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Predicting the Effectiveness of Wildlife Trade Policies Using Machine Learning Techniques

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Abstract. Deepening globalization has made the illegal wildlife trade a growing problem, and this paper uses modern information technologies, such as big data analysis and machine learning, for monitoring and evaluation, which are essential for understanding trade dynamics, predicting trends, and assigning responsibilities. This study uses Klein's comprehensive national power equation to establish a scoring system to select the countries or organizations with the most rights, resources, and interest in the management of illegal wildlife trade as the subject of behavioral implementation. Data-driven methods such as nonlinear regression, ARIMA time series forecasting, and the Random Forest algorithm were then used to demonstrate the relevance of the policies and actions of the study subjects to illegal wildlife trade management. The United States, with the highest score 93.0, 1.8 points higher than the second placed IUCN , was identified as the actor with existing policies and actions that are highly relevant to illegal wildlife trade management.

Keywords: illegal wildlife trade; machine learning; The United States; correlation.

1. Introduction

With the increase of industrialization and the gradual deepening of social capitalization, our reverence for nature is gradually declining, and the phenomenon of illegal wildlife trade is getting more and more intense, it is estimated that the annual amount of illegal trade is as high as 26.5 billion U.S. dollars, which is considered the fourth largest illegal trade in the world, and the illegal trade of wildlife not only endangers the ecological environment and public health safety, but also breeds a series of crimes such as illegal hunting and transportation, seriously disrupting social order[1]. For example, The demand for pangolin slices, meat, and skin from multiple countries around the world first caused a decline in the domestic population in China, and then fueled the illegal trade of pangolin in Southeast Asia, gradually spreading to more regions[2]. Therefore, effectively monitoring and combating illegal wildlife trade will become one of the major challenges facing the international community. In existing research, much literature has used data-driven methods such as big data analysis to analyze the characteristics of illegal trade in wildlife in a targeted manner, to identify problems, and to provide suggestions. For example, Chen Jimin[3]. and others used the snowball method to systematically sort out relevant literature and materials in the field of illegal trade in wildlife and crime research, comprehensively analyze the regulatory status and governance difficulties, and propose targeted suggestions. Wang Wenxia et al. analyzed and studied the smuggling of wild animals and their products in China over the past decade based on data released on the official website of the General Administration of Customs of China from 2008 to 2018. They identified problems and proposed suggestions for wildlife smuggling[4].

For this study, we use Klein's comprehensive national power equation to quantify the index of each country's trade protection, to determine which country or organization has made the greatest contribution or even the greatest possibility of trade protection; with this as the keynote, we not only use Pearson's correlation analysis to derive the correlation between the policy and the goal based on the existing data and literature, but also observe the functional relationships, add data and then use

ARIMA time series forecasting and the Random Forest algorithm to predict the results that the policy can yield, to have a correct expectation of the whole policy process.

2. Optimizing Client Selection for Effective Wildlife Protection

2.1. Model Introduction: Klein's comprehensive national power equation

Since the project we developed is more suitable for application in larger scenarios, to ensure the smooth implementation of the project, we have identified large-scale global animal protection organizations, national governmental agencies, and animal protection alliances consisting of multiple national agreements as our potential clients. We further conducted a comprehensive multi-dimensional user profile of potential clients, quantifying and comparing power, resources, and interest, and ultimately selected the right clients, i.e., the ones we believed would have the greatest positive impact on the realization of the project we developed. We have developed programs that identify potential clients with power and scale in this area of wildlife conservation that is greater than or equal to the power and investment of national governments in this area. Therefore, in our evaluation system, global organizations, national agencies, and multinational compacts will use a unified and improved Klein's comprehensive national power equation to measure the suitability of the client. Cline's National Power Equation refers to the formula proposed by the American scholar Ray.S. Cline in his 1975 book The Evaluation of World Power, which provides a comprehensive assessment of a nation's power:

$$P_0 = (C_0 + E_0 + M_0) \times (S_0 + W_0) \tag{1}$$

C_0 is Critical Mass, E_0 is Economic Capability, M_0 is Military capability, S_0 is Strategic Purpose, and W0 is Will to Pursue National Strategy. The scoring criterion is that the country with the largest value of each indicator, or the United States, is given a standardized score, and other countries are scored according to their ratio to the standardized country. counts the standardized score, and the other countries are scored according to their ratio to the standardized country:

$$t_i = \frac{t}{t_0} \times 100 \tag{2}$$

Klein's evaluation method of comprehensive national strength has taken a key step in the index system and quantitative analysis and has had a great influence on the subsequent quantitative research of comprehensive national strength. Up to now, many scholars put forward the comprehensive national strength evaluation formula is still not completely out of its calculation model[5]. The comprehensive national strength assessment method is widely used and fits well with the capacity of different organizations in the management of illegal wildlife trade to be measured in this paper, we introduced Cline's National Strength Assessment Equation model into our client's assessment system[6], re-establishing the indicators for the assessment on a case-by-case basis:

$$P = (C + E + M) \times (S + W) \tag{3}$$

To simplify the scoring process for the potential clients, which include a large number of international organizations and countries, the urgency (i.e., the interest mentioned in the question) of wildlife conservation was used as a criterion for scoring the potential clients based on the newly established metrics, as it would be difficult to convince the client to invest significant human and financial

resources in the promotion of the project if the client body did not have a strong need for the project. We used the volume of wildlife trade in illegal imports and exports as a measure of the urgency of a country's government agencies to protect wildlife, and global conservation organizations as a standard volume. We made a hierarchical regional map of global import and export trade volumes from 2014-2023, from which we selected the top 20 countries in terms of trade volume and potentially assessed them to obtain scoring data.

2.2. Highest score under the Cline scoring formula: U.S

We used the volume of wildlife trade in illegal imports and exports as a measure of the urgency of a country's government agencies to protect wildlife, while global conservation organizations were noted as the standard measure. We made a hierarchical regional map of global import and export trade volumes from 2014-2023, from which we selected the top 20 countries in terms of trade volumes and potentially assessed them to obtain scoring data to make the colored map Figure 1.

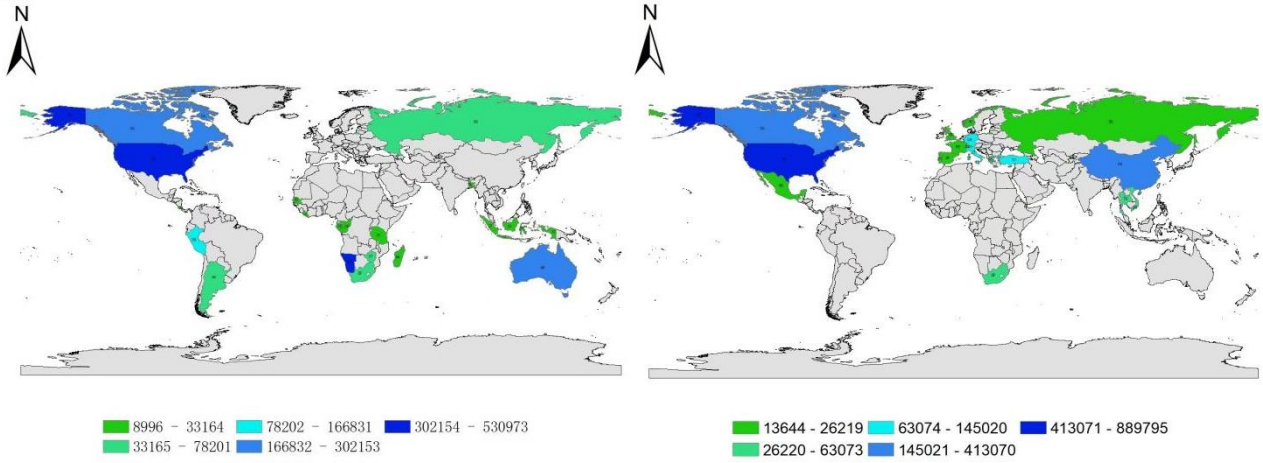

Figure 1. Distribution of exports and imports in illicit trade

From the two figures provided, We can see that the graph on the left shows the exports of countries around the world in the illegal wildlife trade. The shade of the color indicates the size of the export volume:

(1) The dark blue color represents the largest exporting countries, with a range of 302154 to 530973, indicating that these countries play a major exporting role in the illegal wildlife trade.

(2) The medium blue color represents countries with high export volumes, with a numerical range of 166,832 to 302,153, and these countries also have relatively high export volumes.

(3) The light blue and green colors represent countries with relatively small export volumes, corresponding to a range of 78202-166831 and 8996-33164, respectively, which indicates that these countries have a smaller export role in the illegal wildlife trade.

(4) The figure on the right looks at the number of imports for each country:

(5) The dark blue color represents the countries with the highest import volumes, with a range of 413071 to 889,795, which are the main destinations for illegal wildlife products.

(6) The medium blue color represents countries with high import volumes, with a range of 145021 to 413070, which are also relatively active in the illegal wildlife trade.

(7) The light blue and green colors represent countries with low import volumes, corresponding to a range of 63074 to 145020 and 13644 to 26219, respectively, indicating that those countries have low import volumes in the illegal wildlife trade.

By comparing the two graphs, we can approximate the distribution of data on the world's illegal wildlife trade to make our next score:

As can be seen from the scores in the Table 1, the U.S. government has a higher overall score compared to other organizations and countries, although the U.S. government's level of wildlife resources and personnel in the unit space is not outstanding compared to other organizations, it has a very high level of funding, personnel, and interest in the maintenance of the world's ecosystems, which is also mainly because the U.S. is currently in the position of being the number one country in the world, and it is a combination of political and economic factors. Role. At the same time, we also made bar charts and heat maps in Figure 2 to show the differences between the ratings of each organization and its performance in each project, and it can be seen that the U.S. government has a good rating in all aspects, which makes it the best client for us.

Most importantly, we have enough historical data to build a database and train models on illegal wildlife trade.

Table 1. Summary of Nations/Organizations Performance

Nations/Organizations	Wildlife Resources	Members	Fund	Policy	Urgency	Points
US	65	80	80.0	90	91.7	93.0
CN	55	100	100.0	73	23.2	53.7
Canada	48	77	86.0	82	44.8	60.4
South Africa	100	65	55.0	95	16.6	50.2
IUCN	60	60	65.0	100	95.4	91.2
CITES	60	56	72.3	96	75.0	82.2
WWF	60	60	70.0	88	60.0	70.0
Traffic	60	57	69.4	84	70.0	73.5

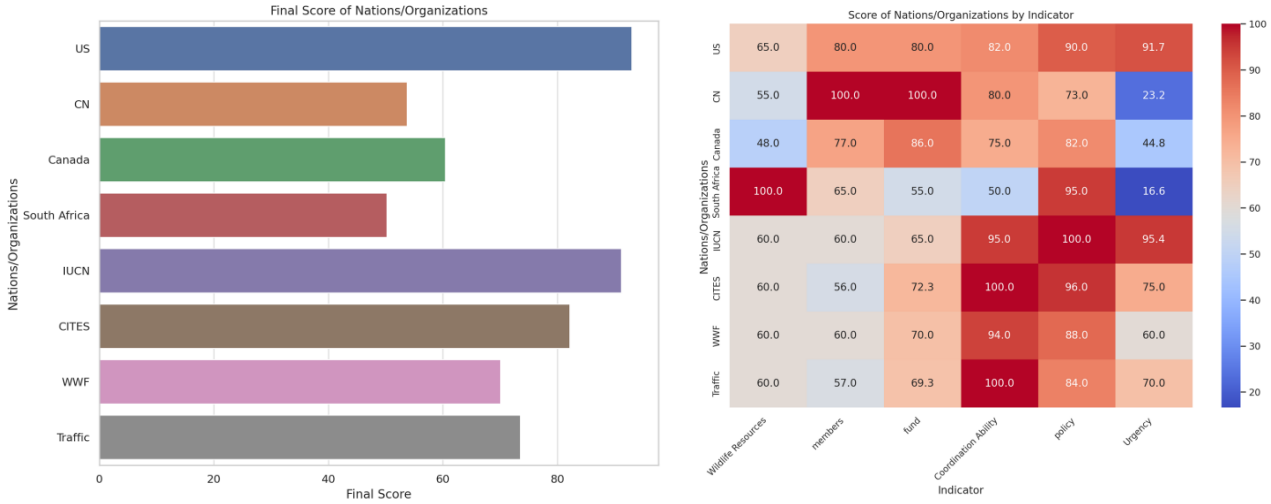

Figure 2. Histogram of composite scores for individual countries/organizations(left) and Heat maps of organizations/-countries(right)

3. Work done by the U.S. government has strong relevance to our program

3.1. An analysis based on literature and research

The U.S. employs a multi-faceted approach to managing illegal wildlife trade, enhancing knowledge through data analysis, bolstering enforcement against trade, and fostering international collaboration. Utilizing case databases with comprehensive metadata allows for effective measures against this networked, concealed trade. Precise, lawful, and sustainable data governance is crucial for analyzing and regulating wildlife trade to ensure data utility and effectiveness. These efforts support the U.S. government's objectives in combating illegal wildlife trade activities[7].

3.2. Illustrating the coherence of policy objectives using big data analysis

3.2.1. Background Introduction

1. Difficulties with statistics on illegal trade in wildlife

In China, for example, there are currently two main sources of data for illicit trade statistics, one being estimates based on confiscated quantities and the other using market surveys. However, because of the hidden nature of illegal trade, real illegal trade may not always be seized, and it is even more difficult to obtain complete data from market surveys, neither of these two methods can directly obtain the exact amount of illegal trade, seriously underestimating the amount of illegal trade that exists[8].

2. Data management and mining are critical to wildlife regulation

In the document *Analysis of Information Characteristics of Criminal Cases of Illegal Trade in Wild Animals*, to analyze the basic characteristics of the case, the textual features of the case are analyzed, and the valuable information is extracted according to the textual features through self-built thesaurus and programming, and this process is also known as the structured processing of the data. Firstly, the useful information features are extracted by natural language processing, to get the characteristics of the crime behavior. Then the types of animals attacked and the percentage of product types are analyzed, and then the visualization is used to intuitively analyze the case trends.

Similarly, in the document *Big Data: A Sharp Weapon for Protecting Wildlife and Animals*, the authors point out that in the process of police investigating the case of illegal trafficking of pangolins, the criminal gangs showed strong organization and anti-detection ability, which brought considerable difficulty in detecting the case. Therefore, the use of big data, the power of science and technology, and online platforms are utilized to assist in solving cases of illegal wildlife trade.

The wildlife trade is vast, the illegal wildlife trade is intermingled, and regulation of the illegal trade is difficult because the overall trade is so complex. Therefore, the United States Government, as one of the most powerful and resourceful organizations in the world, must reduce illegal trafficking and increase the benefits to people from the legal and sustainable trade in wildlife species, to reduce the international ecological and social-environmental damage caused by the illegal trade.

3. Coherence of policy objectives

Collecting data on the intensity of the U.S. government in terms of power, resources, and interest, a scatterplot was created and fitted to produce the corresponding functional relationship. Based on these functional relationships, data for all four indicators can be made up over the next five years. With the data of the indicators from 2000 to 2022, it is possible to make the trend of the number of illegal trades under the influence of the four indicators. Then the time series prediction is carried out, the influence of all indicators is taken into account, and the Random Forest algorithm is utilized to obtain the predicted data for the next five years, which is directly compared with the unaffected data, i.e., it can be concluded whether or not there is consistency in policy

3.2.2. Model introduction

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The U.S. Government's mandate to reduce illegal wildlife trade is reflected in the following data indicators: Enhanced real-time data monitoring. The U.S. government has now established an endangered species database and has initiatives in illegal trade data regulation, which is a good fit for this project. Through information query and data collection, the indicators of the development of the scale of illegal trade and the task of reducing illegal wildlife trade are quantified. Illegal trade data management is considered in terms of data integrity, standardization, real-time, accessibility, early warning capacity transparency, etc. Taking illegal trade data management as a benchmark, its score in terms of construction to strengthen real-time monitoring of data was obtained, and then, after reviewing the current status of the organization's database establishment and management, the grading of data construction was obtained under different levels of illegal trade data management. So we're going to use Spearman's correlation analysis to determine if the work done by the U.S. government is strongly correlated with the project we're going to undertake:

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}} \tag{4}$$

where r is the correlation coefficient and x and y represent the number of transactions and the number of people in the relevant part of the U.S. government's statistics, respectively

3.2.3. Finding Functional Relationships

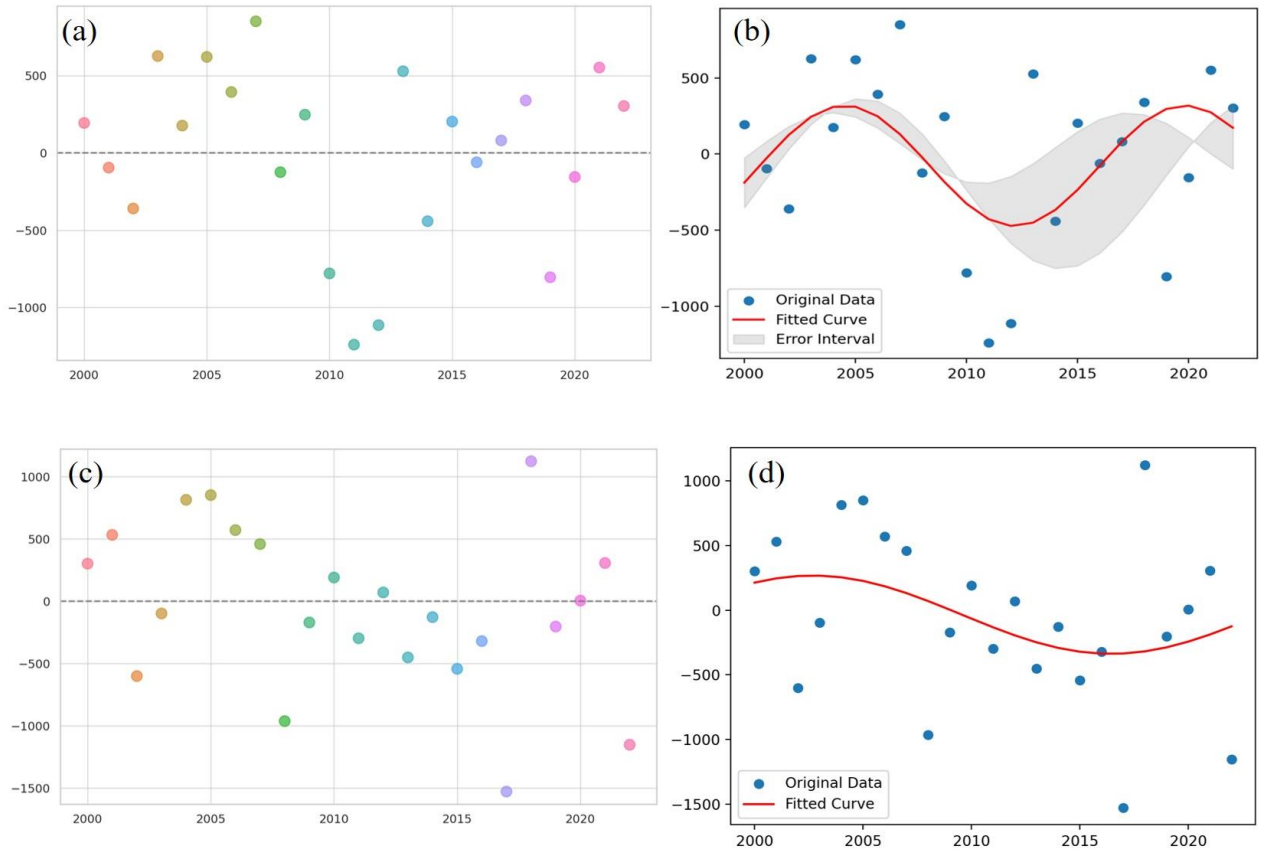

Figure 3. Indicators and fittings

Through the data given, it is possible to understand that the number of specimens traded in wildlife reaches more than billions annually. In terms of country distribution, the countries that have imported and exported the most wildlife in recent years are the Netherlands, the United States, and China. In the year 2022, the country with the highest number of specimens traded in wildlife, the Netherlands,

exported a total of 33,228,258 specimens[9] and imported a total of 5,901,4303 specimens. Wildlife specimens are traded in a variety of forms, the most numerous being the LIVE form. The global supply chain of wildlife provides livelihoods for hundreds of millions of the world's poor. At the same time, illegal trade - one of the world's most lucrative criminal activities - contributes to environmental degradation and economic loss. The wildlife trade is huge, the illegal wildlife trade is intermingled, and the regulation of illegal trade is difficult because the overall trade is too heterogeneous[10]. So we use the above ideas as a basis, we collected data on the strength of the U.S. government in terms of power, resources, and interest to produce a scatterplot, and found that there is a roughly cyclical mapping between indicators and years, as illustrated in the following eight graphs, the left-hand side is a scatter plot based on the data, and the right-hand side is a plot fitted using the python language. This left-right comparison provides a better visualization of the nature of the periodic function, from top to bottom, Rights1, Rights2, Urgency, and New Energy in Figure 3:

3.2.4. Adding data based on functional relationships

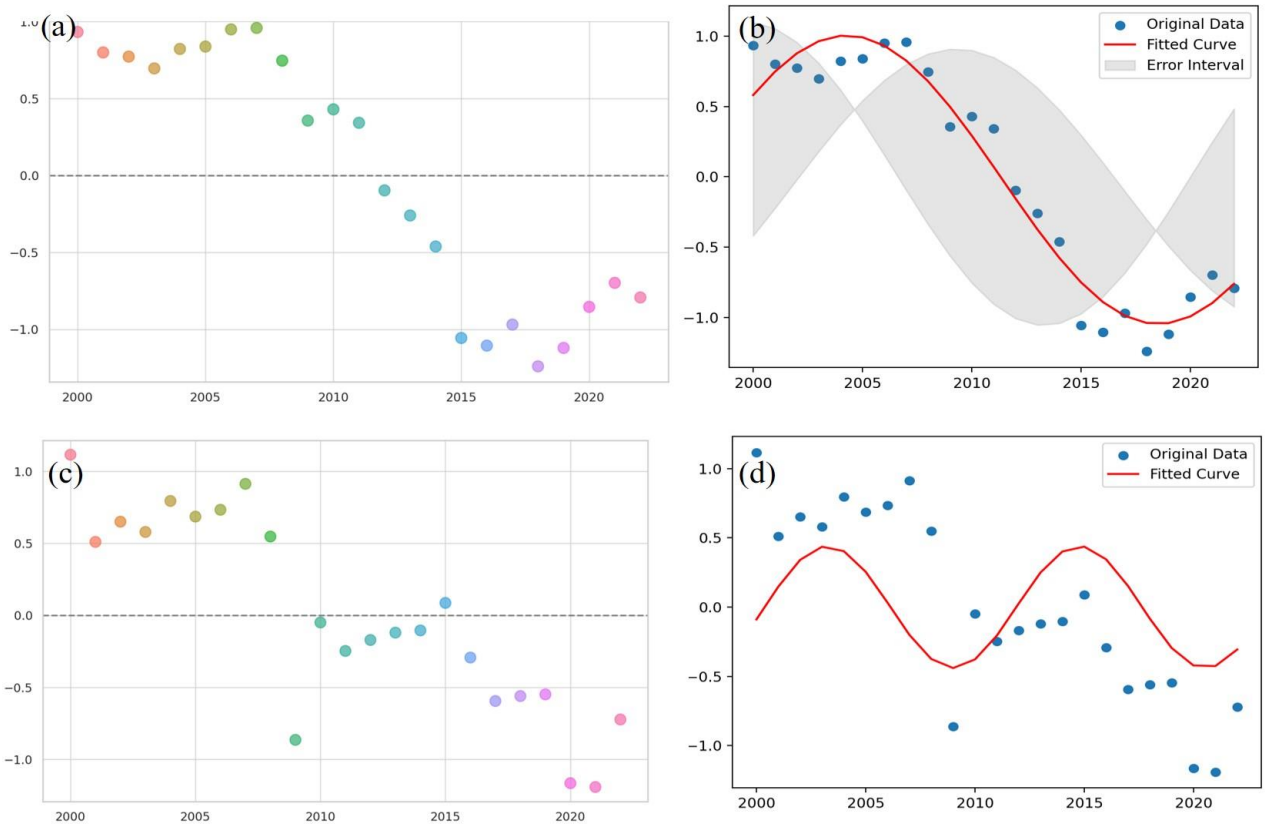

Figure 4. Indicators and fittings

Based on the above functional relationships, the data for all four indicators can be made up over the next five years. With the data of the indicators from 2000 to 2022, it is possible to make the development trend of the volume of illegal trade under the influence of the four indicators(Figure 4).

3.2.5. Forecasting Future Data Trends

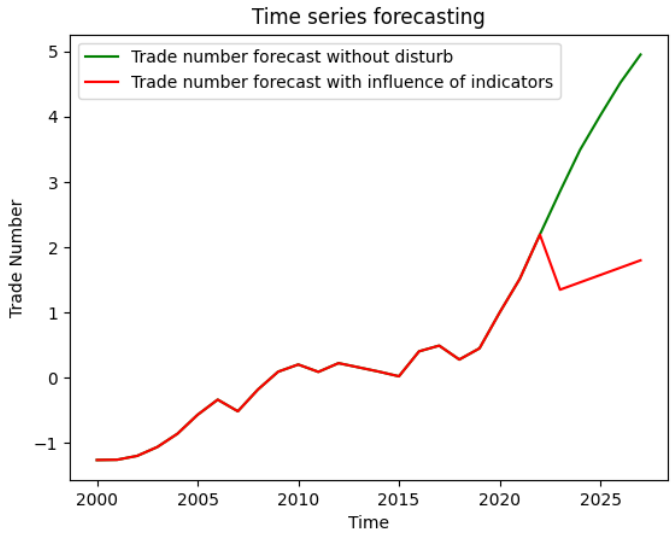

Figure 5. Time series forecasting

In the process of ARIMA time series forecasting, the impact of indicators is taken into account, and the Random Forest algorithm is used to obtain the forecast data for the next five years, which is compared with the data that is not affected by the direct forecast, and from the figure below, we can intuitively feel that the direction of the efforts of the measures taken by the U.S. government is precisely to reduce the illegal wildlife trade [11]. This is in line with our project concept, which is to establish a case database and conduct data mining to realize the efficient fight against illegal wildlife trade, as shown in the following Figure 5:

3.2.6. Spearman correlation coefficient

In addition, the relatively rich and detailed data in Cites is also largely due to the support of the U.S. government in all aspects of implementation and funding, which they have been doing for a long time, and according to the calculation of the Spearman correlation coefficient public, the correlation coefficient r is equal to about 0.76(According to the formula 4). It can be seen that the actions of the U.S. government in reducing illegal wildlife trade show a strong correlation with the amount of illegal wildlife trade, and their actions can effectively improve the management of illegal wildlife trade data.

4. Conclusions

In conclusion, this study has highlighted the growing problem of illegal wildlife trade in the era of globalization and demonstrated the effectiveness of modern information technologies, such as big data analysis and machine learning, in monitoring and evaluating this complex issue. By utilizing Klein's comprehensive national power equation, we have established a scoring system that allows us to identify the key countries or organizations with the most significant rights, resources, and interests in managing the illegal wildlife trade. Through advanced data-driven methods, including nonlinear regression, ARIMA time series forecasting, and the Random Forest algorithm, we have further validated the relevance of policies and actions undertaken by these actors, particularly the United States, which scored the highest with 93.0. Our findings underscore the importance of targeted and coordinated efforts in addressing the illegal wildlife trade, emphasizing the need for strengthened cooperation and policy implementation among key players to effectively tackle this global challenge. At the same time, it is important to underscore the need for a unified, global approach in fighting against such transnational challenges. As the world becomes increasingly interconnected, it is imperative that nations work together, sharing resources, intelligence, and best practices to effectively combat illegal activities that threaten our biodiversity and ecological balance. The future of wildlife conservation depends on our collective ability to leverage technology and cooperation to protect our planet's precious resources.

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