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Optimization Research on Natural Resource Management in China through Multi-Model Comprehensive Evaluation

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Abstract: As global awareness of ecological protection increases, illegal wildlife trade has become a focus of international attention that threatens biodiversity and public health safety, with China's conservation measures having a significant impact on the effectiveness of global wildlife conservation. This paper proposes an innovative five-year wildlife conservation program for wildlife conservation measures. This paper applies hierarchical analysis and portfolio evaluation model to screen the project object and takes the Guangdong Province Natural Resources Department as the object. Finally, the number of wildlife smuggling cases is compared before and after the project implementation through a comprehensive prediction model, and it is found that the project has reduced the number of wildlife smuggling cases by more than 20% each year. Therefore, the project has a good effect on wildlife protection.

1. Introduction

With the deterioration of the global ecological environment and increased awareness of natural resource protection, the issue of illegal wildlife trade is receiving increasing attention from the international community. Illicit wildlife trade not only threatens biodiversity but also poses a major challenge to animal welfare and global public health security. As a major biodiversity country, China's strategy and effectiveness in wildlife conservation and combating illegal trade have a direct impact on the effectiveness of global wildlife conservation efforts. To combat illegal wildlife trade more effectively, this paper utilizes data analysis to develop a scientifically sound and intelligent five-year plan and applies assessment and prediction models for various analyses. liu et al on the intelligent means of wildlife research[1]. To plan the specific measures for this project, this paper conducted a study of China's Web-Based Promotional Publications (WBPB), Enforcement Feedback on Wildlife Conservation (EFOWC), UAV Market Volume (UAVMV), Mobile Robotics Market Volume (MRMV), Function, and Functionality (F) for the period of 2008 to 2022. Volume (UAVMV), Mobile Robotics Market Volume (MRMV), Fine (F), and Number of Wildlife Smuggling Cases (NOWSC) were visualized and analyzed, and the average of the change rate of the first five variables was taken as the effect of the project. The average rate of change of the first five variables was taken as the effect of the project, and the average rate of change of NOWSC was taken as the project expectation of the project.

In this paper, this paper uses a hierarchical analysis algorithm and entropy weight combination weighting method to screen the project implementation targets. liu et al use hierarchical analysis to classify the functions of nature reserves[2]. yang et al use the entropy weight combination weighting method in the field of natural resources protection analysis[3]. The article also utilizes the ARIAM prediction algorithm and ridge regression algorithm to make predictions on several variables. zhu et al apply the ARIMA algorithm to the study of carbon emissions[4], and li et al also apply the ARIMA algorithm to the analysis of the illegal smuggling and trade of wildlife[5].

To determine the implementation target of the project, this paper first uses the hierarchical analysis method to screen the natural resources protection units at the three levels of world level, national level, and provincial level, and the results show that the provincial nature protection unit is the optimal level. Then, this paper uses the portfolio evaluation method to screen 31 provincial nature conservation units and finally selects the Guangdong Province Nature Conservation Office as the optimal target. Finally, this paper uses the combined prediction model to make a prediction assessment of the model.

2. Resource Department Selection and Evaluation

2.1 Data Collection

The data sources for this study are shown in Table 1:

Table 1: Source of data

Data Source	Website
National Bureau of Statistics	https://www.stats.gov.cn/sj/ndsj/
National Data	https://data.stats.gov.cn/easyquery.htm?cn=C01
Guangdong Provincial Public Security Bureau	https://gdga.gd.gov.cn/xxgk/sjtj/content/post-3247749.html
State Forestry and Grassland Administration	https://www.stats.gov.cn/fw/bmdcxmsp/bmdcxmml/202302/t20230215-1906974.html
China Labor Yearbook	https://cnki.nbsti.net/CSYDMirror/trade/Yearbook/Single/N2021020042?z=Z001

2.2 Selection of Client-Level

For the selection of project counterparts, this paper performed a hierarchical screening process. First, this paper used the hierarchical analysis method to filter out which level of natural resource management our project applies to at the world, national, and provincial levels, as follows:

This peper sets the Selection of Object Level as the target layer, Popular Attention, Implementation Effectiveness, Local Impact, and Wildlife Smuggling Crackdown as the criterion layer, and put the World Society for the Protection of Animals, National Ministry of Natural Resources, and Provincial Ministry of Natural Resources as the program level to establish the evaluation system is shown in Figure 1:

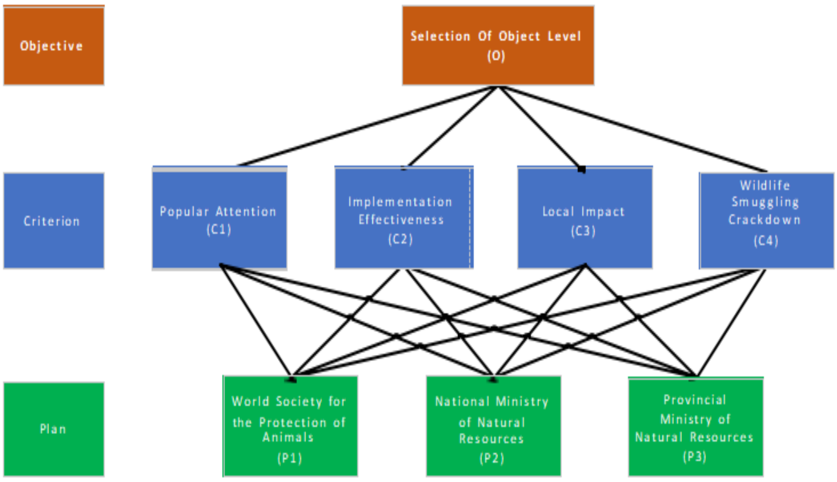

Figure 1: Distribution of Wildlife Nature Reserve

This paper collected data by collecting questionnaires and applied the data to the criterion layer for two-by-two comparisons to construct a judgment matrix is shown in Table 2:

Table 2: O-C Judgment Matrix

O	C1	C2	C3	C4
C1	1	4	2	2
C2	$\frac{1}{4}$	1	$\frac{1}{2}$	$\frac{1}{2}$
C3	$\frac{1}{2}$	2	1	1
C4	$\frac{1}{2}$	2	1	1

For the criterion layer, this paper compares the scenario layer two by two, collect data through questionnaires, and construct a judgment matrix is shown in Table 3:

Table 3: C-P Judgment Matrix

C_1	P_1	P_2	P_3	C_2	P_1	P_2	P_3
P_1	1	$\frac{1}{2}$	$\frac{1}{8}$	P_1	1	$\frac{1}{2}$	$\frac{1}{4}$
P_2	2	1	$\frac{1}{4}$	P_2	2	1	$\frac{1}{2}$
P_3	8	4	1	P_3	4	2	1
C_3	P_1	P_2	P_3	C_4	P_1	P_2	P_3
P_1	1	$\frac{1}{4}$	$\frac{1}{8}$	P_1	1	2	2
P_2	4	1	$\frac{1}{2}$	P_2	$\frac{1}{2}$	1	1
P_3	8	2	1	P_3	$\frac{1}{2}$	1	1

This paper does consistency checks on each of our early enough judgment matrices with the following operational formula:

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{1}$$

where CI is the consistency index, λmax is the maximum eigenvalue of each judgment matrix, and n is the order of each judgment matrix.

$$CR = \frac{CI}{RI} \tag{2}$$

Where, CR is the consistency ratio, which can be used to measure whether the judgment matrix passes the consistency test, if CR<0.1, then the judgment matrix passes the consistency test.RI is the average stochastic consistency index, the value of this index is related to the matrix order n, and the value of RI is shown in Table 4:

Table 4: The Value Of RI

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R I	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.49	1.52	1.54	1.56	1.58	1.59

Using the eigenvalue method, this paper calculated the consistency coefficients for each judgment matrix as Table 5:

Table 5: The value of CR

CR1	0.027
CR2	0
CR3	0
CR4	0

So, the judgment matrices this paper constructed all pass the consistency test and this paper can proceed to the next step of computation.

This paper weights the judgment matrix with the following formula:

$$\omega_i = \frac{\left(\prod_{j=1}^{n} a_{ij}\right)^{\frac{1}{n}}}{\sum_{k=1}^{n}\left(\prod_{j=1}^{n} a_{kj}\right)^{\frac{1}{n}}}, \quad (i = 1, 2, \cdots, n) \tag{3}$$

Where ω_i is the magnitude of the weights and $\left(\prod_{j=1}^{n} a_{ij}\right)^{\frac{1}{n}}$ is the process of multiplying the judgment matrices by the rows and opening $\frac{1}{n}$ to the sub-vectors. $\sum_{k=1}^{n}\left(\prod_{j=1}^{n} a_{kj}\right)^{\frac{1}{n}}$ denotes the process of normalizing the new vectors, and the result of the computation is the weight values.

This paper derives the object rank weight case as shown in Figure 2:

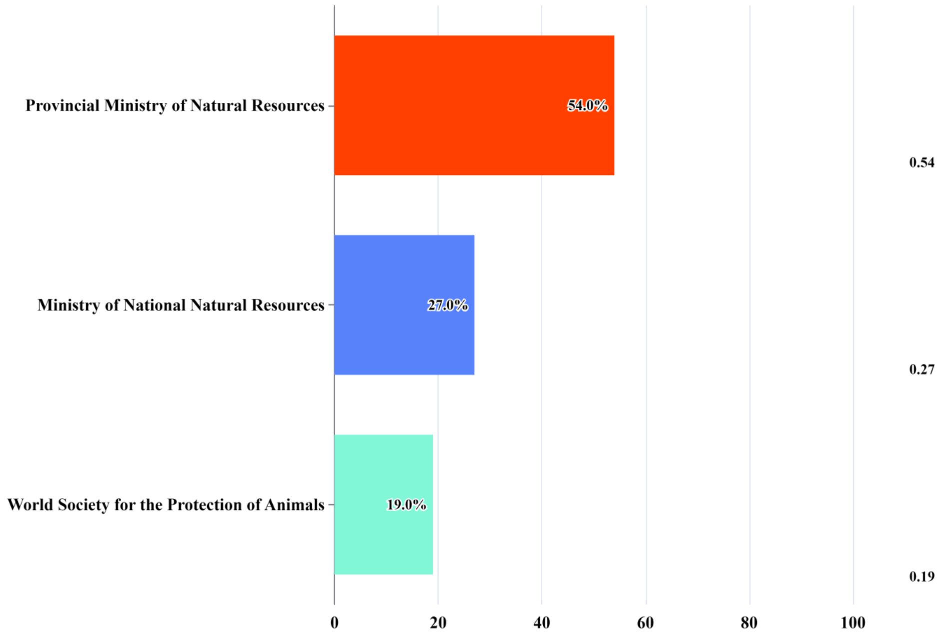

Figure 2: The object rank weight case

2.3 The Selection of Provincial Ministry of Natural Resources

After selecting the institutional hierarchy, this paper identify the provincial natural resource offices as the optimal targets to be used for the project, and next, this paper uses the CRITIC-Entropy-Topsis method to filter the best targets among the provincial natural resource offices in the 31 provinces.

2.3.1 Weighted Combination of CRITIC and Entropy Method

Next, this paper have to consider setting scientific and reasonable weights for several indicators, such as the amount of technology trading market, financial income, population density, the area of the nature reserve, and the number of smuggling cases, and this paper chooses to set the weights by using the method of combining CRTIC and Entropy Method. CRITIC weighting is a method of comprehensively measuring the objective weights of the indicators based on the comparative strength of the evaluation indicators and the conflict between the indicators. The method of objective weights of the indicators reflects the relative importance and conflict between the factors to measure the return of the indicators. The entropy Method is a weight allocation method based on information theory, which sets the weights of indicators according to the amount of information of each indicator and can fully reflect the diversity of indicators. Combining the two, the weight value of the combination of the two is defined as Portfolio weights (Portfolio weights), and the calculation formula[6] is as follows:

$$w_p = \beta w_1 + (1-\beta) w_2, \beta \in [0,1] \tag{4}$$

This calculation integrates the conflict and independence between indicators, making the weights more scientific and reasonable. This paper use Figure 3 to represent our calculation idea:

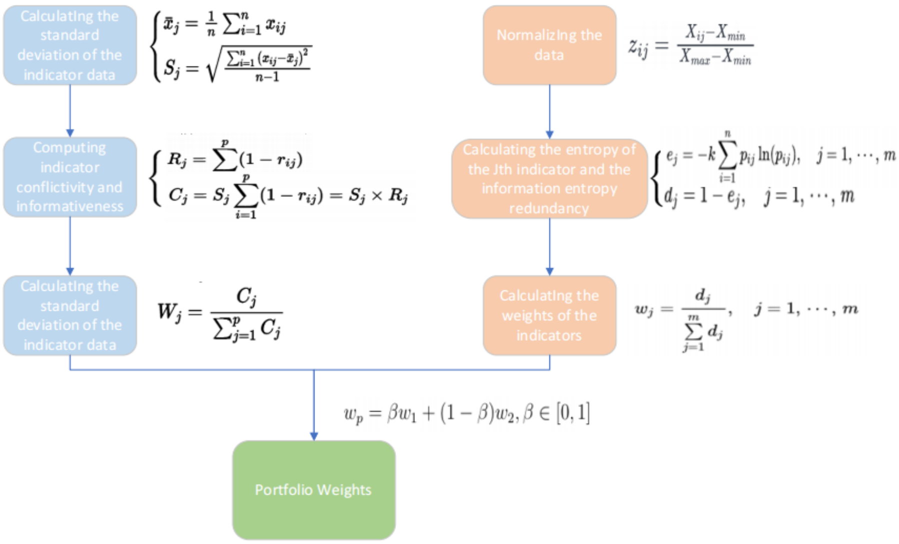

Figure 3: Calculation idea

As shown in Figure 3, the weight combination is essentially a weighted sum of two methods, CRITIC and Entropy method, which are calculated in Table 6:

Table 6: The results of the calculations

Indicator	CRITIC	Entropy Method	Portfolio weights
Population Density	30.15864	0.23283	0.19574
Area of nature reserves	0.00362	0.10192	0.05227
Technology market turnover	0.34076	0.22040	0.28058
Fiscal revenues	0.48714	0.11900	0.30307
Number of wildlife trafficking cases	0.00985	0.32584	0.16785

2.3.2 The Selection of Client Based on Portfolio Weights-Topsis

After scientifically determining the weights of each indicator, this paper establishes The Model of Client Selection based on TOPSIS.TOPSIS method is an effective multi-objective decision analysis method and a commonly used method. Its basic principle is to calculate the distance between the evaluation object and the positive and negative ideals. The closer to the positive ideal, the more superior the indicator is. This paper combines Portfolio weights to rank 31 provinces for Topsis comprehensive evaluation with the following steps:

This paper performs a matrix construction of the data for the five main indicators:

$$\begin{vmatrix} 436 & 8 & 2875.45 & 3589.14 & 10 \\ 1333 & 2 & 7947.51 & 5714.36 & 12 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 612 & 11 & 2435.07 & 8039.85 & 57 \\ 389 & 6 & 559.47 & 2103.42 & 0 \end{vmatrix} \tag{5}$$

This paper defines the positive ideal distance (Z^+) and the negative ideal distance (Z^-) using the following equations:

$$Z^+ = (Z_1^+, Z_2^+, \cdots, Z_m^+) = (\max\{z_{11}, z_{21}, \cdots, z_{n1}\}, \cdots, \max\{z_{1m}, z_{2m}, \cdots, z_{nm}\}) \tag{6}$$

$$Z^- = (Z_1^-, Z_2^-, \cdots, Z_m^-) = (\min\{z_{11}, z_{21}, \cdots, z_{n1}\}, \cdots, \min\{z_{1m}, z_{2m}, \cdots, z_{nm}\}) \tag{7}$$

Where n is the number of indicators and m is the number of data for the indicator.

This paper normalizes the indicator matrix using the following equation:

$$z_{ij} = \frac{X_{ij} - X_{\min}}{X_{\max} - X_{\min}} \tag{8}$$

This paper defines the distance between all the data in the normalized matrix of the five indicators and their respective maximum values (D_j^+) and the distance from the minimum distance(D_j^-) as follows

$$D_j^+ = \sqrt{\sum_{i=1}^{n} w_i \times (Z_i^+ - z_{ij})^2} \quad (i = 1, 2, \cdots, n) \tag{9}$$

$$D_j^- = \sqrt{\sum_{i=1}^{n} w_i \times (Z_i^- - z_{ij})^2} \quad (i = 1, 2, \cdots, n) \tag{10}$$

This paper quantitatively assessed each indicator for each province, and the formula for calculating the indicator scores is as follows:

$$G_j = \frac{D_j^-}{D_j^+ + D_j^-} (j = 1, 2, \cdots, m) \tag{11}$$

where G_j denotes the comprehensive evaluation score obtained by each province.

Using the above formula, this paper analyzed the Topsis comprehensive evaluation for each of the 31 provinces, and the higher the ranking, the more suitable the provincial Department of Natural Resources (replaced by the name of the province) is for our project, as ranked in Table 7:

Table 7: The result of Topsis

Name	Positive Ideal Distance(D^+)	Negative Ideal Distance(D^-)	Aggregate Score Index	Ranking
Beijing	0.626765824	0.598195691	0.488338355	3
Fujian Province	0.859777548	0.173339175	0.167782759	16
Gansu Province	0.945872191	0.100872668	0.096367961	25
Guangdong Province	0.479772483	0.742434381	0.607453945	1
until 1959, Guangxi province	0.913304476	0.128536648	0.12337452	21
Guizhou Province	0.92233243	0.090194645	0.089078749	27
Hainan Province	0.9558838	0.059092223	0.058220314	28
Hebei Province	0.842881426	0.189969857	0.183927599	14
Henan Province	0.827366151	0.203774467	0.197620444	13
Heilongjiang	0.921589258	0.235918103	0.20381564	12

province				
Hubei Province	0.790519625	0.260944168	0.248172281	9
Hunan Province	0.807028637	0.235905938	0.226194379	11
Jilin Province	0.951933283	0.112540681	0.105724221	23
Jiangsu Province	0.672968506	0.441399524	0.396098517	4
Jiangxi Province	0.878119406	0.147459197	0.143781468	19
Liaoning Province	0.874471586	0.148548469	0.145205823	18
Inner Mongolia Autonomous Region	0.911343596	0.172831369	0.159412802	17
Ningxia Hui autonomous region	0.973515187	0.041131831	0.040538069	30
Qinghai Province	0.985960577	0.027632844	0.027262257	31
Shandong Province	0.695794288	0.372182916	0.348493315	6
Shanxi Province	0.904966795	0.143502286	0.1368684	20
Shaanxi Province	0.795687203	0.269725581	0.253165332	7
Shanghai	0.532994181	0.607043589	0.532476734	2
Sichuan Province	0.805267914	0.269880634	0.251017066	8
Tianjin	0.845222381	0.184955203	0.179537204	15
Xizang Autonomous Region	0.990903075	0.043790054	0.042321779	29
Uighur Autonomous Region	0.947582932	0.095854051	0.091863767	26
Yunnan	0.917657678	0.120074003	0.11570814	22
Zhejiang Province	0.682002092	0.386073024	0.361466172	5
Chongqing	0.913470597	0.100986098	0.099546978	24
Beijing	0.626765824	0.598195691	0.488338355	3
Fujian Province	0.859777548	0.173339175	0.167782759	16

As can be seen from the above rankings, our final selected Client is the Guangdong Provincial Department of Natural Resources. The Guangdong Provincial Department of Natural Resources is an official organization that manages wildlife resources, and the organization has strong financial resources, which provides a deep foundation for the implementation of our project. It is also located in Guangdong Province, which is densely populated and rich in human resources, which is conducive to the implementation of the first year's initiative to increase public awareness; Guangdong Province has a high level of technology, which is conducive to the implementation of the second year of the drone monitoring program and the fourth year of the mobile robot capture project; the agency has a close relationship with the provincial government and the provincial public security department, which is conducive to the implementation of the third year of the program to strengthen the supervision of the law and the fifth year of the program to increase the amount of fines.

3. Project Adaptability and Predictive Analysis

3.1 The Construction of the Ridge Regression Model

Ridge regression is a type of regression method and belongs to statistical methods. It is also known as weight decay in machine learning. Ridge regression mainly solves two kinds of problems: one is when the number of predictor variables exceeds the number of observed variables, and the other is when there is multicollinearity between data sets, i.e., correlation between predictor variables. In general, ridge regression is used to solve the problem of multicollinearity in OLS, and below this paper analyzes the data for OLS constructs as well as linear regression.

This paper takes the number of illegal wildlife smuggling cases as the dependent variable (y), the number of wildlife science publications as x1, the market size of drones as x2, the number of online platforms-enforcement opinions as x3, the market size of mobile robots as x4, and the number of fines as x5. This paper constructs a linear relationship for each indicator as follows:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \mu \tag{12}$$

Where μ is an unobservable and completely random perturbation term, β_0 is a constant term, and $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$ are linear regression coefficients.

This paper performed a joint significance test on the regression coefficients βi in front of the five independent variables to get with the VIF test, and the results are as shown in Table 8:

Table 8: Results of linear regression analysis

Indicator	Unstandardized Coefficient		Standardized Coefficient	t	P	VIF	R^2	Adjusted R^2	F
	B	Standard Error	Beta						
Constant	62.81	7.406	-	8.481	0.000***	-	0.975	0.964	F=91.925 P=0.000***
WBPB	-0.005	0.003	-0.576	-1.628	0.129	58.91			
EFOWC	-0.001	0.001	-0.254	-1.005	0.335	30.189			
UAVMV	-0.009	0.024	-0.247	-0.388	0.705	191.746			
MRMV	0.045	0.134	0.171	0.334	0.744	123.817			
F	0	0	-0.113	-0.704	0.495	12.197			

From the above Table, this paper can see that the significance P-value is 0.00031, which presents significance at the level and rejects the original hypothesis that the regression coefficient is 0, so the model meets the requirements. But VIF>10, so the model exists multicollinearity, so this paper uses ridge regression notation for further analysis.

Next, this paper uses the ridge regression idea for β with the following formula:

$$\hat{\beta}^{\text{bridge}} = \operatorname{argmin}_{\beta} \left\{ \sum_{i=1}^{N} \left(y_i - \beta_0 - \sum_{j=1}^{p} \beta_j x_i \right)^2 + \lambda \sum_{j=1}^{p} \beta_j^2 \right\} \tag{13}$$

Where $\sum_{i=1}^{N} \left(y_i - \beta_0 - \sum_{j=1}^{p} \beta_j x_i \right)^2$ are the regression coefficients computed by using the Least Square method, and the Ridge Regression computation is followed by a penalization term i.e., with $\lambda \sum_{j=1}^{p} \beta_j^2$ in the penalization term being the parameter to be sought.

This paper visualizes the results as Figure 4 and Figure 5:

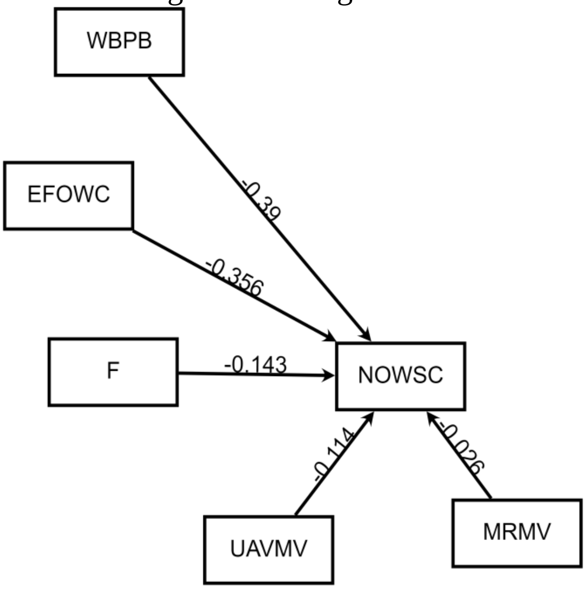

Figure 4: Variable weighting path diagram

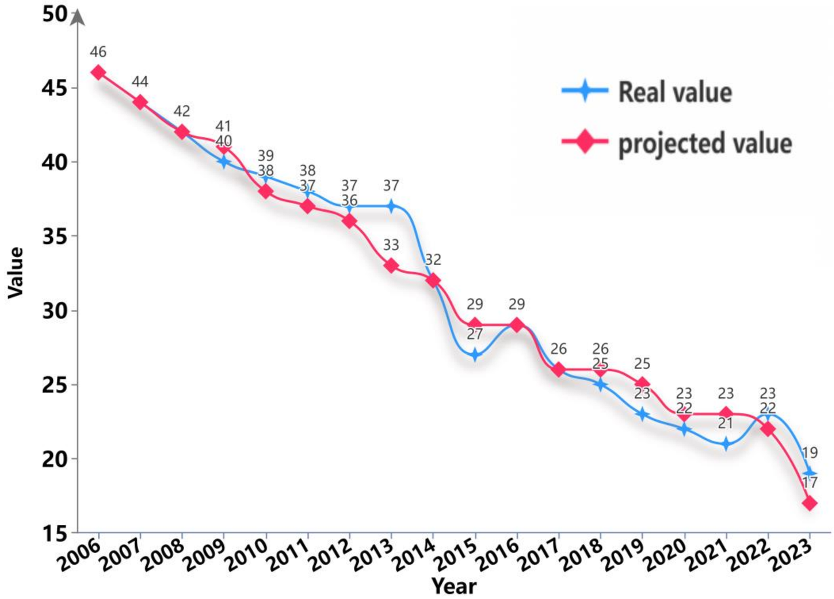

Figure 5: Model results graph

3.2 Combination of ARIMA and Ridge Regression

Having derived the ridge regression equation, this paper now projects the data for the five measures corresponding to the indicators and the number of illegal wildlife trafficking cases using the time ARIMA algorithm to predict the data for the five years 2024-2028. Then the project was implenmented on the data of 2024, adjust the indicators accordingly, and then use this as the basis to predict the data of the five indicators in 2025-2028 using the ARIMA algorithm, and finally bring the data of each year into the regression equation to get the number of cases of illegal wildlife trafficking in the years of 2024-2028, and then this paper compares and analyzes the data of the cases that have not implemented the project with the data of the cases that have implemented the project. The case data from the unsimple- mentioned project and the implemented project were then compared and analyzed to derive the percentage change and quantify the effect of the project. After ARIMA forecasting, this paper substitutes the ARIMA data for the five indicators after the implementation of the program into the regression equation to find the NOWSC for the calendar year, and then analyze it in comparison with the ARIMA forecasted data for the NOWSC without the program, which this paper represent in the following picture:

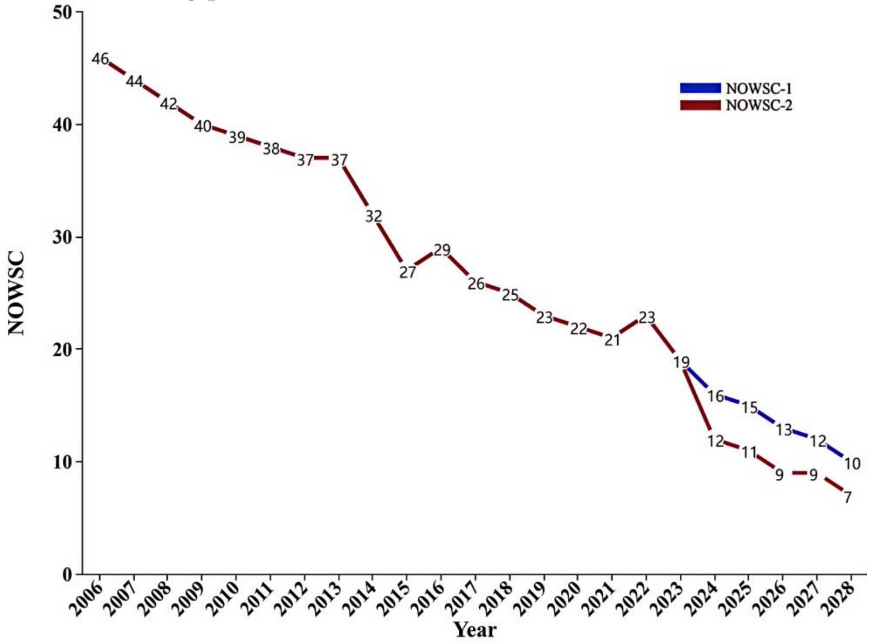

Figure 6: Comparative chart of changes in the number of NOWSC

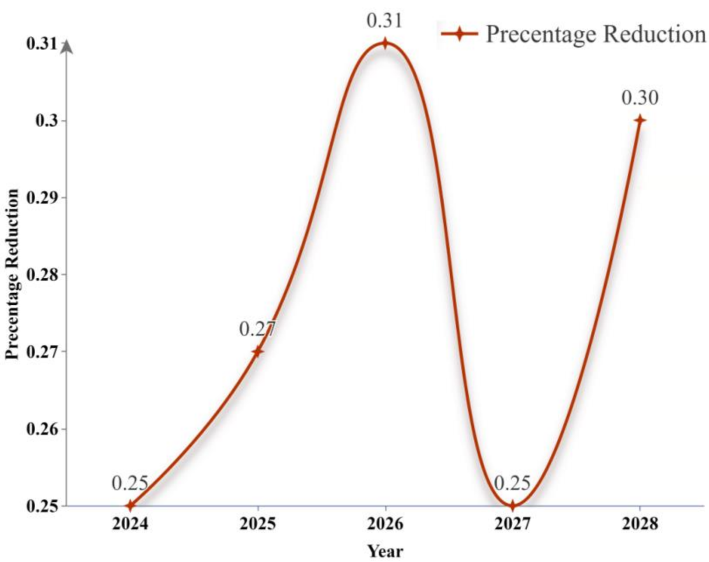

Figure 7: Precentage Reduction of NOWSC

NOWSC-1 in Figure 6 shows the curve of change in NOWSC before implementation of the project. NOWSC-2 shows the curve of change in NOWSC after implementation of the project. Figure 7 reflects the percentage decrease in NOWSC after implementation of the project relative to NOWSC without implementation of the project. This paper shows that after the implementation of the project, NOSWC decreased more than 20% each year, so this project has excellent results.

4. Conclusions

This paper predicts the number of smuggling cases after the implementation of the project through a comprehensive prediction model and finds that after the implementation of the project, the number of smuggling cases in Guangdong Province has decreased significantly by more than 20%, so this project has a high value of implementation. This study reveals innovative projects that can help to effectively combat wildlife smuggling. This paper provides a research idea and framework applied to the field related to wildlife protection and proves the feasibility of the methodology.

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