and statistical test results for models 01–05

No.	Configurations	Estimated value (standard error)	Z-value	P-value	AIC	BIC	Log-Likelihood
Model 01	edges	-0.5645 (0.1343)	-4.204	< 1e-04 ***	316.32	319.81	-157.16
Model 02	edges	-2.6529 (0.6683)	-3.97	< 1e-04 ***			
	gwesp.fixed.0.25	1.2017 (0.4172)	2.881	0.00397 **	307.6	314.56	-151.8
Model 03	nodematch.group	-0.1112 (0.2361)	0.2361	-0.471	334.49	337.97	-166.24
Model 04	edges	-2.7794 (0.6554)	-4.241	< 1e-04 ***			
	gwesp.fixed.0.25	1.1759 (0.4116)	2.857	0.00428 **			
	nodematch.group	0.5502 (0.2588)	2.126	0.03350 *	305.67	316.11	-149.84
Model 05	edges	-0.29623 (0.2851)	-1.039	0.2989			
	gwdsp.fixed.0.25	-0.18521 (0.0916)	-2.022	0.0432 *			
	nodematch.group	0.67347 (0.2972)	2.266	0.0235 *	312.13	322.58	-153.07
Denote: *** P < 0.001; ** P < 0.01; * P < 0.05.							

Further, the box plots (Fig. 3) demonstrate the soundness of the above analysis. The black lines of the coefficients of the three configurations, i.e., the edges, GWESP, and identity, are close to the medians, indicating a good fit of the model. Specifically, the black line on the GWESP's plot is close to the median, confirming a good model fit of Model 04.

The graph of Model 04 obtained from the simulation (Fig. 4) was used to evaluate the GOF and the model performance. The results demonstrate that Model 04 has high stability and high GOF for all configurations. In addition, means from simulation of edges, GWESP, and identity are 87.91, 98.29 and 34.11, respectively. They are very close to the observed mean values of these three configurations, which are 87, 96.9 and 34, respectively. Therefore, Model 04 is suitable for practical applications.

4.1.2 Structural effects

The significance levels of the edge and GWESP configurations are high in Model 04, indicating high density and information transmission in the network. Therefore, hypothesis H1 can be confirmed. The practical implications of the results of the empirical analysis are as follows. First, all stakeholders have been involved in tourism waste management in the study area. Moreover, communication among different groups participating in tourism waste management occurs frequently. Second, according to the GWESP configuration, the level of information transmission of the network is significant, indicating efficient information exchange between different actors in the stakeholders' network.

The parameters of the GWDSP configuration in Model 05 show a significant positive effect, i.e., an intermediary effect similar to a structural hole occurs in the stakeholders' network of tourism waste management. However, the overall fit of Model 05 is poor. Hence, it is possible to conclude that waste management is not controlled or constrained by a few intermediaries. This conclusion further confirms the results presented in the previous paragraph. Therefore, we cannot confirm hypothesis H2.

4.1.3 Attribute effect of the actors: the identity effect

The attribute effect, i.e., the identity effect, can be used to estimate the influence of stakeholders with different identities on the formation of network relationships. In Model 04, the attribute effect of the nodes is significant. Therefore, we can confirm hypothesis H3. Hence, it can be concluded that the influence of the stakeholders from different sectors is evident in the tourism waste management network.

However, it is important to note that the structural effect is greater than the attribute effect in this network. In other words, the implementation of tourism waste management does not primarily depend on the identity of the stakeholders. That is, the information transmission driven by administrative power is not apparent. In contrast, the current case network structure is relatively flat. Task allocation and coordination among stakeholders engaged in different jobs are highly shared in the network.

4.2 Discussion

In summary, relatively frequent and efficient communication and cooperation occur between different departments in tourism waste management in Motuo County. The main reason is that our case has begun to explore diversified and market-based eco-compensation mechanisms since the end of the admission-free mechanism in 2020 and has placed waste management at the forefront of environmental protection and pollution control. For example, the Motuo County Environmental Protection Bureau, the Housing and Construction Bureau, the Urban Management Bureau, and the Culture and Tourism Bureau have widely publicized the ecological compensation policy to local residents and foreign businesspeople and have made efforts to conduct practical measurements.

Moreover, Motuo County has begun to admission revenue to alleviate the financial burden of environmental management and has taken advantage of the press to disseminate practices worthy of emulation to various groups of stakeholders, encouraging and guiding them to participate in waste management. In terms of infrastructure, the county's waste disposal site was completed, ending the practice of using an open landfill.

Therefore, Motuo County should take advantage of the current situation and, more importantly, focus on information transmission in the network, emphasizing the role of residents in tourism waste management, particularly families and residents involved in tourism development. This approach will increase the number of channels to inform the public, creating flat channels of information dissemination and reducing the number of channels through which policies or tasks are passed on by government departments. These measures will increase the efficiency of waste management.

Finally, our results also suggest that it is crucial to policy implementation to enhance the influence of the government in the network. Moreover, it is necessary for the government to continue to advocate for all interest groups to treat tourism waste as a common mission and responsibility. The identity role of NGOs, scientific institutions, and tourists as information disseminators, collectors, and feedback providers should be valued, and their position in the network of tourism waste management should be enhanced.

5. Conclusions

Tourism waste in scenic areas has long plagued tourism managers and has deteriorated the tourism image of destinations. Southeastern Tibet, China, is no exception. Tourism waste is the main constraint to developing ecotourism in the Motuo region of the Yarlung Zangbo National Park. The ERGM model was used to investigate the collaboration and participation of various stakeholders in tourism waste management since it is well suited for this task.

High-order dependence models were used to analyze the network of waste management to ensure the objectivity of the results, which is a highlight and novelty of this paper. Unlike dyadic independence and dependence models, high-order dependence models that use decay coefficients do not exaggerate the influence of k- star and triads. To the best of our knowledge, this paper is the first attempt to establish a high-order dependence model for analyzing network relations in tourism waste management.

A questionnaire survey was conducted of participants in tourism waste management. Two structural effects and one attribute effect were used in the model to analyze the survey data. The results confirmed the validity of the theoretical model (Model 04) with the GWESP and identity configurations, indicating that triads was crucial for coordinating and communicating with multiple stakeholders. In addition, the stakeholders' identity had a significant impact on the partnership structure.

This paper highlighted the advantages of the ERGM, i.e., its ability to analyze the structure of a network and clarify the formation of the partnership network, the characteristics of the networks' configuration, and the nodes. Moreover, the ERGM can simultaneously analyze the endogenous and structural effects of the networks. In particular, the stakeholders' partnerships can be visualized by modeling high-order dependency models based on relational data obtained from a field survey.

In future studies of tourism waste management, researchers should continue to explore multifaceted and collaborative management models. Motuo County should not only improve the endogenous development momentum of waste management but also use technology to reduce and recycle tourism waste, preventing the deterioration of the tourism image and promoting sustainable tourism development.

It should be noted that this paper has two limitations. First, we focused on only one network. The tourism waste management network should be refined into several networks from different aspects, which would facilitate the analysis of exogenous variables between different networks, providing a more detailed understanding of the problems in tourism waste management. Moreover, the identity effect was considered a main effect, whereas other attribute effects were not addressed. In addition, we did not conduct a cross-sectional comparative analysis of the attribute effect, which was related to the other limitations.

Declarations

Credit Author Statement Xiu-mei Xu: conceptualization, formal analysis, writing - original draft; Yicheng Huang: data preprocessing, writing - review & editing; Qun Lai: investigation, data preprocessing, writing - review & editing; Chao Feng: methodology, software, supervision, writing - review & editing

Funding Not applicable

Availability of data and materials: The datasets used in this study are available from the corresponding author on reasonable request.

Ethical Approval Not applicable.

Consent to Participate We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

Consent to Publish The authors agree to publish this article in the Environmental Science and Pollution Research.

Competing Interests: The authors declare no competing interests.

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Figures

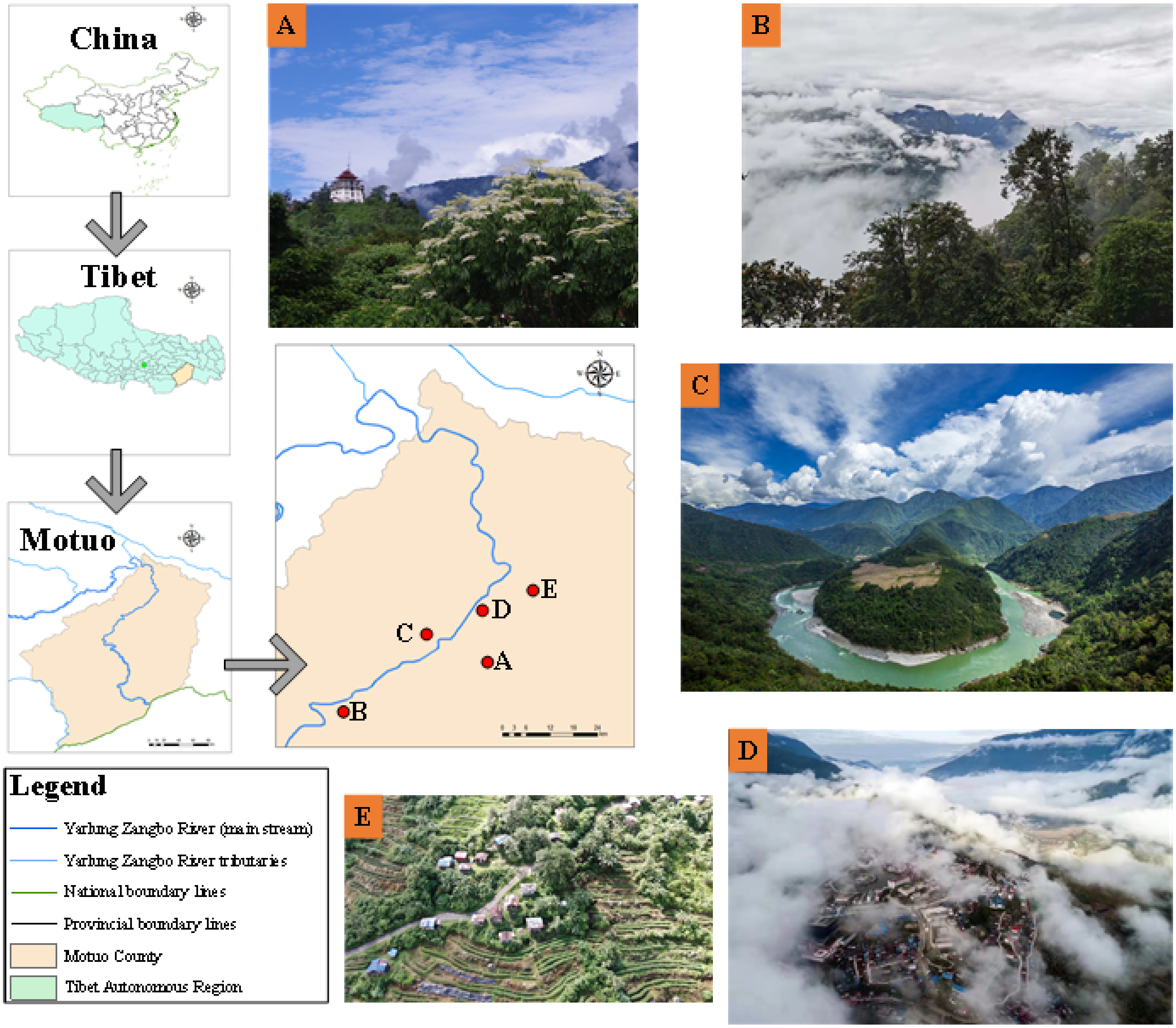

Figure 1

Location of the Motuo County and photos of representative ecotourism areas

Note: Landscape photos are courtesy of Qun Lai; A–E represent Renqin Temple, Bengbei Town Scenic Spot, Guoguotang Big Turn, Motuo Town, and the Green’s Vegetable Garden, respectively.

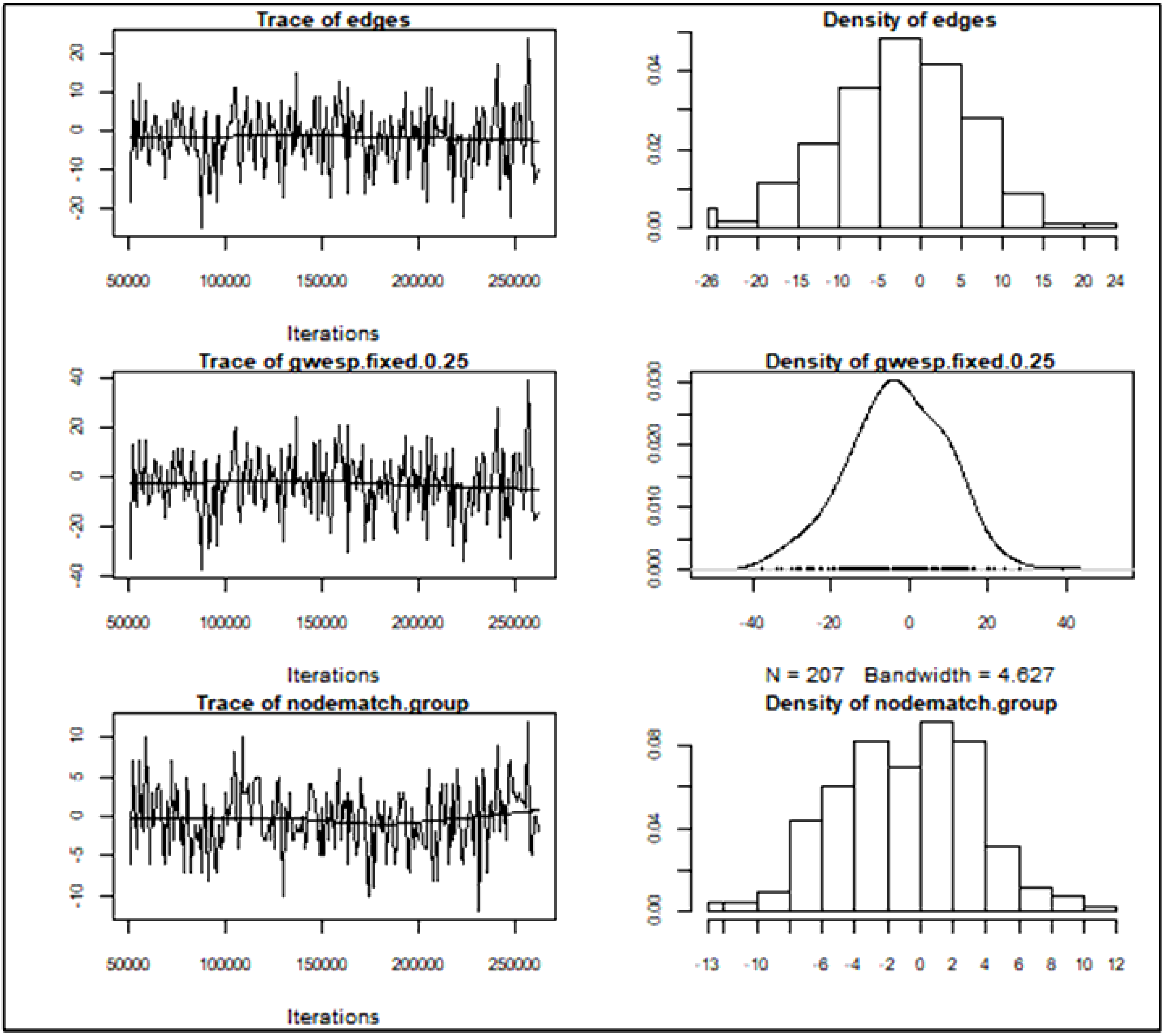

Figure 2

The histograms of the MCMC samples of Model 04.

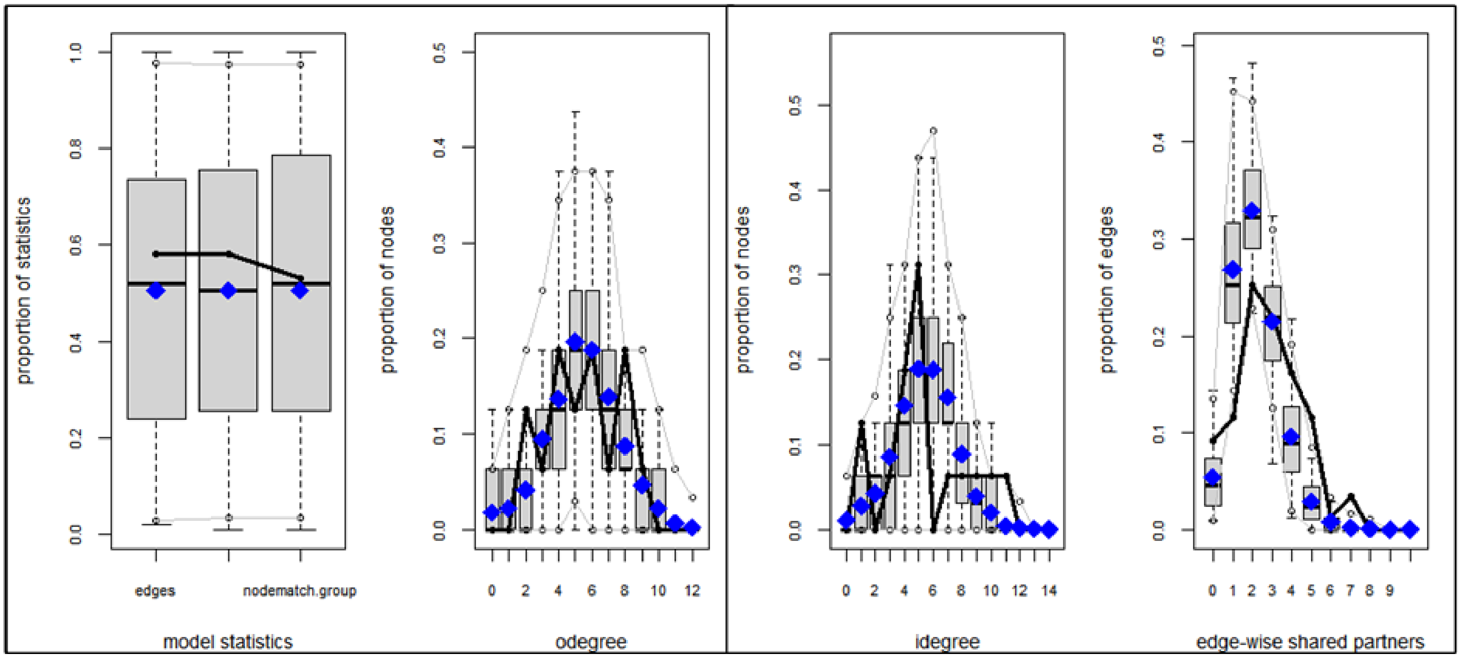

Figure 3

Box plot of the configurations' parameters for Model 04.

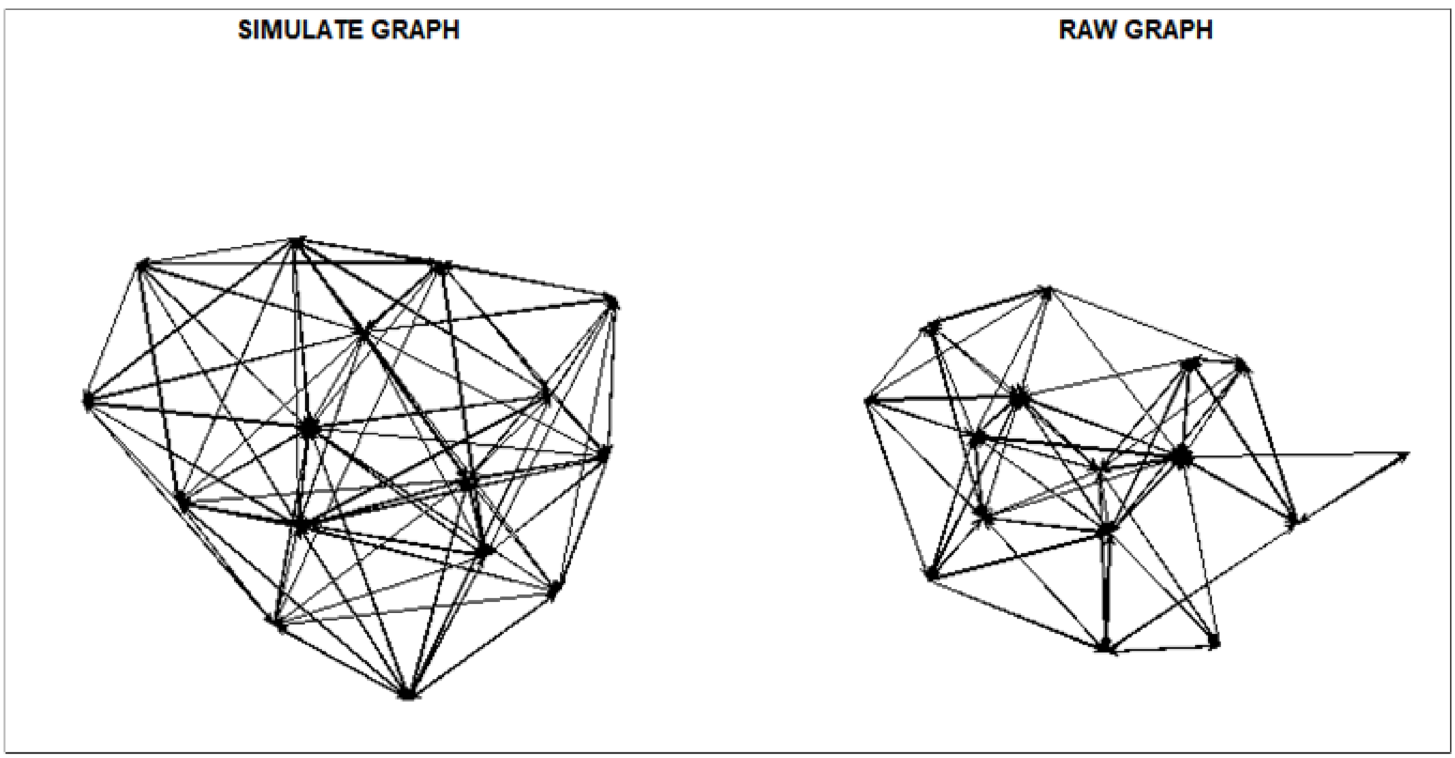

Figure 4

The simulated graph and raw graph of Model 04.

Supplementary Files

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- Appendix.docx