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Study on the management program of Massai Mara national reserve based on indicator analysis

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Abstract. The Maasai Mara National Reserve is rated as one of the seven natural wonders of Africa and one of the ten wonders of the world. To reduce the impact of human activities on wildlife and further consolidate the balance between humans and nature, this paper proposes a research analysis method for the Massai Mara National Reserve. First, the influencing factors were divided into four indicators: wildlife, economy, resident life and non-animal resources. For these four indicators, eight main factors are further divided, including employment, native resource destruction, poaching, injuries to personnel, crop destruction, causing dissatisfaction among tourists, revenue brought in by tourists, the cost of conserving biological resources. The relationship between these factors and indicators produced the influence on the number of visitors and the development trend of human footprint. Subsequently, the reasons for these important indicators are analyzed, and corresponding solutions are put forward, such as strengthening the management of protected areas, expanding the scope of protected areas, and formulating unified charging standards.

Keywords: Reserve; Scheme design; Maasai Mara; Game Analysis.

1. Introduction

Kenya is in eastern Africa, most of which is highland, and only the coastal areas are plains. The Maasai Mara National Reserve borders Tanzania's Northern National Park and is in the southwest of Kenya. The Maasai Mara National Reserve has been expanded several times and covers an area of 1510 square kilometers [1].

The Maasai Mara National Reserve is famous as one of the most important wildlife reserves in Africa. The area is rich in natural resources and diverse animal species, and before environmental awareness became widespread, the area was a "poachers' paradise". Roan Antelope was once one of the most widely distributed antelope in Africa, but due to poaching and habitat expansion [2], Roan Antelope has become locally extinct in the Maasai Mara National Reserve [3]. To better protect the diversity of species and maintain the balance of the food chain and ecological environment, the area was transformed into a game reserve in 1961. The Kenya's parliament passed the Wildlife Conservation and Management Act in 2013 and has continued to develop and improve on this basis to maintain harmony in the Maasai Mara region [4-8]. So, it's necessary to find alternative ways to manage resources within and beyond the boundaries of the Maasai Mara National Protected Area, not just primarily concerning economic growth [9-10]. Based on the background above, this paper has conducted a specific discussion and analysis, including the specific: Provide specific policy and management strategies for people living near protected areas to mitigate human impacts and reduce negative interactions between animals and attracted people. Rank according to the strategies and management methods, find the optimal solution, considering the economic impact. This paper also gives specific reference policies regarding the adjustment of natural resource and human-interaction areas based on the mathematical modelling and analysis implemented in the paper.

2. Process Analysis:

2.1. Symbols instruction

Symbol Definition Instruction is shown in table 1.

Table 1. Symbol Definition Instruction

Symbol	Definition
A	Wildlife
B	Economy
C	Resident life
D	Non-animal resources
E	Number of tourists
J	Employment
K	Native resource destruction
N	Poaching
P	Injuries to personnel
Q	Crop destruction
R	Causing dissatisfaction among tourists
S	The area occupied by human activities
T	The management system of protected areas is not perfect
W	Revenue brought in by tourists
Z	The cost of conserving biological resources
$r_{(ij)}$	The correlation of the ith independent variable index to the jth dependent variable index, i=1,2,j=1,2,3,4
$g_{(j)} / h_{(j)}$	The correlation weights of the first and second independent variable indicators to the jth dependent variable index j=1,2,3,4, respectively
$F_{(ij)}$	In the $\lceil j/2 \rceil$ dependent variable indicator, the impact of E and S changes corresponding to the ith policy on this indicator
$L_{(ij)}$	The magnitude of the impact of the ith policy on the jth indicator
Y	Calculate the equation for the E and S trends
U	Model 2 calculates the combined impact of the two independent variable indicators on the dependent variable indicators in each policy

Note: The symbol A, B, C, D are the dependent variable, and the symbol D, E are the argument. And every symbol passed through unity unification, the range is zero to one.

2.2. Clustering abstract of factors and relationships and specific policy and management strategies list

Step 1: Four impact indicators

The influencing factors of the Maasai Mara National Reserve are divided into 4 indicators that influence and balance each other.

A: Wildlife. The protection of wildlife is an important factor, and only on this premise can human beings better balance the relationship between animals and people.

B: Economy. While protecting wildlife, it is also necessary to ensure the reasonable interests of the residents near the reserve, that is, economic income.

C: Resident life. When seeking development and protection,pay attention to the living environment of people.

D: Non-animal resources. Natural resources are fundamental to the survival of people and animals.

Step 2: Eight impact factors

For the 4 indicators divided in step 1, there are 8 main subdivided impact factors. Employment(J), Poaching(N), Injuries to personnel(P), Crop destruction(Q), Causing dissatisfaction among tourists(R), The management system of protected areas is not perfect(T), Revenue brought in by tourists(W), The cost of conserving biological resources(Z). These eight factors together determine the development trend of Number of tourists(E) and The area occupied by human activities(S).

Step 3: Cause analysis

After analyzing the reasons for the four important indicators proposed in step 1, three influencing reasons under each indicator are proposed , and the effects (increases or decreases) of the 8 factors and 4 indicators in step 2 are counted according to the influencing causes. The trend is changed by "-" for "decrease" and "+" for "increase".Performance statistics table for eight factors are shown in table 2.

Table 2. Performance statistics table for eight factors

Four impact indicators	Reason	J	K	N	P	Q	R	W	Z
A	The management system of protected areas is not perfect (T)	-	+	+	+	+	+	-	+
	Development of wildlife hunting tourism (N)	+	+	+				+	+
	Human activities lead to habitat loss (K)		+		+	+			+
B	Customer satisfaction is not high (R)	-					+	-	
	Unsafe tourist destinations (T)	-			+		+		
	The charges are unreasonable (R)			+			+	+	
C	Vigorously develop tourism (J)	+	+	-		+		+	
	The quality of life of nearby residents has decreased (P&Q)			+	+				+
	Environmental pollution (K)		+				+	-	+
D	The tourism infrastructure is not perfect (R)	-	+		+	+	+	+	
	Human activities destroy natural resources (K)		+		+		+		+
	Environmental education is missing (K&T)		+	+			+		+

Step 4: Calculation results

The different factor changes caused by each cause in step 3 are calculated. E and S are analyzed. The result is the calculation in Table 3. The calculation formula is:

$$Y_i = \sum a_i \left(a = J, K, N, P, Q, R, W, Z, i = 1,2,3,...,12\right) \quad (1)$$

Among them, Y represents the equation that calculates the change in the trend of E and S, and i represents the ranking of the 12 causes in Table 3 from top to bottom.

Table 3. E and S trends

Reason	E	S
1	-	
2	+	+
3	+	+
4	-	
5	-	-
6	-	-
7	+	+
8	-	-
9	-	-
10	-	
11		-
12		+

*1 to 12 represent the top to bottom ranking of the 12 reasons in Table 2.

*The impact of empty space is too small to be considered.

Depending on the area of use, the Maasai Mara National Reserve is divided into 5 regions. They are: Water source protection areas, Animal reserves, Buffer zones, Development areas and Unused areas.

Based on the calculation results obtained in Table 4, a corresponding strategy is proposed. The results are as follows:

Table 4. Policy results map

Reason	Areas of influence	Policy
1	Water source protection areas, Animal reserves	Strengthen the management of protected areas and establish and improve laws and regulations [5].
2	Development areas	Increase the recreational hunting area to satisfy the desire of travelers for hunting [4].
3	Buffer zones, Unused areas	Expand the area of protected areas to provide a better living environment for wildlife.
4	Water source protection areas, Animal reserves	Reduce commute time and plan your route wisely [4].
5	Development areas	Raise the overall image and strive to create a safe and peaceful atmosphere [4].
6	Water source protection areas, Animal reserves	Strengthen the control of fees and formulate unified fee standards.
7	Unused areas	Increase the proportion of online tourism and pay attention to online promotion.
8	Buffer zones	Increase compensation for damage caused to residents.
9	Water source protection areas, Animal reserves, Development areas	Supervise residents and foreign tourists to do a good job in environmental protection.
10	Unused areas	Increase the cooperation of the Ministry of Tourism with other stakeholders [6].
11	Development areas	Control the scope of human activities and take the sustainable development route.
12	Water source protection areas, Animal reserves, Development areas	Awards are given to those who have made outstanding contributions to environmental protection [7].

*1 to 12 represent the top to bottom ranking of the 12 reasons in Table 2.

2.3. Method of combined analysis of quantitative data and district community index construction

The collected relevant data is processed in the same way so that they can effectively represent the six variable indicators A, B, C, D, E, and S, and the data are displayed as Table 5 by using the ratio of each value to the maximum value of these values to represent the corresponding values under each of these values.

Table 5. Normalized Data

	2013	2014	2015	2016	2017	2018	2019	2020	2021
A	1.000	80.2%	54.5%	60.9%	71.7%	81.3%	83.2%	84.0%	86.7%
B/hundred million	60.607 0.635	55.303 0.580	64.409 0.674	72.189 0.756	78.965 0.827	87.779 0.919	95.503 1.000	60.400 0.632	77.243 0.809
C	78.5%	66.8%	77.9%	79.5%	80.6%	82.3%	84.7%	57.3%	70.4%
D1	0.741	0.416	0.800	0.600	0.337	0.597	0.702	1.000	0.516
D	0.754	0.547	0.684	0.750	0.385	0.699	0.690	0.915	0.642
D2	0.707	0.677	0.567	0.700	0.433	0.800	0.677	0.833	0.767
E/ten thousand	149 72.8%	89.4 43.7%	114.3 55.8%	134.2 65.5%	147.4 72.0%	180.6 88.2%	204.6 100%	56.8 27.7%	87 42.5%
S	0.233	0.313	0.533	0.300	0.367	0.200	0.333	0.167	0.2330

In this section, fitting analysis on the obtained data is performed firstly, obtaining that the four dependent variable indicators of A, B, C, D are affected by the two independent variable indicators E and S, to obtain the correlation coefficient r, as shown in Table 6.

According to Equation 2, it is assigned a pair-1 weighting assignment to the degree to which each dependent variable indicator is affected by two independent variable indicators (in order to consider that the degree of influence of a change in one independent variable indicator on each dependent variable is constrained by another independent variable indicator), four sets of eight values representing constraints are given here, as shown in Table 7.

$$\left\{\begin{array}{l} r_{1j}=\dfrac{r_{1j}}{r_{1j}+r_{2j}} \\ r_{2j}=\dfrac{r_{2j}}{r_{1j}+r_{2j}} \end{array}\ (j=1,2,3,4)\right\} \tag{2}$$

After that, the image is visually judged and analyzed and linked to the actual meaning, and a certain degree of influence of the change of each independent variable indicator on each dependent variable indicator is obtained.Equation 3 is applied to calculate the corresponding values of F, g and h to obtain the U value. Because the actual meaning contribution is large, it is difficult to express it in mathematical expressions, so several sets of data in the table are used as examples.

$$\begin{aligned} \mathrm{U11} &= F11*g(1)+F12*h(1) \\ U12 &= F13*g(1)+F14*h(1) \\ U21 &= F21*g(1)+F21*h(1) \end{aligned} \tag{3}$$

According to the U value obtained in the Table10 combined with the 1-9 Saaty scale, the importance judgment is made, and the 4 scheme layer 3x3 judgment matrix required by the analytic hierarchy method used is constructed according to this. The criterion layer 4x4 judgment matrix constructed according to the proportion of the four dependent variable indicators of the population to each other

represents the natural philosophy to some extent. Apply analytic hierarchy method to calculate the district community index.

2.4. The specific game analysis of indicators, influencing factors and policies

Visualize the obtained data on a line chart, finding that the use of E and S to reflect the overall human impact is quantifiable, and there is a certain game relationship between the two on the four dependent variable indicators. And the relationship between each independent variable indicator and the dependent variable indicator is more significant and realistic, so determine that the selected indicator is appropriate.

Step 1: Start by showing it in a line chart(figure 1 and figure 2).

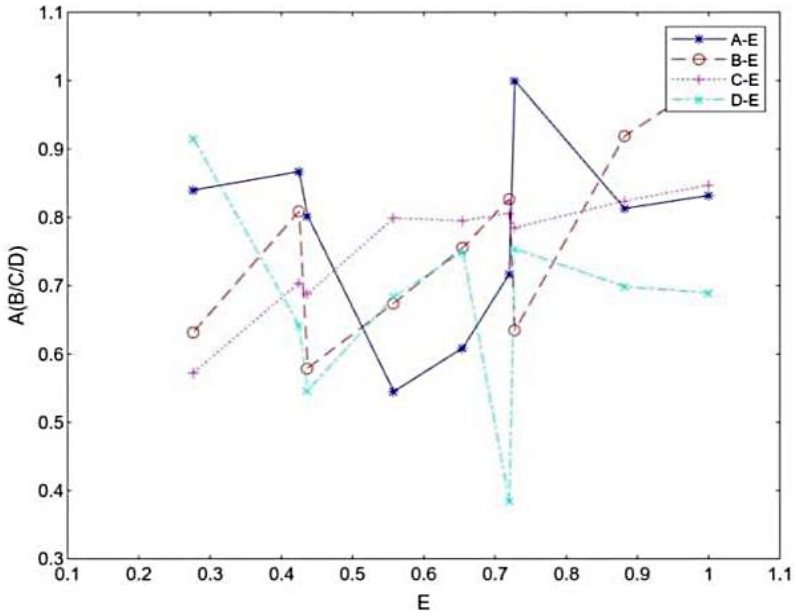

Figure 1. A line chart of the relationship between the four dependent variable indicators affected by the number of visitors indicator

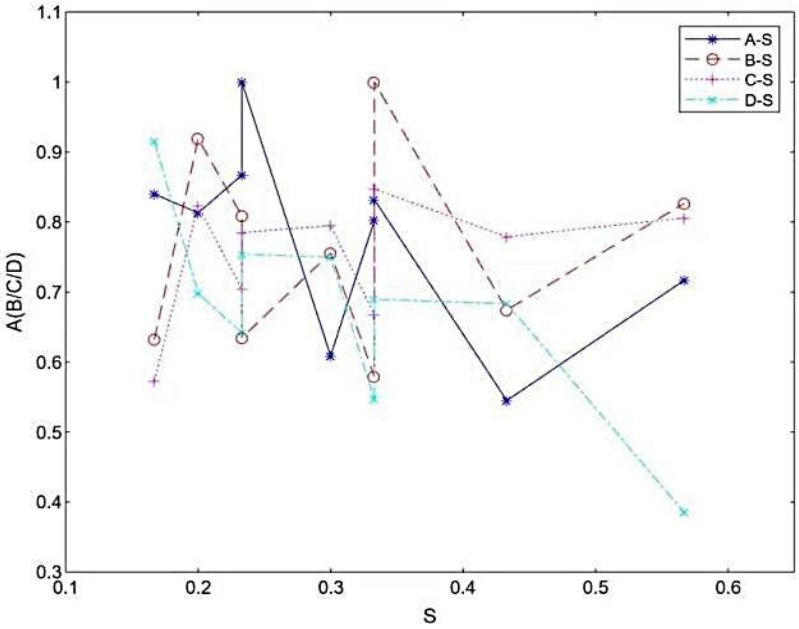

Figure 2. A line chart of the relationship between the four dependent variable indicators and the Human Activity Footprint Ratio metric

In these two figures, it's easy to find that there is a certain analyzable relationship between the two independent variable indicators and the four dependent variable indicators, and naturally the relationship analysis of the game occurs. After that, the fitting analysis is carried out. A table of correlation coefficients is shown in Table 6.

Table 6. The correlation coefficient of the dependent variable indicator that is affected by the independent variable indicator

r	A	B	C	D
E	0.779	0.829	0.891	0.954
S	0.842	0.812	0.833	0.93

Then, according to the Equation 2, the relevant numerical calculations are carried based on table 6, as shown in table 7.

Table 7. The correlation weights of the first and second independent variable indicators to the jth dependent variable index

	A	B	C	D
g(/E)	0.48	0.505	0.516	0.506
h(/S)	0.519	0.495	0.483	0.493

Table 8. judgment methods

	A		**B**		**C**		**D**	
	E	S	E	S	E	S	E	S
Left	0.05	0.02	0.07	0.02	0.10	0.03	0.02	0.02
Center value	0.78	0.24	0.88	0.35	0.72	0.34	0.87	0.3
Right	0.02	0.04	0.04	0.01	0.08	0.02	0.03	0.02
	A--E	A--S	B--E	B--S	C--E	C--S	D--E	D--S

According to table 8, this judgment method is to select a more realistic segment on the image to obtain the degree of influence, add a certain step size to its left and right, and judge the degree of influence of this practice on the index, left represents the step size of the change to the left, right represents the step size of the change to the right, and center value represents the center value of the better independent variable index interval. This judgement methods is the base of the acquisition of Table 9. The Table 9 is shown below.

Table 9. F diagram

F	A		B		C		D	
	E	S	E	S	E	S	E	S
Policy 1	0.74	0.80	0.79	0.73	0.74	0.75	0.71	0.70
Policy 2	0.91	0.84	0.87	0.80	0.81	0.77	0.75	0.72
Policy 3	0.80	0.78	0.73	0.76	0.77	0.73	0.73	0.68

The 1-weighted allocation value representing the degree to which each dependent variable indicator is affected by the two independent variable indicators is then calculated from Equation 3 according to Table 9 and Table 7 to obtain Table 10. It represents just a key interaction between human activities and non-human resources. Table 10 is shown below.

Table 10. The impact of different policies on different indicators

U	A	B	C	D
Policy 1	0.7704	0.7603	0.74409	0.70436
Policy 2	0.87276	0.83535	0.78987	0.73446
Policy 3	0.78882	0.75525	0.74991	0.70462

Step 2: Then, according to Table 10,Saaty1-9 scale and Table 6, the importance judgment is judged, and four 3x3 scheme layer judgment matrices, as shown in Figure 3 to Figure 6 and one 4x4 criterion layer judgment matrix, as shown in Figure 7.

1	1/3	1/2
2	1	2
3	1/2	1

Figure 3. The first scenario layer judgment matrix

1	1/2	2
2	1	3
1/2	1/3	1

Figure 4. The second scenario layer judgment matrix

1	1/3	1/2
3	1	2
2	1/2	1

Figure 5. The third scenario layer judgment matrix

1	1/2	1
2	1	2
1	1/2	1

Figure 6. The fourth scenario layer judgment matrix

1	4	3	1
1/4	1	1	1/4
1/3	1	1	1/3
1	4	3	1

Figure 7. Criterion layer judgment matrix

And the analytic hierarchy method is applied, and the rational analysis is carried out according to the combined analysis of quantitative data, and three mathematical policy district community indices are obtained, namely:

- Mathematical policy 1: E relative increases to the right of the better interval and S relative decreases to the left of the better interval.
- Mathematical Policy 2: E and S both fluctuate in the better range.
- Mathematical Policy 3: E relative decreases to the left of the better interval and S relative increases to the right of the better interval.

The relative decreases or increases in three policies could also represent the relativity among three policies, not merely in some policy.

Based on these three mathematical policies, combined with the clustering abstract of factors and relationships and specific policy and management strategies list, policy recommendations for the physical world are carried out.

3. Results

After obtaining three kinds of suggestions, they are applied to the specific game analysis of indicators, influencing factors and policies to obtain the community indices under the three policies, and rank them comparatively. The result is that, to a certain extent, Mathematics Policy 2 is better than Policy 3 than Policy 1, but Policy 1 and 3 are not too different, and Policy 2 is always better than the other two mathematical policies.

In view of the above results, the following suggestions for the regional feasibility and dynamics of the physical world are given:

Policy recommendation 1: The visitor ratio was controlled at 0.82 to 0.84 and the human activity footprint was controlled at 0.26 to 0.3.

Policy recommendation 2: The proportion of tourists is controlled at 0.82, and the area occupied by human activities is controlled at 0.3.

Policy recommendation 3: The visitor ratio was controlled at 0.79 to 0.82, and the area occupied by human activities was controlled at 0.3 to 0.33.

Specific to deal with different actual situations, policies can be found in the policy list of this paper based on the data analysis conducted above.

Note: All policies in the table represent the mathematical level of policies, and the response to actual policies can only be a guiding and auxiliary role.

4. Conclusion

By selecting some indicators that can clearly reflect the impact of human activities, use specific analysis method to make mathematical policy judgment. First, using the positive and negative effects to add and subtract between different scales, reasons are summarized according to the degree of subjective (qualitative) influence. In addition, the top 12 management recommendations are listed. Then, the specific game analysis of indicators, influencing factors and policies are performed and the principles of analytic hierarchy are used to calculate the district community index under different scale combinations. Combining the visitor number indicator and the human footprint indicator, three mathematical policies are obtained: Policy I: When the proportion of tourists is 0.82 to 0.84, the human area should be 0.26 to 0.3. Policy II: When the proportion of tourists is 0.82, the human area should be 0.3. Policy III: When the proportion of tourists is 0.79 to 0.82, the human area should be 0.3 to 0.33. And, generally, Policy II is better than Policy III and better than Policy I. Specific to deal with different actual situations, policies can be found in the policy list of this paper based on the data analysis conducted in this paper. This paper will provide certain technical support and basis for Masai Mara and other protected areas to help managers in better decision-making so as to raise the overall image.

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