

Study on the Selection of Countries for Wildlife Trade Protection Based on Comprehensive Evaluation Methods

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Abstract. The aim of this study is to develop a data-driven 5-year project to combat illegal wildlife trade. Drawing upon resources such as TRAFFIC, a wildlife trade monitoring network, we identified 3 superior indicators and established 15 inferior indicators for illegal animal trade. Through the use of Entropy Weight Method (EWM) and Analytic Hierarchy Process (AHP), we calculated the weights of these inferior indicators, subsequently determining the weights of the inferior indicators. Utilizing the Topsis score, we evaluated and ranked countries based on these indicators, ultimately selecting the United States, Russia, Canada, Australia, and Brazil as priority targets for intervention.

Keywords: Illegal wildlife trade, Conservation program, Data-driven approach.

1. Introduction

Illegal wildlife trade (IWT) represents a pressing global challenge that threatens biodiversity, ecosystems, and the livelihoods of communities worldwide. The exploitation and trafficking of endangered species and their products not only pose a grave threat to the survival of numerous animal and plant species but also undermine efforts towards sustainable development and conservation [1-2].

Against this backdrop, there is an urgent need to establish effective measures to combat IWT and mitigate its adverse impacts. However, addressing this complex issue requires a comprehensive understanding of its underlying drivers, as well as targeted interventions that are informed by reliable data and evidence-based approaches [3].

In this context, this article aims to highlight the importance of establishing a data-driven conservation program to combat illegal wildlife trade. By examining the current state of IWT and its implications, as well as identifying key challenges and opportunities, we seek to lay the groundwork for a proactive and coordinated effort to address this critical issue. Through a combination of rigorous analysis, innovative methodologies, and strategic partnerships, we endeavor to develop actionable solutions that can contribute to the protection of wildlife, the preservation of ecosystems, and the promotion of sustainable development globally.

2. Establishment of the IWT Conservation Program

First of all, we need to define the IWT Conservation Program globally: to work together to prevent, combat and eradicate the illegal trade in wildlife and plants and their products through international cooperation and policy measures, restricting and prohibiting the import and export of illegal wildlife and plants and their products, strengthening law enforcement, cracking down on illegal trafficking networks, and enhancing international cooperation and information sharing to achieve the objectives of protecting wildlife and plant species, safeguarding ecological balance and protecting human interests. species, maintain ecological balance and protect human interests². "IWT can be suppressed in every country, regardless of the policies adopted and the strength of the crackdown in those countries." Therefore, the IWT conservation projects we identified should have the following characteristics [4-5]:

- The model is a good measure of the current problems facing all aspects of IWT

-The model should take into account a fuller range of factors, including the structure of the regional economy, the history of the country, and the geographic culture.

-The model is universal. When the world situation changes, our model can measure global equity by giving appropriate indicators.

-The model should be robust. The evaluation results of the IWT model are relatively stable, but there are uncertainties that interfere.

2.1. Selection of indicators

Constructing a high availability indicator system requires selecting representative indicators. We summarized the factors that influence IWT in each country: with reference to TRAFFIC, a wildlife trade monitoring network of researchers and practitioners hosted by the World Wide Fund for Nature (WWF) and the International Union for Conservation of Nature (IUCN), as well as the Fuller Symposium of the WWF, which focuses specifically on the science of behavioral change and effective methods for influencing behavior. We make the necessary changes to the original framework to better fulfill our purpose. Firstly: we incorporate the cross-international nature of the illegal wildlife trade into the context of our modeling, incorporating the difficulty of enforcement in each country. Secondly: we modify the specific indicators in the original framework with the primary goal of reducing the total illegal wildlife trade [6].

Our inferior indicators are displayed below:

Ecosystem: The ecosystem is closely related to human beings and affects their living and productive activities. Biodiversity is manifested in the animal resources that can be provided by the place of trafficking, which is a great reflection of the ecological environment. Brazil, for example, has the largest rainforest in the world, with a rich variety of animal species, which also provides a good hunting ground for traffickers who are only in it for profit. Wildlife resources are also a key factor for us to consider, such as ivory products that can be found everywhere in Thailand. The most essential element of the ecological environment is the local ecological conditions, which provide the fundamental guarantee for the survival and continuity of the animals. The main habitats for wildlife are undoubtedly the forests and rivers, with the forest area and water resources being the main influencing factors.

National Economy: firstly, we consider the economic level of different countries, if a country has a complete industrial chain and its citizens are generally more affluent, then there will be relatively few poachers who choose to peddle wildlife. Secondly. We consider the difference between the rich and the poor of the nationals, the large gap between the rich and the poor is due to the uneven economic development of the country, which is also the main reason for some poachers and traffickers to engage in illegal wildlife trade. The last level is the market price of wildlife trafficking, which is a consideration for traffickers to choose the place of trafficking. For example, the Amazonian food market in Peru attracts many consumers due to the abundance of species for sale and the low market price, which stimulates the growth of the illegal trade, and is known as the "hell of wildlife". Looking up information on GDP, it is understood that the national economy is determined by national policies and is based on labor resources [7-8].

Cultural education: The level of education of a country's citizens greatly affects their awareness of IWT, and the social inclusiveness of this illegal trade is inversely proportional to the level of national education. For the aspect of bad traditional customs, such as indiscriminate consumption of wild animals, is one of the important markets for IWT. Mass awareness, which mainly refers to the protective attitude of the country's citizens towards animals, plays a crucial role in curbing the wildlife trade market. The assistance of the legal system is needed to improve social customs and to achieve justice and rule of law. Finally, the education of the country's citizens shows a 0-1 distribution with the amount of education supply in the country, making it a very important dependent indicator. Display of indicators are shown in figure 1.

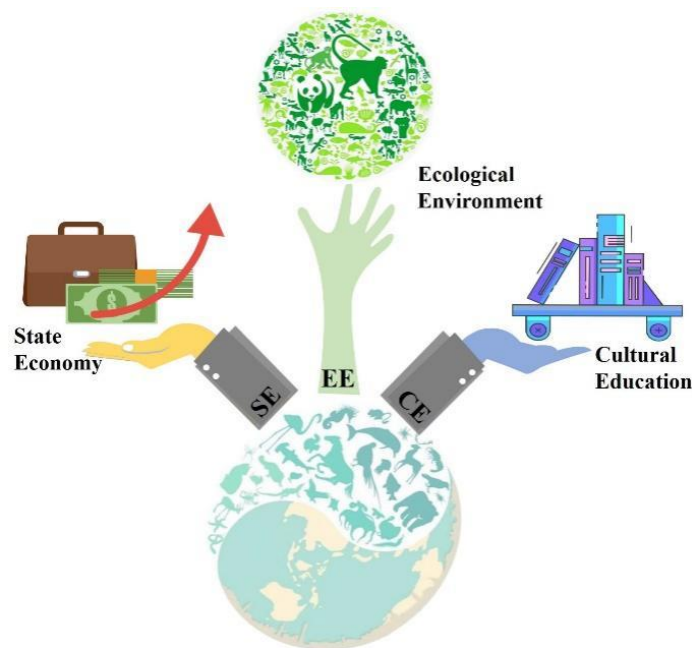


Figure 1. Display of indicators

After defining the indicator framework, we collected relevant data from authoritative websites such as the World Bank and Wikipedia. The system of indicators is presented as Figure 2:

Level 1	Level 2	Description	Type
Ecological Environment	DS	Diversity of Species	+
	WR	Wildlife Resources	+
	FA	Forest Area	+
	EC	Environment Conditions	+
	WRC	Water Resource Conditions	+
State Economy	GDP	Gross Domestic Product	+
	NP	National Policy	+
	PRG	Poor-Rich Gap	+
	MP	Market Price	-
	LR	Labor Resources	+
Cultural Education	EL	Educational Level	-
	LS	Legal System	-
	TC	Traditional Custom	+
	ES	Education Supply	+
	PA	Public Awareness	-

Figure 2. Display of indicators

Note: "+" stands for very large, "-" for very small.

The three metrics that need special mention are WD, EL, and PC:

The indicator of the difference between the rich and the poor is quantified by the Engel's coefficient, the use of which is justified by the fact that the indicators we have chosen are all regional in nature. Obviously, the smaller the Engel coefficient, the smaller the gap between the rich and the poor, which is minimal type. Here we use 40% as the measurement division, and above 0.4, it is regarded as a large gap between the rich and the poor.

Mass awareness of wildlife conservation can be quantified by monitoring the frequency of donations and grants. Here we have collected the frequency of donations to wildlife in each country

over the course of a year, using the country as the basic unit. Obviously, for IWT as an evaluation system, mass awareness of wildlife conservation is a minimal type

The level of education of the nation can be measured by the ratio of national expenditure on education to GDP. We collected the ratio of total public expenditure on education to GDP from the World Bank and averaged the ratios for the last three years, and concluded that when $PC < 4.2$, it is considered to be a low level of education, and when $PC > 4.2$, it means that the country attaches more importance to the overall education of the nation [9-10].

2.2. Data pre-processing

In order to assess the health of the economy, the data collected was processed and weights were calculated.

2.2.1. Data Filling:

Due to limited access to national data, the data had some missing values. The following approach was taken to address this issue:

If a country has fewer missing years of data for an indicator and the variance of that indicator is small, we use the mean-completion method to fill in the missing years with the average of the other years

Regression interpolation is used if there are fewer missing years of data for an indicator in a country and the indicator is more strongly correlated with the yearly indicator

If data for all years are missing for an indicator for a country, given the specific meaning of the indicator, we populate the indicator with the average of all countries

By processing missing values, we selected complete data for the last 10 years for 25 countries (covering all continents except Antarctica), including the United States, China, Japan, India, Singapore, Laos, Vietnam, Germany, France, and Russia.

2.2.2. Outlier handling:

We analyzed the indicators of these 25 countries and found that some of them had significant anomalies in certain years due to national policies and wars, among other factors. For example, the Russian-Ukrainian war, Russia's economy, cultural capital investment, and ecological environment were all significantly different from normal values. We dealt with these indicators by removing the outliers and filling in the missing values.

2.2.3. Data standardization

Now that we have the complete dataset, in order to better determine the IWT index, we need to normalize this data so that it can be measured on the same dimension. As discussed earlier, we have divided these 15 indicators into two categories and only need to positively normalize the minimal type:

$$\tilde{x}_i = x_{max} - x_i$$

2.3. Determination of indicator weights

After that we have to determine the weights of these metrics in order to arrive at the Topsis score we need. Considering that Analytic Hierarchy Process (AHP) relies on the judgment of the decision maker and is subjective. (EWM) Entropy Weight Method, although determined by the data itself and normalized, does not exclude the case that the data does not match the actual situation. So we use a combination of EWM & AHP to determine our final weights to improve the accuracy of the IWT index.

2.3.1. EWM Determination of Weights

In EWM, the greater the dispersion of an indicator, the higher its corresponding weight. The data we collect is real, so it reflects the information in reality well. We have 25 evaluation objects and 15 evaluation indicators, and the normalization matrix formed by these indicators is as follows:

$$X = \begin{pmatrix} x_{11} & \cdots & x_{115} \\ \vdots & \ddots & \vdots \\ x_{251} & \cdots & x_{2515} \end{pmatrix}$$

Normalizing the matrix X yields the $\tilde{Z}$ matrix, and the individual elements of the matrix are represented as shown in (2):

$$\tilde{z}_{ij} = \frac{x_{ij} - \min\{x_{1j}, x_{2j}, \dots, x_{ij}\}}{\max\{x_{1j}, x_{2j}, \dots, x_{ij}\} - \min\{x_{1j}, x_{2j}, \dots, x_{ij}\}}$$

This results in a non-negative matrix: $\tilde{Z} = (z_{ij})$

We first standardize the measurements. Denote the standardized value of the i th indicator for sample country j as p_{ij} .

$$p_{ij} = \frac{\tilde{z}_{ij}}{\sum_{i=1}^{25} \tilde{z}_{ij}}$$

Calculate the entropy value of the i th indicator as E_i :

$$E_i = \frac{1}{\ln n} \sum_{i=1}^n p_{ij} \ln(p_{ij})$$

The larger E_i is, the greater the degree of differentiation, the greater the corresponding amount of information, which should be given greater weight, and the entropy weight of each indicator can be obtained by normalizing the information utility:

$$W_{ewm} = 1 - E_i / \sum_{i=1}^n (1 - E_i)$$

The results are shown in the figure 3:

	Indicator	Weight		Indicator	Weight
Ecological Environment	DS	0.2062	Ecological Environment	DS	0.2421
	WR	0.3002		WR	0.2914
	FA	0.2011		FA	0.2036
	EC	0.2102		EC	0.2012
	WRC	0.0823		WRC	0.0617
State Economy	GDP	0.1417	State Economy	GDP	0.1529
	NP	0.2526		NP	0.2321
	PRG	0.1968		PRG	0.1994
	MP	0.2135		MP	0.2235
	LR	0.1954		LR	0.1921
Cultural Education	EL	0.1623	Cultural Education	EL	0.1513
	LS	0.1358		LS	0.1424
	TC	0.2124		TC	0.2215
	ES	0.1811		ES	0.1964
	PA	0.3084		PA	0.2884

Figure 3. EWM and AHP weights

Finally, we apply EWM to the EE, SE, and CE dimensions to obtain preliminary weights for these indicators.

$$w_{EWM} = (0.5430, 0.1830, 0.2740)$$

2.3.2. Weights determined by the AHP

Similarly, we take the three superior indicators and the subordinate inferior indicators as an evaluation system, and use AHP to determine the weight of the j th indicator identified by the i th evaluation subject w_{ij} . In order to determine the IWT index, we also analyzed the three superior indicators EE, SE, and CE using hierarchical analysis to give the following judgment matrix:

$$\begin{matrix} & EE & SE & CE \\ EE & 1 & 5 & 3 \\ SE & 1/5 & 1 & 1/2 \\ CE & 1/3 & 2 & 1 \end{matrix}$$

Note: This judgment matrix is subjective

The resulting matrix, which yields $CR=0.0036<0.1$ passes the consistency test and proves that our results are acceptable. In order to make our obtained weights more convincing, we use the geometric value method, arithmetic mean method, and geometric mean method to determine the weights respectively, and then average these three results to get the final weights. The results are shown as follows.

$$W_{AHP} = (0.5150, 0.1578, 0.2502)$$

2.3.3. Determination of composite weights

We combined EWM and AHP to determine the weights:

$$w = \frac{w_{EWM} + w_{AHP}}{2}$$

The final weighting of each upper and lower level indicator is calculated as Figure 4.

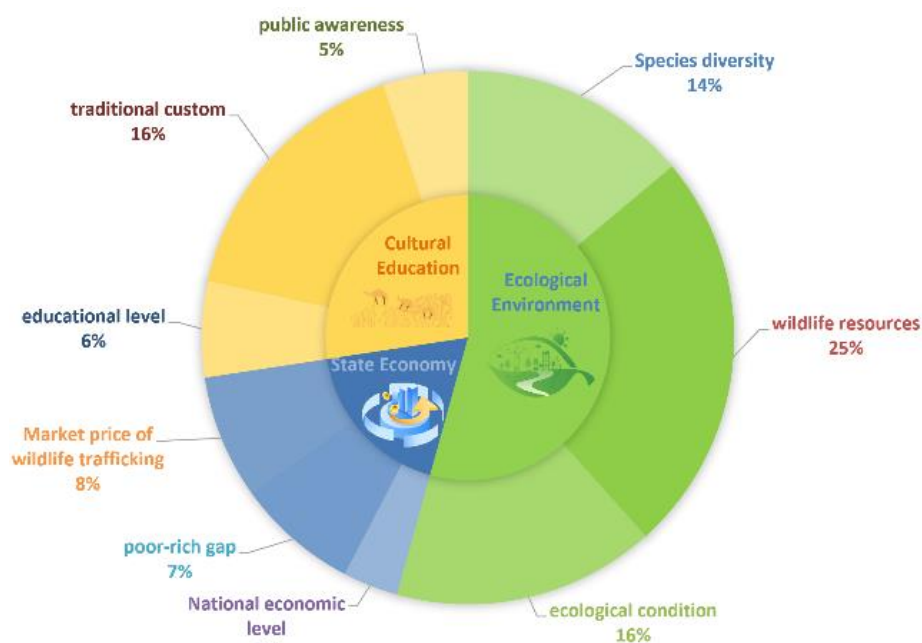


Figure 4. Display of final weights

The final weights is:

$$w = (0.5291, 0.1704, 0.2621)$$

2.4. Establishment of the IWT index scoring system

We used the Topsis method to determine the scores for each of the superior indicators, which are now used as the three evaluation systems. There are now 25 countries and 15 evaluation systems, and based on our previous normalization results, the indicators corresponding to these countries are formed into a normalization matrix $X = (x)_{ij}$. Then, the matrix for their normalization is denoted as Z (in italics), and each element in Z :

$$z_{ij} = x_{ij} / \sqrt{\sum_{i=1}^n x_{ij}^2}$$

We selected the maximum value under the i th indicator for each of the 25 countries as an element in the new vector Z_i^+ , and this element represents the maximum facilitator in the illegal wildlife trade. The maximum value is defined as:

$$Z^+ = (Z_1^+, Z_2^+, \dots, Z_m^+) \\ = (\max\{z_{11}, z_{21}, \dots, z_{n1}\}, \max\{z_{12}, z_{22}, \dots, z_{n2}\}, \dots, \max\{z_{1m}, z_{2m}, \dots, z_{nm}\})$$

Similarly, define the minimum value as:

$$Z^- = (Z_1^-, Z_2^-, \dots, Z_m^-) \\ = (\min\{z_{11}, z_{21}, \dots, z_{n1}\}, \min\{z_{12}, z_{22}, \dots, z_{n2}\}, \dots, \min\{z_{1m}, z_{2m}, \dots, z_{nm}\})$$

After that, we calculate the distance of the i th evaluation metric from the maximum and minimum values:

$$D_i^+ = \sqrt{\sum_{j=1}^m w_j (Z_j^+ - z_{ij})^2}, D_i^- = \sqrt{\sum_{j=1}^m w_j (Z_j^- - z_{ij})^2}$$

Define the ratio of distances: $S_i = \frac{D_i^-}{D_i^+ + D_i^-}$ and we can calculate the score:

$$\tilde{S}_i = \frac{S_i}{\sum_{i=1}^n S_i}$$

It can be seen that: $\sum_{i=1}^{25} \tilde{S}_i = 1$, so we can obtain the score of the superior indicator based on the scores of the inferior indicators subordinate to the superior indicator, corresponding to the sum of the scores of the superior indicators:

$$S = (S_{wd}, S_{el}, S_{pc})$$

Finally, we can derive the IWT index for the i th country:

$$IWTI = (S_{wd}, S_{el}, S_{pc}) \cdot w^T$$

After that, we ranked the 25 countries according to the scores of the IWTI, and since countries have different IWTI scores, the most vulnerable aspects of the national illegal wildlife trade do not overlap, and the policies adopted should be tailored to the local context. We ranked the countries in descending order of their scores and selected the top five: Russia, Canada, Australia, the United States, and Brazil.

3. Conclusion

In summary, our efforts have been directed towards developing a comprehensive strategy to combat illegal wildlife trade (IWT) over a 5-year period. By leveraging data-driven approaches and referencing reputable sources such as TRAFFIC, we identified key indicators to measure and monitor IWT. Through the application of Entropy Weight Method (EWM) and Analytic Hierarchy Process (AHP), we determined the weights of these indicators, allowing us to prioritize interventions effectively.

The establishment of a robust indicator system, coupled with the calculation of indicator weights, provided a structured framework for evaluating the severity of IWT in different countries. Using the Topsis score, we ranked countries accordingly, with the United States, Russia, Canada, Australia, and Brazil emerging as priority targets for our proposed conservation efforts.

Moving forward, the implementation of targeted projects and policies aimed at reducing IWT in these countries will be essential. By fostering international cooperation and leveraging data-driven strategies, we can work towards the shared goal of protecting wildlife, preserving biodiversity, and safeguarding ecosystems for future generations.

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