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Research on the Impact of Wildlife Trade Based on a Linked Comparative Forecasting Model: A Case Study of ASEAN

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Abstract. This study examines the challenges faced by ASEAN countries in combating illegal wildlife trade and implementing CITES. Despite efforts, illegal trade persists due to technological limitations, inadequate permit systems, poor interagency coordination, corruption, and low public awareness. The paper proposes project suggestions, including drone monitoring, a unified wildlife health information system, and improved enforcement mechanisms. Data analysis and empirical research confirm the alignment of these suggestions with ASEAN wildlife conservation plans. Predictions using linked models and ARIMA models suggest a high probability of successful illegal wildlife trade mitigation with adequate resources. The study provides a feasible approach for ASEAN to promote sustainable human-nature coexistence.

Keywords: Illegal wildlife trade, Spearman correlation analysis, linked forecasting comparative model, ARIMA time series model.

1. Introduction

Wildlife constitutes a vital natural and ecological resource. The wildlife trade, a global industry valued at tens of billions of dollars annually, exerts extensive and profound impacts on biodiversity, affecting the majority of major taxonomic groups. Currently, the wildlife trade market faces challenges including illegal and unsustainable wildlife trade, insufficient governance capacity, lack of transparency and accountability, and corruption.[1] Despite existing conservation measures, their effectiveness in preventing species decline remains limited, particularly in trade fishing activities within protected areas. Research demonstrates a strong correlation between species threat status and population decline, indicating higher risks of local extinction and extinction for traded species.[2]

To assess the extent of global illegal wildlife trade, this paper analyzes wildlife trade data from 208 countries and regions from 2014 to 2023. Among them, the eleven ASEAN countries are not only sources, transit points, and consumers of wildlife in the region and other parts of the world, but also origins, markets, and logistics hubs for both legal and illegal wildlife trade. [3] By comparing the data of ASEAN countries with global wildlife trade data through stacked and charted analyses, we observe a striking similarity in illegal wildlife trade trends, as shown in Figure 1.

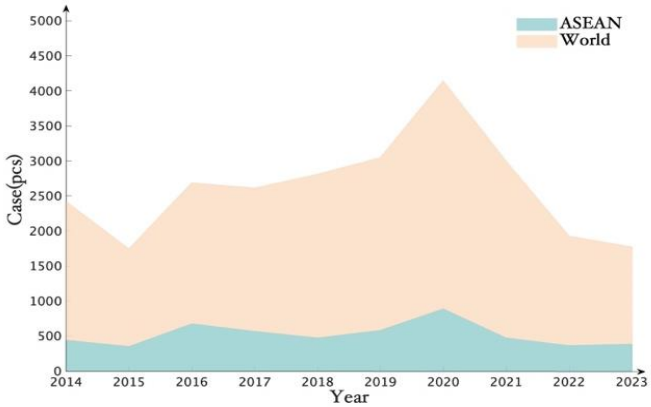

Figure 1. Illegal wildlife incidents (case) in the whole world and in ASEAN.
Data credit: https://tradeview.cites.org/en

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Therefore, it can be concluded that ASEAN countries are representative in the issue of illegal wildlife and plant trade, and have already successfully implemented many international projects for the protection of wildlife and plants in the region, indicating good feasibility and development space for research. In light of this, this paper takes the eleven ASEAN countries as an example to study the current illegal wildlife trade issue that profoundly impacts global ecology and international trade. Using ASEAN as an example, this paper designs comprehensive wildlife and plant protection policies for ASEAN in the current situation through the comprehensive evaluation and analysis of past projects, visualizes the impact of these policies, and proposes corresponding solutions to the severe situation of wildlife and plants, in order to provide ideas for the formulation and implementation of relevant policies and contribute to the global wildlife and plant protection cause.

2. Project Suggestions for Strengthening Wildlife Protection in ASEAN

2.1. Existing Research

2.1.1. Science and Technology

Studies have shown that drone technology plays a crucial role in wildlife protection. For example, the DJI Zenmuse H20N assisted the Kekexili Tibetan Antelope Protection Project, achieving long-term, undisturbed tracking of Tibetan antelope populations at night through high-power zoom infrared thermal imaging, night vision, and laser ranging functions. Additionally, drone technology has demonstrated its advantages in scientific observation during the northward migration of Asian elephants. These cases prove the potential of drone technology in improving the accuracy and comprehensiveness of wildlife monitoring in the wild, indicating that combining drone aerial photography, tracking, detection, and statistics can promptly monitor illegal wildlife poaching and provide an effective means for wildlife protection.[4]

2.1.2. Safety and Health

ASEAN official documents emphasize the necessity of establishing a multi-sectoral coordination mechanism for “One Health”. ASEAN member states must strive to narrow the gap in One Health development and work towards establishing a formal One Health multi-sectoral coordination mechanism.[5] The One Health Quad Alliance has issued a call to action for building a safer world, emphasizing the importance of strengthening cooperation and commitment to translating One Health policies into action in all countries. This indicates the urgent need to establish an effective One Health information system to promote communication and information sharing among member states. Although ASEAN countries have deeply recognized the importance and necessity of promoting One Health and taken a series of actions, there is still a lack of a One Health information system for wildlife diseases among health and health departments of member states, maximizing the reduction of barriers in communication and information sharing.

2.1.3. Legal and Policy

Trend change reports on wildlife conservation in Southeast Asia and China emphasize significant progress in protection legislation and related analysis of illegal wildlife cases in Southeast Asia and China in 2019. Additionally, the cooperation between China and ASEAN countries in combating illegal wildlife and plant trade demonstrates the importance of regional cooperation in combating illegal trade. Currently, a major pain point in combating transnational illegal wildlife trade is the lack of coordination between law enforcement departments and other departments and the complexity of cooperation procedures.[6]These developments indicate the need to strengthen international cooperation and regional coordination at the legal and policy level to effectively combat transnational illegal wildlife trade. At the same time, the risk of corruption runs through all links of the wildlife trade supply chain. Reducing corruption requires comprehensive solutions beyond the scope of protection agencies and should explore more strategic and gradual solutions.[7] To further curb the smuggling of wildlife and their products, it is recommended that source countries improve their law

enforcement and regulatory capacity, deepen international law enforcement intelligence exchanges, strengthen the supervision of inbound and outbound mail, and implement a broader ivory ban.[8]

2.1.4. Other Aspects

Existing research has also put forward a series of key suggestions, including building a good governance system, improving transparency and traceability, strengthening law enforcement, respecting the rights and interests of indigenous peoples and local communities, and involving multiple stakeholders to promote the sustainable development of the natural market of wildlife. At the same time, relevant research also emphasizes the key role that the financial sector can play in promoting sustainable wildlife management, combating illegal trade, and protecting biodiversity.[9]

2.2. Project Suggestions for Strengthening Wildlife Protection in ASEAN

Through research and analysis of wildlife and plant protection projects already implemented in ASEAN, combined with the specific national conditions of the eleven ASEAN countries, this paper designs a series of policies and project suggestions aimed at promoting the protection of wildlife and plants. These suggestions not only cover programs that utilize advanced technology to improve protection efficiency, such as drone monitoring and information system construction, but also include humanistic strategies that raise public awareness and participation through laws and education, aiming to build a more coordinated and consistent wildlife protection network and form effective protection and management mechanisms globally. By introducing these policies and project suggestions, it is hoped to provide a comprehensive perspective on how to implement wildlife and plant protection in modern society. This is not only a supplement to existing research but also a forecast of future potential development directions. The following content will elaborate on the specific details of these policies and project suggestions and how they collectively contribute to the overall wildlife and plant protection.

2.2.1. UAV(Unmanned Aerial Vehicle)

By gradually incorporating UAV into the team fighting against animal crimes, we have significantly improved the efficiency and accuracy of wildlife inspections. Therefore, this project will apply drone technology based on the SAF R-CNN model proposed by Li J[10] and others for wildlife detection. This model, based on the Fast R-CNN network, extracts feature maps from shared bottom convolution and sets up a dual-path structure for detecting targets of different sizes. The final result is obtained by fusing the detection results of the dual-path structure through a weighted layer.

2.2.2. ASEAN Unified Wildlife Health Information System

Wildlife is an important host for emerging infectious pathogens. Many wildlife infectious diseases are characterized by fast transmission, wide impact, and severe losses, thus requiring the ASEAN countries' unified health departments to respond quickly and efficiently. Therefore, this project will build an ASEAN Unified Wildlife Health Information System, beneficial for countries to coordinate wildlife information uniformly, achieve disease monitoring, rapid response, and reduce health risks.

2.2.3. Law

While ASEAN countries have enacted comprehensive laws to combat illegal wildlife trade, corruption and lax enforcement pose significant challenges, prolonging the struggle against wildlife crime. Currently, corruption is becoming increasingly relevant in discussions related to CITES implementation. Therefore, this project will establish a staff and close relative income and expenditure declaration system within the CITES authorities of ASEAN countries. Additionally, it will advocate for the establishment of dedicated committees or working groups within ASEAN’s criminal justice system to address corruption issues related to illegal wildlife trade, aiming to better tackle corruption.

Furthermore, in the context of transnational illegal wildlife trade, the effectiveness of combating wildlife crime is limited if customs authorities do not promptly cooperate with law enforcement

agencies to investigate seizures of illegal wildlife. Therefore, this project will establish dedicated fast-track channels between customs and law enforcement agencies in each member state, enabling law enforcement agencies to take swift action against wildlife crime following customs seizures.

2.2.4. Education

For professionals combating illegal wildlife trade, this project will organize specialized training camps and other training programs to enhance their ability to combat wildlife crime.

For the general ASEAN public, this project will promote "Anti-Illegal Wildlife Trade Campaigns in Schools" to instill anti-wildlife crime awareness among the younger generation. Additionally, we will invite reputable artists to produce public welfare science popularization short videos and advertisements to raise public awareness of wildlife science knowledge.

2.3. Program Fit Verification Based on Data Analysis

Data analysis can more intuitively demonstrate the alignment between the client's own plans and expected goals and the aforementioned projects. Firstly, this study collected data on scientific research investment, legal policies, and education and training expenditures in wildlife protection in ASEAN countries over the past five years. In terms of budget estimation, reference was made to the five-year biodiversity conservation project in Vietnam conducted by the World Wide Fund for Nature (WWF) based on the United States Agency for International Development (USAID) and projects implemented by organizations such as Traffic in ASEAN. By analyzing the expenditure and investment of these implemented projects, the budget of each project was estimated. Finally, this study will adopt Spearman correlation analysis to determine the degree of alignment between the projects and ASEAN plans.[11]

The specific algorithm and basis for evaluation of Spearman are as follows:

$$Mr = \frac{\sum_{i=1}^{n}(x_i - \overline{x})\,(y_i - \overline{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \overline{x})^2 \sum_{i=1}^{n}(y_i - \overline{y})^2}} \tag{1}$$

Where, r represents the correlation coefficient, x_i, $y_i$respectively represent the ith value of the two variables, $\overline{x}$, $\overline{y}$ respectively represent the mean values of the two variables. Where r ranges from [-1, 1], association of with relevance is shown in table 1, and we consider:

Table 1. Association of $|r|$ with relevance.

$\|r\|$	**Correlation**
$\|r\| < 0.3$	No linear correlation
$0.3 < \|r\| < 0.5$	Low linear correlation
$0.5 < \|r\| < 0.8$	Significant linear correlation
$\|r\| > 0.8$	High linear correlation

Finally, we calculated the correlation matrix of various factors and produced a visualization of the correlation heatmap in Figure 2.

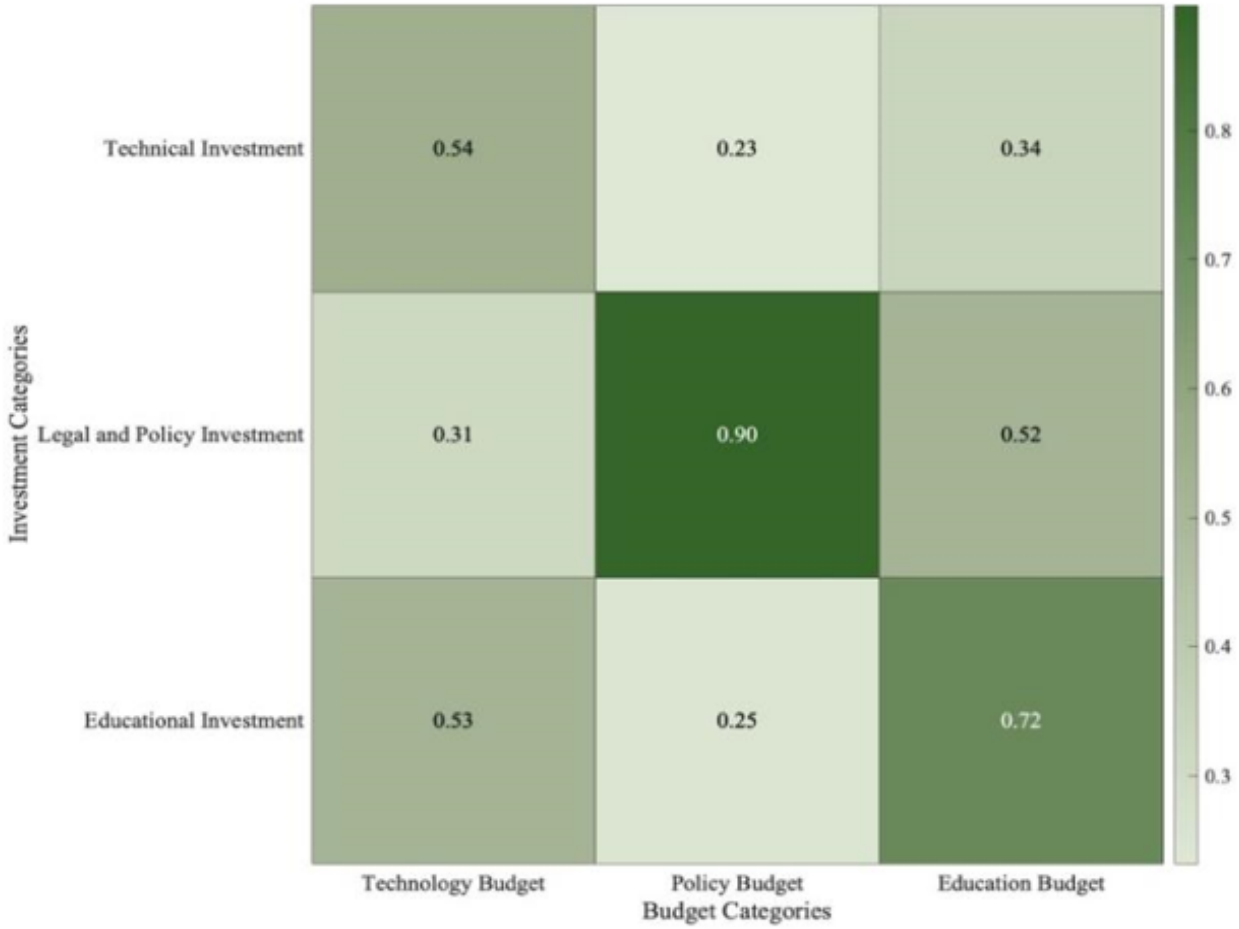

Figure 2. Visual correlation heat map.

It's evident that in research, we believe the project has significant relevance to client expectations, and in legal and education aspects, we believe the project has high linear correlation with client expectations. Overall, through data-driven analysis, our project highly matches the client's own plans and anticipated goals, making it highly suitable for ASEAN.

3. Project Impact Prediction Based on Linked Models and ARIMA Time Series Models

3.1. Basic Chain Model

Our project is implemented from both scientific and social scientific aspects, so its impact can be directly observed from changes in relevant indicators in research, law, and education. Therefore, we have constructed a chain prediction comparison model for project-indicator impact-illegal wildlife trade impact.

Firstly, we need to build a chain of impact from the project's direct effects on research, legal, and education aspects on the quantity of illegal wildlife trade in the ASEAN region. We selected ASEAN's research and education investment ratios and related legal documents as intuitive indicators reflecting the project's impact, using them as independent variables to fit the dependent variable of the ASEAN region's illegal wildlife trade quantity through a multiple linear regression model.

Secondly, we need to preprocess the data before fitting. We collected data on the independent variables in the ASEAN region over 15 years and created corresponding box plots to clean up outliers, as shown in Figure 3.

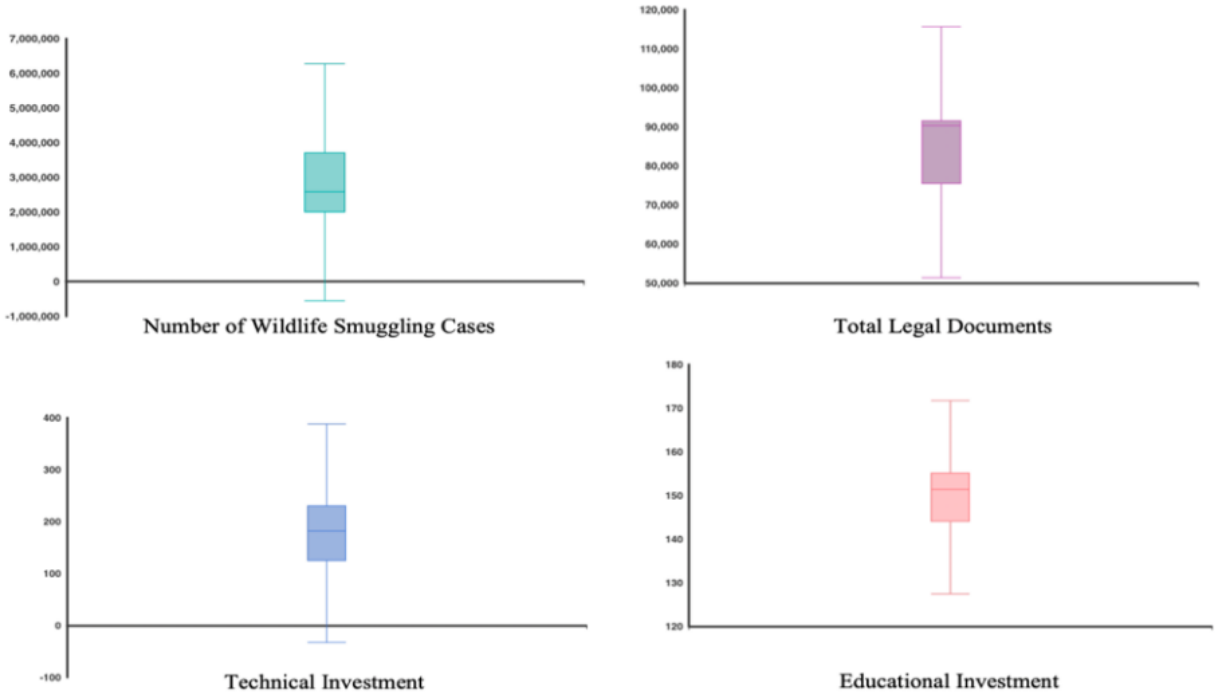

Figure 3. The framework of 3S Project and relevant existing research.

We choose to directly remove outliers and then use Newton's interpolation method to fill in missing data, resulting in a complete dataset. We used the preprocessed data to fit the number of illegal wildlife trades to the indicators of technology, education, and law through multiple linear regression. It can be represented by the following formula m:

$$\hat{y}_N = 5.541x_{Law} + 15731.499x_{Sci} - 94969.605x_{Edu} + 13887610.846 \quad (2)$$

We drew a fitting chart of the prediction points obtained through multiple linear correlation with the actual data, Figure 4 visually reflects that our multiple linear correlation analysis can very accurately construct the relationship between the number of illegal wildlife smuggling and changes in indicators related to research, education, and law.

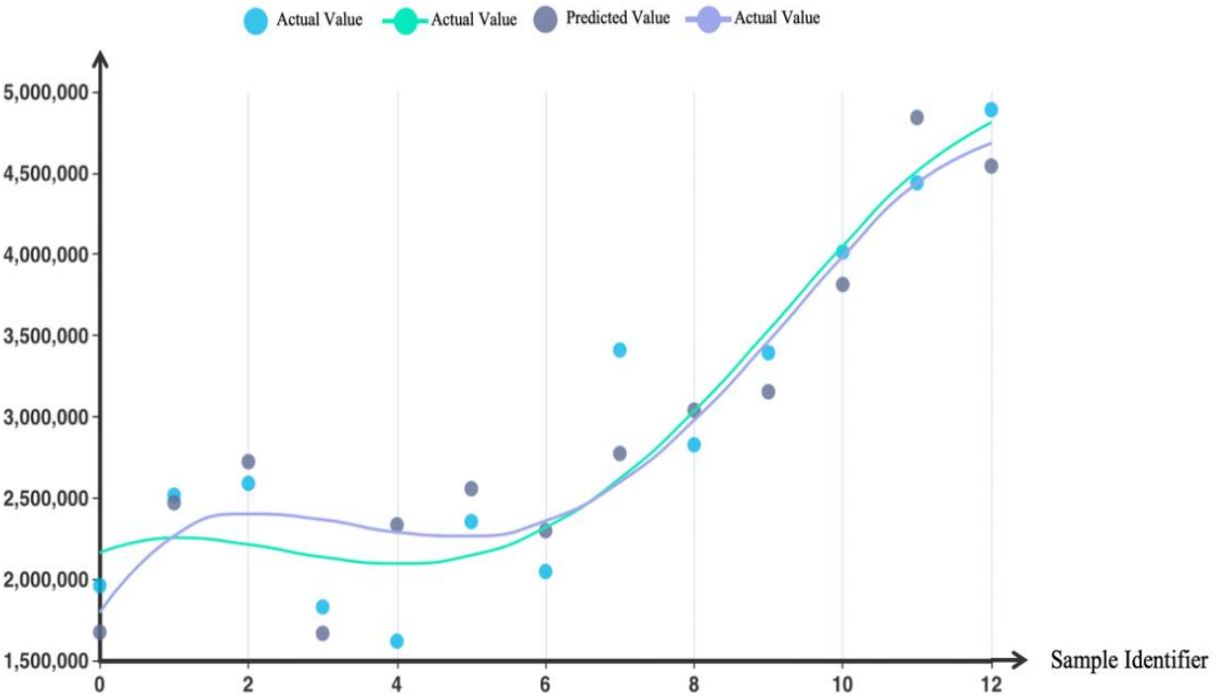

Figure 4. Relationship between illegal wildlife smuggling and changes in indicators.

Next, we need to complete another part of the chain model, predicting the impact of the project on technology, law, and education through scientific and social science means, and compare it with the prediction data without the implementation of the project, thus constructing the entire chain prediction comparison model.

Similarly, we referred to and researched projects on wildlife protection that have been carried out and achieved significant results in the ASEAN region by various organizations worldwide. We believe that, after implementing our project, the indicators of technology, education, and law will show a natural exponential growth level over a period of time, namely $\boldsymbol{x_{T-t} = x_t e^{T-t}}$. From this, we can obtain the future indicator data under the implementation of the project, then input the data into formula 2, and get the number of illegal wildlife trade in the ASEAN region under the intervention of the project N_{sss}.

We also need to predict the number of illegal wildlife trades in the ASEAN region in the future without the implementation of our project. We use the ARIMA time series model for this prediction. The basic principles and construction process of the ARIMA time series model can be intuitively seen in Figure 5:

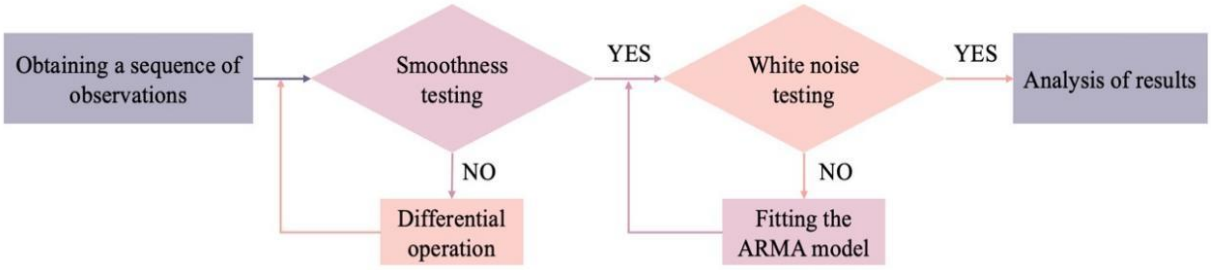

Figure 5. The basic principle and construction process of ARIMA time series model.

Through the time series model, we can get the number of illegal wildlife trades in the ASEAN region in the future without the implementation of the project N_{ARIMA}. Thus, we have completed the construction of the chain prediction comparison model, and finally, our project's impact on ASEAN's illegal wildlife trade can be quantified as formula 3:

$$I_{sss} = \sum_{i=1}^{5} \Delta N_i = \sum_{i=1}^{5} (N_{ARIMA} - N_{sss})_i \tag{3}$$

The project is predicted to reduce the number of illegal wildlife trade by approximately 2.14 million over five years, equating to a reduction of about 428,000 annually.

3.2. Complex systematization of chain models

We believe that illegal wildlife trade is part of a larger complex system. The impact of wildlife protection is broad and complex, so we attempt to construct connections between illegal wildlife trade and areas of environment and economy, thereby expanding and perfecting our chain model to make it an effective complex system and create more opportunities for synergy among actors in this system. We believe this connection can be measured by the benefits to other areas brought about by the reduction in the number of illegal wildlife under the impact of the project. The value of wildlife protection can be divided into three parts: economic value, ecological value, and future development value, namely:

$$V_{Total} = V_{Eco} + V_{Env} + V_D \tag{4}$$

We learned from organizations like WWF that the economic value of wildlife protection can be reflected in aspects such as tourism resources and biological information resources; while the

ecological value of wildlife protection can be intuitively reflected in biodiversity, we use the Red List Index to quantify biodiversity in the ASEAN region, and the development value is more reflected in the marginal benefits to the environment brought by wildlife protection. Finally, we constructed a formula to measure the benefits brought to other areas by the reduction in the number of illegal wildlife, using economic knowledge, which means:

$$V_{Total} = \frac{\alpha V_{\text{Eco}} + \beta(V_{\text{Env}} + \int_0^I ME_{\text{Env}}(i)d_i)}{(1+r)^t} \tag{5}$$

Where, the value of development is measured by $\int_0^I ME_{\text{Env}}(i)d_i$, representing the total sum of marginal gains in environmental value. r is the social discount rate, used to convert future benefits or costs into present value. t represents the time span, used to calculate the present value from now until the realization of future benefits, here we take t=5.

Ultimately, we found that our project implementation contributes an annual economic value increase of approximately $242 million to the ASEAN region, along with an annual growth of about 0.057% in the RLI.

4. The Probability of Achieving Expected Outcomes and Analysis of Unforeseen Events

4.1. Logistic regression based on scenario analysis

Considering that the achievement of project expectations is influenced by complex non-linear factors, we decided to analyze the probability of achieving project expectations using logistic regression. We first constructed a discriminant function, namely:

$$d_i = \alpha_i + \beta_1 \log(C_{Sci}) + \beta_2 \log(C_{Soi}) \tag{6}$$

In the formula, C_{Sci}, C_{Soi} refer to the completeness of the project plans in science and social science aspects, which we log-transform to make the distribution closer to normal distribution, α_i, β_1, β_2 are constants. We searched for wildlife protection projects conducted in the ASEAN region by various organizations worldwide and built a training set, then obtained its cost function $J(d_i)$ through maximum likelihood estimation, and minimized it using gradient descent to obtain the optimal parameters. The probability of the project achieving its future targets $p_i$is:

$$p_i = \frac{e^{d_i}}{1+e^{d_i}} \tag{7}$$

After calculation, when completely excluding the influence of other external factors, which means maintaining the natural growth level of investment in science and social science aspects of the project, the probability of project success reached over 72%. If ASEAN can obtain sufficient power and resources as analyzed in our previous text, the probability of project success will reach an astonishing 93% or more. Therefore, we believe our project is robust and highly beneficial.

4.2. Analysis of contingencies under contextualization

We have conducted a sensitivity analysis in the logistic regression model and found our project to be robust. Therefore, disproportionate assistance or harm primarily comes from external factors.

We use the McKinsey tree method to identify and analyze these external factors, as shown in Figure 6.

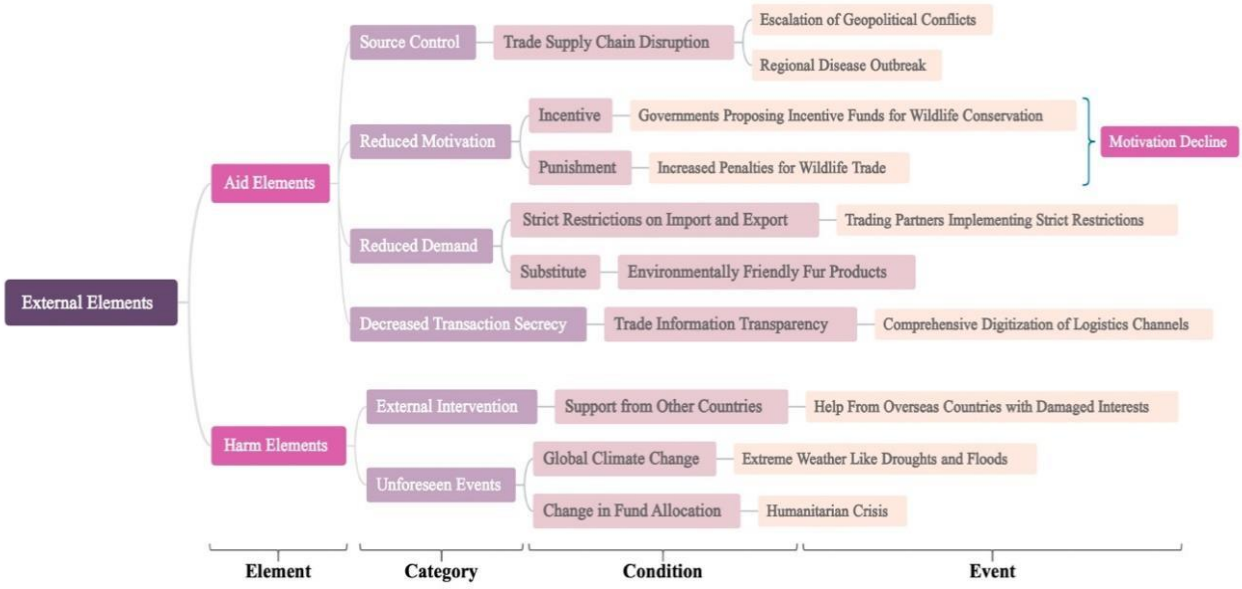

Figure 6. The McKinsey tree of external factors.

Examples are given below:

1) The illegal wildlife trade may face obstacles at its source, such as escalating geopolitical conflicts among ASEAN countries or global or regional disease outbreaks, creating barriers to trade.

2) On the demand side, if ASEAN's ten countries' trade partners implement strict import and export restrictions on wildlife and plants, the volume of illegal wildlife trade within ASEAN could significantly decrease. Additionally, the large-scale development of environmentally friendly products, such as faux fur, in the ASEAN region, producing high-performance, low-cost alternatives, could potentially replace wildlife products.

These conditions could disproportionately aid our project.

3) During the implementation of the project within ASEAN, there could be risks from countries outside the region whose interests are harmed, intending to interfere.

4) If global climate changes, such as droughts or floods, occur within the five years of the project's implementation, it could lead to a relative decrease in government funding for wildlife protection, reducing the urgency of the conservation crisis.

If these conditions occur, they could harm our project.

5. Conclusion

This study has delved into the challenges faced by ASEAN countries in implementing the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and combating illegal wildlife trade. The findings reveal that a lack of technology, inadequate information systems, weak interdepartmental coordination, corruption, and insufficient public awareness are the primary factors contributing to the persistence of illegal trade. In response to these challenges, this study proposes a series of innovative project suggestions, including the use of drone aerial photography and twin network structure models for precise monitoring, the establishment of a unified ASEAN wildlife health information system to facilitate rapid response, and the creation of anti-corruption mechanisms and efficient enforcement mechanisms.

Through the analysis of existing data and empirical research, this paper confirms the high degree of alignment between these project suggestions and wildlife conservation plans in ASEAN countries. Predictions based on linked models and ARIMA time series models indicate that, with sufficient resources and power, the implementation of these projects has a probability of over 92% of

successfully reducing illegal wildlife trade. Additionally, through scenario analysis and sensitivity analysis using logistic regression models, this study can predict and mitigate potential unexpected events. In summary, this research not only provides ASEAN countries with a feasible and long-term path to combat illegal wildlife trade but also contributes important theoretical and practical foundations for the sustainable development of humans and nature within the region. Future work should focus on further refining the project suggestions, strengthening international cooperation, and raising public awareness to ensure the effective implementation of these measures.

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