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Research on Reducing the Number of Illegal Animal Trade Based on Machine Learning and Comprehensive Assessment Modeling

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Abstract: This paper explores strategies to reduce illegal animal trade by leveraging machine learning and comprehensive assessment modeling. Using data from the World Bank and the World Justice Project, the study focuses on the financial capacity, human resources, legal integrity, and interest in wildlife conservation of the top ten GDP countries. Employing the TOPSIS evaluation model with entropy weight method, the United States is identified as the most influential nation in combating wildlife trade. Further analysis through Pearson correlation and DEA confirms the negative impact of illegal trade on economic and social indicators. LSTM neural network projections predict a significant reduction in illegal wildlife trade with the implementation of targeted programs, highlighting the potential of strategic interventions in protecting ecosystems and promoting sustainable development.

1. Introduction

Illegal wildlife trade is a global problem that not only threatens biodiversity but also has far-reaching negative environmental, social and economic impacts [1]. With the development of global economic integration and internet technology, the forms and scales of illegal wildlife trade are constantly changing, bringing new challenges to combating and preventing such activities [2]. Therefore, studying how to effectively reduce illegal wildlife trade and protect wildlife resources has become a focal point of concern for the international community [3].

This study aims to explore effective strategies for reducing illegal wildlife trade through machine learning and comprehensive assessment modeling methods. We have selected the top ten countries by GDP as the research subjects. These countries not only have significant economic influence but also play a demonstrative role in law, policy, and international cooperation. By conducting an in-depth analysis of these countries' financial capacity, human resources, rule of law, and interest in wildlife conservation, we hope to identify the key factors affecting illegal wildlife trade and assess the capabilities of various countries in combating it. In terms of research methodology, we have employed the entropy weight method and the TOPSIS evaluation model [4]. These methods can objectively and scientifically assess and compare the performance of different countries in combating illegal wildlife trade. Additionally, we have used Pearson correlation analysis and Data

Envelopment Analysis (DEA) to explore the relationship between illegal wildlife trade and economic and social development indicators [5, 6]. Finally, through the LSTM neural network prediction model, we have predicted the trend of illegal wildlife trade over the next five years and evaluated the potential impact of implementing related projects on reducing illegal wildlife trade [7].

2. Identifying the Target Client

2.1. Data visualization

We have collected the total GDP of all countries in the world from the official website of the World Bank, and we believe that a country's financial capacity is the core driving force in combating illegal wildlife trade. A country can deploy its own resources through financial resources, improve its legal enforcement capacity, promote research on key technologies related to wildlife conservation, and strengthen cooperation with other countries to combat illegal wildlife trade. Therefore, we selected the top ten countries in terms of GDP from 2011 to 2022 as the main target of our project. We further collected data on the total GDP of these ten countries from 1989 to 2021 and drew a radar chart of the data, as shown in Figure 1.

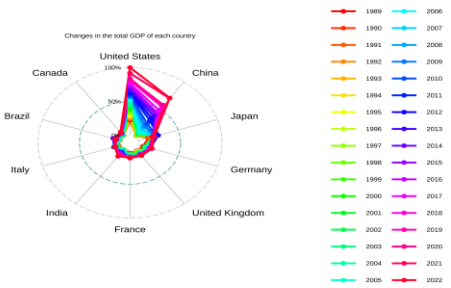

Figure 1: Radar chart of total GDP for top ten countries (1989-2021).

As can be seen in Figure 1, the total GDP of the United States and China shows a steady growth pattern after 2009 and is much higher than the other eight countries. Therefore, we tentatively believe that the U.S. and China are more capable of providing greater assistance to our program development in terms of financial capacity.

Human resources play an important role in carrying out wildlife conservation education and awareness-raising activities, and promoting cross-sectoral international cooperation. We chose to measure countries' human resources using the World Bank's Human Capital Index for Countries, as well as the total population of each country, which takes into account factors such as education level, health status, and labor market information, and can be used as a comprehensive assessment of a country's human resources. When the human resources index is close to 1, it usually indicates that a country has a high level of human resources, and the total population reflects the size of a country's available labor force, we collected the human resources index of each country from 2017 to 2018, and averaged the human resources index of each country for two years.

As shown in Figure 2, we similarly collected data on the total population of each country from 1960 to 2022 as shown in Figure 3.

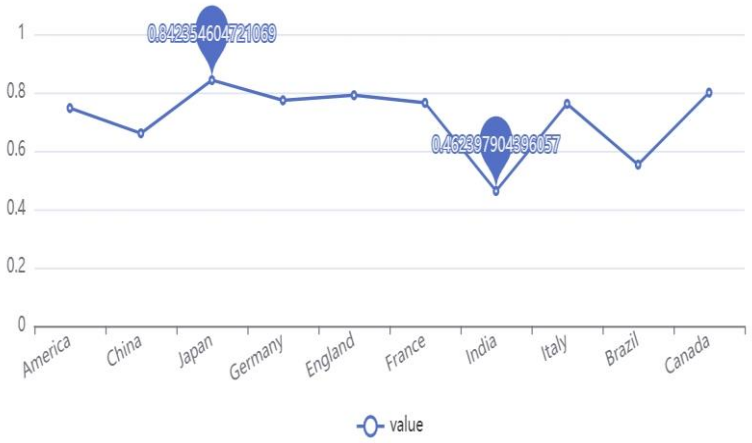

Figure 2: Human capital index of top ten countries (2017-2018).

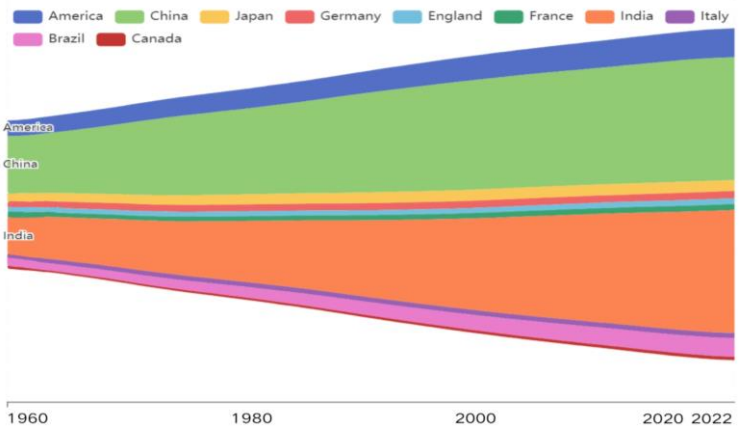

Figure 3: Total population of top ten countries (1960-2022).

From Figures 2 and 3, we can see that the United States and China not only have a higher level of HRI but also have a higher population than other countries, so these two countries not only have a more abundant labor force but also have a higher level of HRI. Though India's population is higher, its HRI is lower. This means that India's human resource level is not very high. From the above analysis, we tentatively think that the US and China can better help our project in terms of human resource room.

A high level of rule of law in a country is critical to combating illegal animal trade and provides the basis for developing strong laws, strengthening enforcement capacity, promoting international cooperation, and establishing monitoring mechanisms. We counted the number of laws and regulations related to illegal animal trade in each country until 2023 and collected the WJP Rule of Law Index for each country in 2023 from the official website of the Wolrd Justice Project. A higher number of laws and regulations usually indicates that the country has a higher level of concern about illegal animal trade and has developed a corresponding legal framework, while the Rule of Law Index measures the level of the rule of law in a country, including the implementation of the law, the independence of the judiciary, and corruption, etc. A higher Rule of Law Index means that a country has a stronger law enforcement agency and a better ability to enforce the law. Figure 4 shows a graph of the extent of the WJP Rule of Law Index for each country in the world, while Figure 5 shows a bar chart of the WJP Index and the number of relevant national laws for the ten target countries.

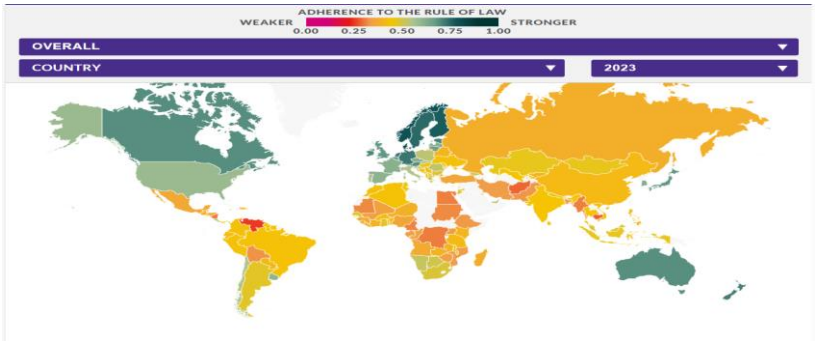

Figure 4: WJP rule of law index global insights.

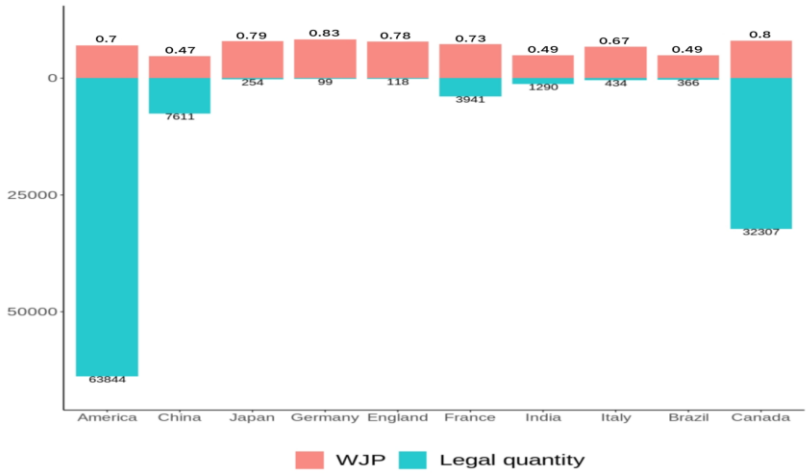

Figure 5: Comparison of WJP index and laws against illegal wildlife trade.

From Figures 4 and 5, we can see that the level of the WJP index in the United States is in the medium-high level, and the number of laws against illegal wildlife trade is much higher than that of other countries. Therefore, we can initially believe that the United States has a high level of rule of law and law enforcement in wildlife protection, and can provide solid legal support for our project.

If a country has a strong interest in protecting wildlife and ecosystems, it will take proactive steps to combat illegal wildlife trade. We collected the number of initiations of activities related to opposing illegal wildlife trade and the number of agencies fighting illegal wildlife trade in each country until 2023, as shown in Figures 6, respectively. The Sustainable Development Goals index SDGs of each country were also collected from the official website of the United Nations, as shown in Figure 7. The number of launching activities related to opposing illegal wildlife trade can reflect the specific actions and initiatives taken by a country in opposing illegal wildlife trade, and the number of agencies combating illegal wildlife trade indicates the country's willingness and determination to combat illegal wildlife trade. The Sustainable Development Goals Index (SDGs) reflects a country's overall efforts towards sustainable development, including its interest in and commitment to combating illegal wildlife trade. We use these three indices to measure countries' interest in wildlife conservation.

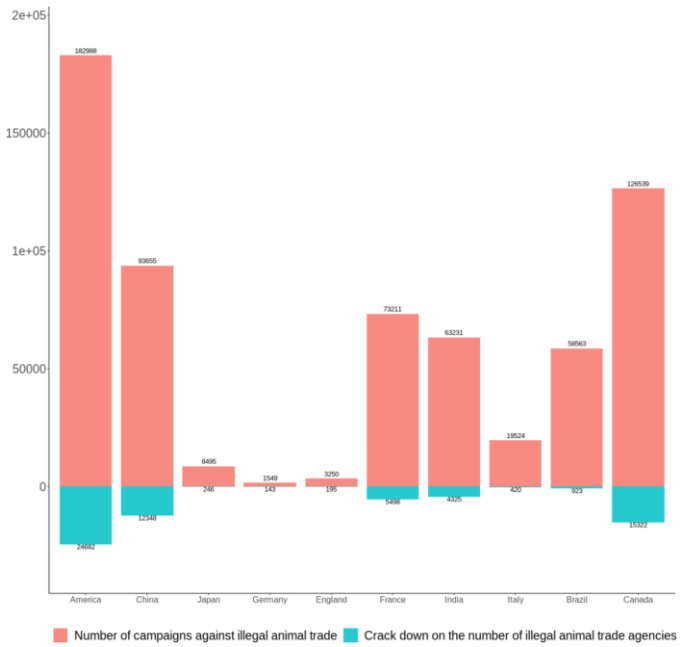

Figure 6: Initiatives and agencies combating illegal wildlife trade.

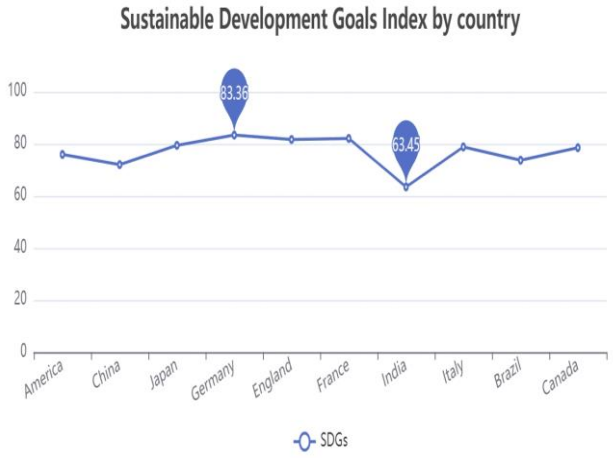

Figure 7: Sustainable development goals (sdgs) index

Based on the above graphs, we conclude that the SDGs index of the United States is at a medium-high level compared to other countries, while the number of related organizations and the number of related activities are much higher than other countries, so we initially believe that the United States has a high interest in joining the fight against illegal wildlife trade.

Taking into account the results of the visualization of financial resources, legal integrity, human resources, and interest data, we have made a preliminary decision that the U.S. would be the best choice for our project against illegal wildlife trade.

2.2. TOPSIS evaluation model based on entropy weight method

In order to further justify our decision, we weighted and summed the WJP indices and the number of relevant laws of each country in 2023 by the entropy power method to obtain a composite score of the power of each country in opposing illegal animal trade. Similarly, by doing the same operation on the total population and human resource index of each country in 2022, we

can get the comprehensive score of each country in terms of human resources against illegal animal trade, and correspondingly, we can get the comprehensive score of each country in terms of interest in opposing illegal animal trade.

Positive assessment indicators are handled through formula (1) and negative assessment indicators are handled through formula (2)

$$z_{ij} = \frac{X_{ij} - X_{min}}{X_{max} - X_{min}} \tag{1}$$

$$z_{ij} = \frac{X_{max} - X_{ij}}{X_{max} - X_{min}} \tag{2}$$

Calculate the entropy of the Jth indicator:

$$e_j = -k \sum_{i=1}^{n} p_{ij} \ln(p_{ij}), j = 1, ..., m \tag{3}$$

Calculate the information entropy redundancy (variance):

$$d_j = 1 - e_j, j = 1, ..., m \tag{4}$$

Calculate the weights of the indicators:

$$w_j = \frac{d_j}{\sum_{j=1}^{m} d_j}, j = 1, ..., m \tag{5}$$

Calculate the gap between each evaluation indicator and the optimal and worst vectors:

$$D_i^+ = \sqrt{\sum_{j=1}^{m} w_j \left(Z_j^+ - z_{ij}\right)^2}, \quad D_i^- = \sqrt{\sum_{j=1}^{m} w_j \left(Z_j^- - z_{ij}\right)^2} \tag{6}$$

Measuring the proximity of the evaluation object to the optimal solution.

$$C_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{7}$$

Through this model, we obtain the weights of each index such as the SDGs index and the WJP index, and also obtain the evaluation matrix of each country's financial resources, power, legal system, human resources, and interests, and then analyze the entropy weight method of the four indicators of each country's financial resources, legal system, human resources, and interest to obtain the respective weights of these four indicators, and finally obtain the final ranking through the TOPSIS evaluation method as shown in Table 1 below.

Table 1: Topsis evaluation results.

Country	America	China	Japan	German	England	India	Italy	Brazil	Canada	French
Final Score	0.65	0.60	0.10	0.09	0.07	0.40	0.04	0.04	0.33	0.15
Rankings	1	2	6	7	8	3	9	10	4	5

The results obtained from this model are in general agreement with the conclusions obtained from our visualization, and therefore we believe that the U.S. government would be the best person to target in our fight against the illegal wildlife trade.

3. Assessment of Illegal Wildlife Trade in the U.S.

3.1. Analysis of the Illegal Wildlife Trade Situation in the United States

Our interest measure for the United States calculated before is 0.963156367, which is at a high level, so we believe that the United States has a strong willingness to participate in our program against illegal wildlife trade. Based on the number of threatened wildlife species in the U.S., we can conclude that the U.S. is still not doing enough to protect wildlife, and the number of threatened wildlife species in the U.S. is still as high as 382. There is no doubt that the illegal wildlife trade will have a detrimental effect on the economic development and ecosystem of the United States, and through our program we can help the United States to protect more species of wildlife and reduce the amount of illegal wildlife trade in the United States in the next five years.

3.2. Pearson Correlation Analysis

We conducted a Pearson correlation analysis of the U.S. SDG index, total population, illegal wildlife trade, and GDP growth rates from 2000 to 2022 with the following equations, and plotted a manpower diagram of the correlation coefficients matrices, as shown in Figure 8.

$$r = \frac{\sum_{i=1}^{n}(X_i - \overline{X})(Y_i - \overline{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \overline{X})^2}\sqrt{\sum_{i=1}^{n}(Y_i - \overline{Y})^2}}. \tag{8}$$

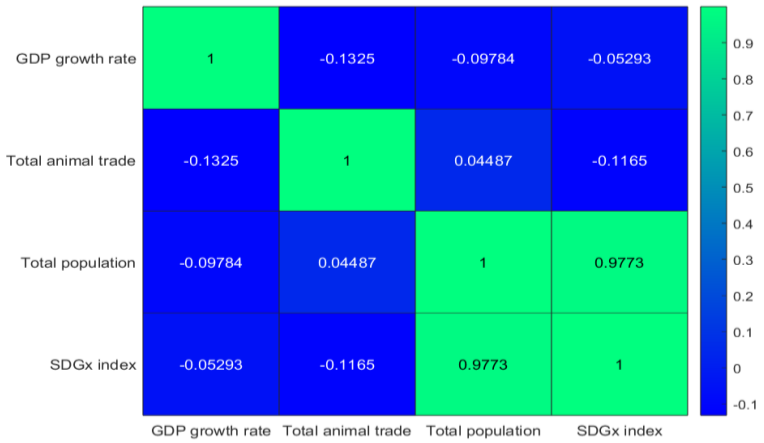

Figure 8: Correlation analysis of U.S. illegal wildlife trade with economic and social indicators.

Through the heat map, it is easy to see that the SDGs index, total population, GDP growth rate and the number of illegal animal trade in the U.S. all show a negative correlation, which is basically consistent with the reality, and these three indicators correspond to the degree of the construction of

sustainability, the total labor force, and the degree of economic development of the United States. Therefore, through our project, we can reduce the illegal wildlife trade in the United States in the next five years, which will increase the construction of sustainability, the labor pool, and the economic development rate of the United States.

3.3. DEA of the Volume of Illegal Animal Trade

We believe that a highly developed ICT infrastructure can facilitate information sharing, monitoring and control of the illegal wildlife trade, that a good rail network can enhance the ability of law enforcement to patrol and monitor border areas, and that increased public spending on education can increase social awareness and understanding of wildlife conservation, thereby reducing the demand for illegal wildlife and its products. We collected data from 2000 to 2020 on the percentage of U.S. information and communication technology (ICT) service exports relative to total service exports, the total kilometers of railways, the percentage of public spending on education relative to GDP, the percentage of natural resource rents relative to GDP, the percentage of merchandise trade relative to GDP, and the quantity of animals in U.S. wildlife trade. Using the quantity of animals in U.S. wildlife trade as the output variable, we employed the BCC data envelopment analysis method with the other five factors as input variables to assess the impact of these factors on the volume of illegal wildlife trade in the United States.

If there are n production decision-making units DMUj(j=1,2,... ,n), each DMU has m items of inputs Xj=(x1j,x2j,... ,xmj),s items of output Yj=(y1j,y2j,... ,ysj), we can get the technical efficiency assessment model of the j0th DMU as follows (1), and get the scale efficiency assessment model as (2), (X0,Y0) are the inputs and outputs of the DMU j0, E is Archimedean infinitesimal, and e is the unit vector.

$$\begin{aligned} max \quad & (\mu^T Y_0 - u_0) \\ s.t. \quad & mu^T Y_j - \omega^T X_j - \mu_0 \leq 0 \\ & \omega^T X_0 = 1 \\ & \omega \geq \varepsilon, \mu \geq \varepsilon, \mu_0, isfree \end{aligned} \tag{9}$$

Through this model, we obtained the values of technical benefits, scale benefits, and combined benefits corresponding to the number of illegal wildlife traded in the U.S. by these five factors in each year, as shown in Figure 9.

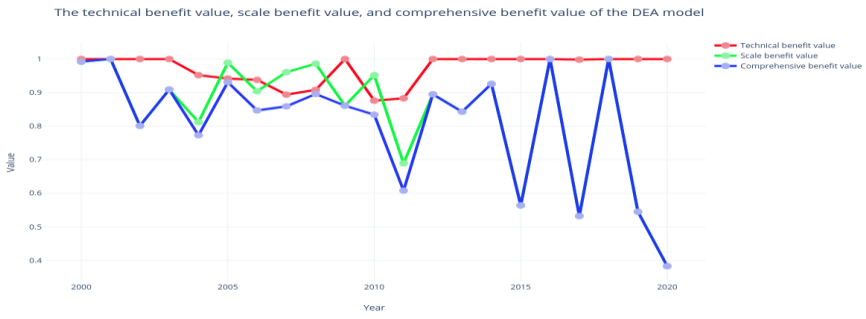

Figure 9: Box plot analysis of data outliers and distribution.

From the Figure 9, we can conclude that the overall comprehensive benefit curve shows a decreasing trend, which indicates that as the country increases resource input or expands the scale in the field of illegal animal trade, the benefit does not increase accordingly, that is to say, these five factors do not have a contributing effect on the increase in the number of illegal wildlife trade in the United States. In other words, it means that with the increase of resource inputs and the expansion

of scale, these five factors can effectively reduce the number of illegal wildlife trade in the U.S., which also verifies our viewpoint.

4. Predicting Wildlife Trade Impact

In our project, we hope to reduce the number of illegal wildlife trade in the United States in the next five years by combining the factors such as the financial strength, manpower, and power of the United States, which have favorable effects on combating illegal animal trade. We use the elements mentioned in the above question such as U.S. financial strength, manpower, and power, as well as the amount of illegal wildlife trade in the U.S. from 2000 to 2022 as the input variables in the input layer of the LSTM neural network, and these input data can be organized into the form of a time series, where each time step represents the input information at a specific point in time, and the inputs at each time step contain multiple features (e.g., financial strength, manpower, power, etc.), the quantity of illegal wildlife trade in the next five years is used as the output layer of the LSTM neural network, an LSTM memory unit as well as that is shown in Fig. 10, and Fig. 11 represents how the data flows through the memory unit and is controlled by its gates.

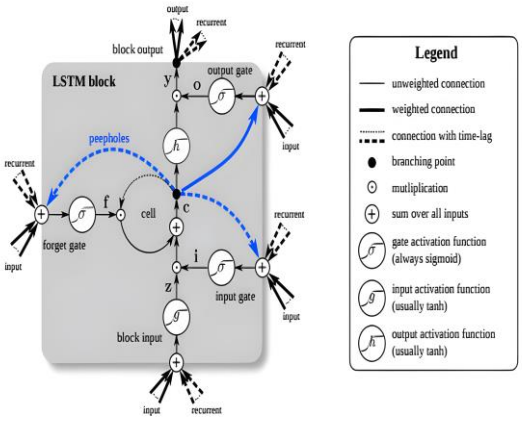

Figure 10: LSTM network architecture.

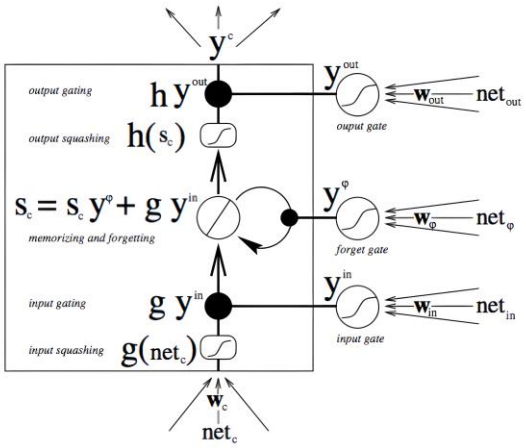

Figure 11: LSTM memory cell dynamics.

Using the model we derived projections for the U.S. illegal wildlife trade for the next five years under two scenarios, one for the likely change in the amount of illegal wildlife trade in the U.S. over the next five years without our program as shown in Figure 12, and one for the likely change in the amount of illegal wildlife trade in the U.S. over the next five years with our program as shown in Figure 13, and the RMSEs and R-squares for the two projections are shown in the Table 2.

Figure 12: Projected illegal wildlife trade without intervention.

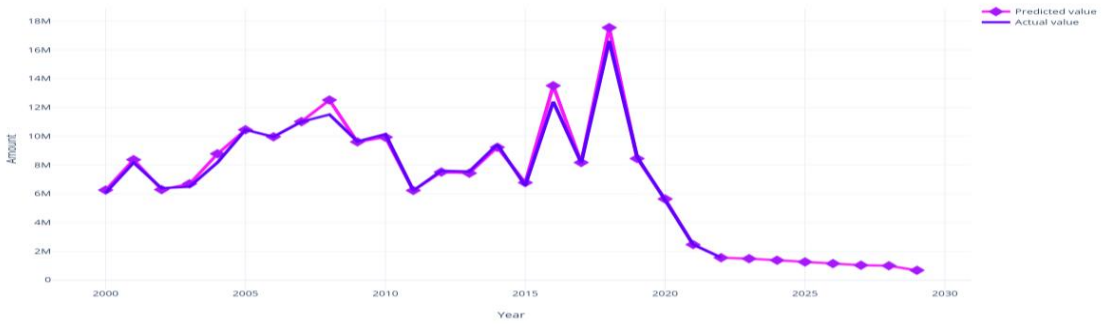

Figure 13: Projected illegal wildlife trade with program implementation.

Table 2: Evaluation of predicted results.

RMSE	404022.1661	373538.8208
R-square	0.984034518	0.986352813

From the RMSE and R-square values in the table we believe that the results of the two predictions are more valid, and from the graph we can conclude that without carrying out our project, probably due to the huge economic benefits involved in illegal wildlife trade, inadequate enforcement efforts, and people's lack of sufficient understanding of the impacts and consequences of the wildlife trade, the number of illegal wildlife trade in the U.S. in the next five years will show With our program, the number of illegal wildlife traded in the U.S. in the next five years will be at a lower level and the overall trend of illegal wildlife trade will be slowly decreasing due to our program's scientific combination of U.S. manpower, financial, and educational factors used to combat the illegal wildlife trade, and we believe our program has a significant effect on reducing the number of illegal wildlife traded. Therefore, we believe that our program will have a significant effect in reducing the number of illegal wildlife trade.

5. Conclusions

This study has evaluated the capabilities of the top ten global GDP countries in combating illegal wildlife trade through the entropy weight method and the TOPSIS evaluation model. The results indicate that the United States stands out in terms of financial capacity, human resources, legal integrity, and interest in wildlife protection, making it a key nation in the fight against illegal animal trade. Further Pearson correlation analysis and Data Envelopment Analysis (DEA) reveal a negative correlation between illegal trade and economic and social development, underscoring the importance of reducing illegal trade for sustainable development. The LSTM neural network prediction model shows that implementing our project will significantly reduce the number of illegal wildlife trades in the United States over the next five years. This suggests that a scientific combination of financial, human, and educational resources can effectively reduce illegal animal trade and protect wildlife resources.

The findings of this study provide a scientific basis for policymakers, highlighting the critical roles of international cooperation, law enforcement, and public education in combating illegal animal trade. We believe that these strategies will contribute to global wildlife protection and sustainable development.

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