Study on the Selection of International Wildlife Trade Partners Based on TOPSIS and Spatial Statistics

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Abstract. Illegal wildlife trade has become one of the primary threats to global biodiversity conservation, as the exploitation of natural resources not only disrupts ecological balance but also profoundly impacts the economic and social structures of multiple countries. To effectively curb this cross-border issue, countries have intensified international collaboration and protective measures. In this context, this study combines the TOPSIS evaluation model and spatial statistical analysis to scientifically assess the collaboration potential of international organizations and examine the spatial patterns of global illegal wildlife trade. Using the TOPSIS model, the World Wide Fund for Nature (WWF) emerged as the ideal partner, with its expertise and resource support significantly enhancing project efficacy. Additionally, Moran's I algorithm was applied to analyze trade activities across 20 countries, revealing geographical clustering and interdependence between neighboring countries in illegal trade. This research offers a data-driven framework for collaboration and precise spatial intervention strategies to address the global wildlife trade crisis.

Keywords: Illegal Wildlife Trade, International Collaboration, Topsis Model, Spatial Statistical Analysis.

1. Introduction

Illegal wildlife trade has become one of the primary threats to global biodiversity conservation[1, 2]. The exploitation of natural resources not only disrupts ecological balance but also exerts profound impacts on the economic and social structures of multiple countries[3]. In recent years, countries worldwide have increased their focus on addressing this issue, aiming to curb these illicit activities through collaboration, legal enforcement, and protective measures[4]. However, given the complexity and cross-border nature of illegal wildlife trade networks, efforts by individual nations alone often fall short of effectively curbing this phenomenon.

In this context, international collaboration becomes crucial, and selecting the right partners among numerous international organizations is key to ensuring successful cooperation. By combining the TOPSIS evaluation model[5] with spatial statistical analysis, this study aims to scientifically assess the suitability of various international organizations and provide an in-depth examination of the global spatial patterns of illegal wildlife trade. The application of the TOPSIS model provides a structured framework for comprehensive evaluation, while spatial statistics reveal the geographical clustering and diffusion characteristics of trade activities, offering a scientific basis for targeted intervention strategies.

This research not only fills a gap in the study of partner selection and spatial dependencies in illegal wildlife trade but also provides data-driven decision-making insights for the international community. By joining forces with suitable international organizations, optimizing resource allocation, and implementing targeted interventions in specific regions, this study aspires to contribute to global efforts in combating illegal wildlife trade.

2. Selection of Partner Organizations Based on TOPSIS Evaluation

Given the critical challenge posed by illegal wildlife trade globally, a collaborative approach involving the United Nations and other international organizations is essential. This study examines the implementation of a project framework for identifying a suitable partner among the International

Union for Conservation of Nature (IUCN)[6], the World Wide Fund for Nature (WWF)[7], the World Trade Organization (WTO)[8], the United Nations Environment Programme (UNEP)[9], and Interpol[10]. Each organization is evaluated across eight key indicators: policy development, legal enforcement, international cooperation, access to funding, technical support, specialized knowledge and networking, continuity and commitment, and openness.

The comprehensive evaluation model provides a structured approach to assess multiple factors or indicators, enabling the assignment of weighted values to each factor and supporting an integrated assessment based on their collective impact on the target outcomes. Widely applied in decision-making, resource allocation, and project management, this model facilitates a deeper understanding of interrelations among factors, promoting a more scientific and objective basis for decision-making. As shown in Table 1.

Table 1: Scoring rules of the target customers

	IUCN	WTO	WWF	UNEP	Interpol
Policy development	5	5	8	10	6
Legal enforcement	6	6	7	10	8
International cooperation	9	9	8	9	7
Access to funds	6	6	9	9	8
Technical Support	8	7	6	7	8
specialized knowledge	9	10	7	8	9
Continuity and commitment	8	7	8	8	9
openness	9	9	6	8	7

Suppose the eight scoring rules are recorded as$x_1, x_2 \ldots\ldots x_8$ and so on.

Preprocessing of the data metrics was first performed by vector normalization:

$$x_{ij}^* = x_{ij} \Big/ \sqrt{\sum_{i=1}^{n} x_{ij}^2} \quad (1 \le i \le n, 1 \le j \le m) \tag{1}$$

The evaluation matrix can be obtained:

$$R = \begin{bmatrix} 0.2311 & 0.2338 & 0.3800 & 0.4072 & 0.2716 \\ 0.2773 & 0.2806 & 0.3325 & 0.4072 & 0.3621 \\ 0.4160 & 0.4210 & 0.3800 & 0.3665 & 0.3168 \\ 0.2773 & 0.2806 & 0.4276 & 0.3665 & 0.3621 \\ 0.3698 & 0.3274 & 0.2850 & 0.2850 & 0.3621 \\ 0.4160 & 0.4677 & 0.3325 & 0.3257 & 0.4074 \\ 0.3698 & 0.3274 & 0.3800 & 0.3257 & 0.4074 \\ 0.4160 & 0.4210 & 0.2850 & 0.3257 & 0.3168 \end{bmatrix} \tag{2}$$

Then the evaluation index is, using the entropy method:

Calculate the characteristic proportion of the i-term evaluation object under the j-term index:

$$p = x_{ij} \Big/ \sum_{i=1}^{n} x_{ij} \left(i = 1, 2, \cdots, n;\ j = 1, 2, \cdots m\right) \tag{3}$$

The entropy of the j-term index is calculated as:

$$e_j = -k\sum_{i=1}^{n} p_{ij}\ln\left(p_{ij}\right)\left(j = 1,2,\cdots,m\right) \tag{4}$$

The difference coefficient of the j-term the index is calculated as:

$$g_j = 1 - e_j\left(j = 1,2,\cdots,m\right) \tag{5}$$

The weight coefficient of the j-term the index is determined as:

$$w_j = g_j \Big/ \sum_{k=1}^{m} g_k \left(j = 1,2,\cdots,m\right) \tag{6}$$

The weight of the decision scheme can be found comprehensively.

$$w = \left(0.4375, 0.3750, 0.3750, 0.3750, 0.3125, 0.4375, 0.2500, 0.4375\right) \tag{7}$$

Finally, the TOPSIS algorithm is comprehensively evaluated.

① The positive and negative ideal solutions are determined, respectively:

$$S^* = \left(0.4160, 0.4678, 0.4276, 0.4072, 0.4074\right) \tag{8}$$

$$S^- = \left(0.2311, 0.2339, 0.2851, 0.2851, 0.2716\right) \tag{9}$$

② by computational formula:

$$d_i^* = \sqrt{\sum_{j=1}^{m}\left(z_{ij} - z_j^*\right)^2} \quad d_i^- = \sqrt{\sum_{j=1}^{m}\left(z_{ij} - z_j^-\right)^2} \quad \left(i = 1,2,3,4\right) \tag{10}$$

The distances of the evaluated objects to the positive and negative ideal solutions were calculated respectively:

$$d^* = \left(0.1548, 0.1723, 0.2948, 0.1987, 0.1902\right) \tag{11}$$

$$d^- = \left(0.3310, 0.2556, 0.1196, 0.2407, 0.2431\right) \tag{12}$$

③ by formula:

$$C_i^+ = \frac{d_i^-}{d_i^- + d_i^*} \quad \left(i = 1,2,\cdots,4\right) \tag{13}$$

The relative proximity of each evaluation object to the ideal solution is calculated as:

$$C = \left(0.3186, 0.4028, 0.7114, 0.4521, 0.4389\right) \tag{14}$$

According to the data analysis using the TOPSIS algorithm, the World Wide Fund for Nature (WWF) achieved the highest relative proximity score, making it an ideal partner in this study. WWF's primary work includes establishing and managing nature reserves, conserving wildlife habitats, promoting research on species and their ecosystems, implementing nature conservation education programs, developing conservation organizations and institutions, and providing relevant training. These initiatives not only strengthen the protection of natural resources but also establish a solid foundation of expertise and practical support, making WWF best ally in the field of wildlife conservation.

3. Spatial Statistical Analysis of Global Wildlife Trade

Building on the identification of the World Wide Fund for Nature (WWF) as a strategic partner based on its high relative proximity score in the TOPSIS model, this study further explores the global wildlife trade landscape by examining import and export activities across 20 countries from 2014 to 2023, as illustrated in Figures 1 and 2. Recognizing that trade volumes between countries are influenced by numerous factors, this study have developed a spatial statistical model that uses the spatial autocorrelation coefficient to reveal the distribution patterns and underlying spatial dependencies in these trade data. Specifically, this paper apply Moran's I algorithm to analyze wildlife export and import datasets, aiming to understand the spatial distribution of trade activities and identify areas of aggregation or dispersion within this global network.

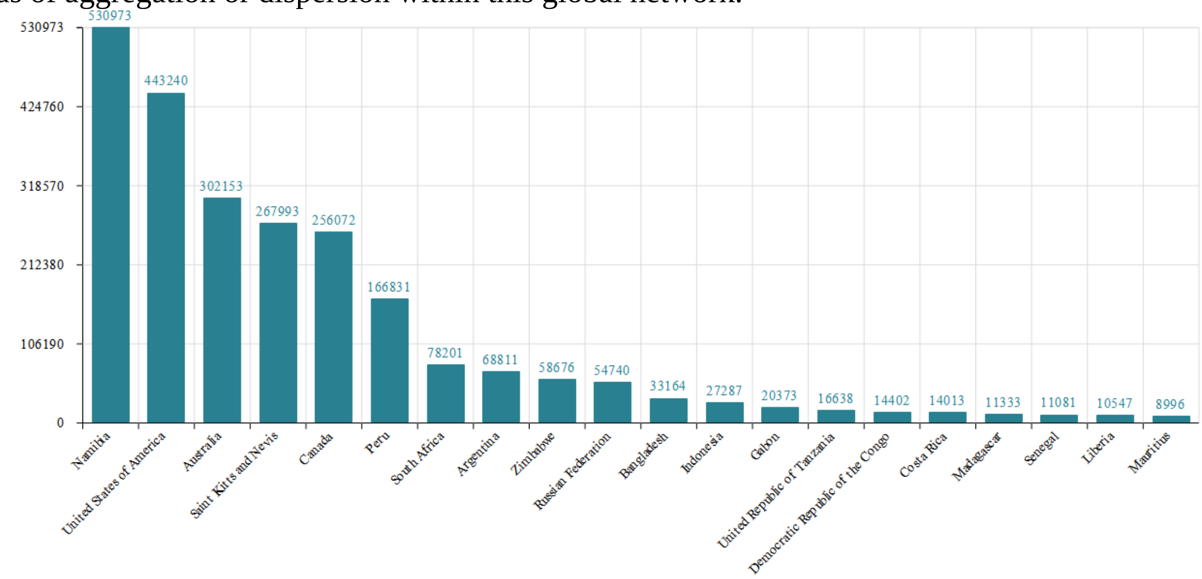

Figure 1: ranking of world exporters of illegal wildlife trade

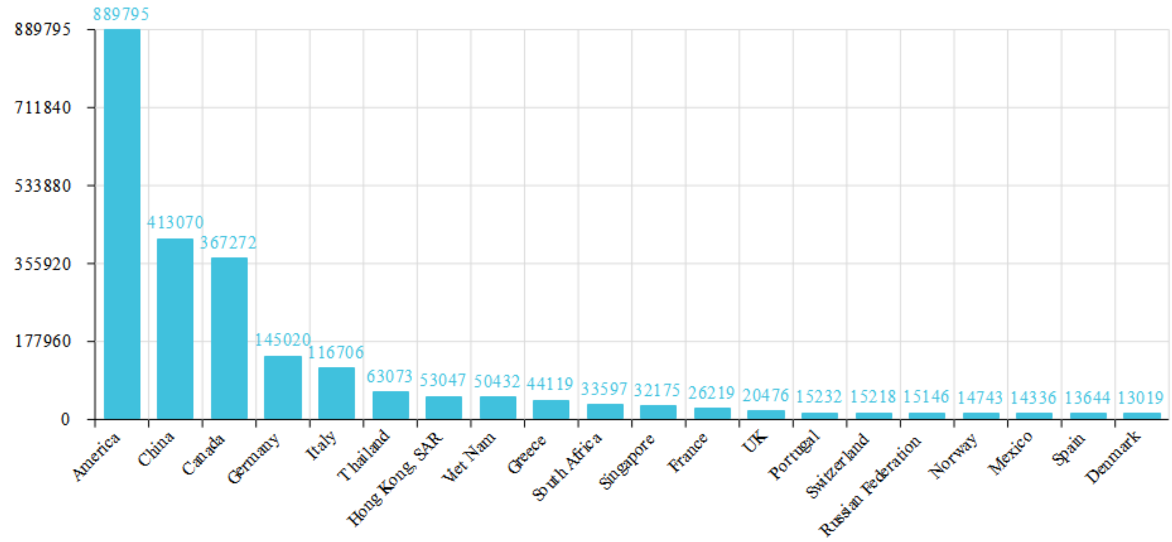

Figure 2: ranking of importing countries in the world's illegal wildlife trade

Specifically, the spatial autocorrelation coefficient indicates potential interdependence among observed data points of certain variables within the same spatial distribution area. The Moran's I algorithm, as a measure of spatial autocorrelation, evaluates the extent of spatial clustering or dispersion within geographic data. The specific formula for the algorithm is as follows:

$$I = \frac{n}{S_0} \times \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\left(y_i - \bar{y}\right)\left(y_j - \bar{y}\right)}{\sum_{i=1}^{n}\left(y_i - \bar{y}\right)^2} \tag{15}$$

Among, n this the number of countries, S_0 is the sum of country weights, and the w_{ij} is the element in the spatial weight matrix, representing the spatial relationship between positions i j. Usually, national spatial weights are defined based on the distance between positions, with closer positions having larger weights. The y_i y_j and are the observed values of regions i and j respectively $\bar{x}$ are the mean of all observed values.

Table 2. Imports of trade between wildlife countries

country name / Space weight	China	Thailand	Holland	Georgia	Turkey
China	0	0.1131	0.3542	0.2441	0.2886
Thailand	0.1131	0	0.3738	0.2507	0.2779
Holland	0.3542	0.3738	0	0.1365	0.1211
Georgia	0.2441	0.2507	0.1365	0	0.0516
Turkey	0.2886	0.2779	0.1211	0.0516	0

Table 3. Exports of trade between wildlife countries

Country name / Space weight	Holland	Germany	America	Vietnam	China
Holland	0	0.0149	0.301	0.386	0.30
Germany	0.0149	0	0.317	0.376	0.291
America	0.301	0.317	0	0.338	0.2854
Vietnam	0.386	0.376	0.338	0	0.0697
China	0.30	0.291	0.2854	0.0697	0

As shown in Table 2 and 3, the coefficient of the predictable export was 0.8231 and the import volume was 0.7965. Because it is close to "1", the illegal wildlife trade is more frequent between neighboring countries.

4. Conclusion

This study emphasizes the critical need for international collaboration to combat illegal wildlife trade effectively. Through a comprehensive evaluation framework and the TOPSIS model, the World Wide Fund for Nature (WWF) was identified as the optimal partner, with its conservation expertise and resource support enhancing the project's impact. Spatial analysis utilizing Moran's I algorithm reveals significant spatial autocorrelation, especially among neighboring countries with concentrated trade volumes. These findings suggest that targeted interventions in specific regions could effectively disrupt trafficking networks.

Future research could integrate dynamic spatiotemporal data to track trade trends over time, identifying new hotspots and evolving routes. Additionally, combining advanced predictive algorithms with the TOPSIS and Moran's I models may provide deeper insights into country-specific trade risks, refining intervention strategies based on emerging patterns. This approach aligns with the study's outcomes and supports more precise actions in international collaboration efforts.

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