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A multi-objective programming model for wildlife and human rights based on ridge regression

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Abstract: Wildlife sanctuaries have been established all over the world to protect wild animals and other natural resources, but there have been serious conflicts between people and wildlife in Africa near sanctuaries. We chose Kenya's wildlife reserves as our research object, created the indicator framework needed for wildlife and natural resource protection research, and quantified the relationship between indicators using fitting methods like ridge regression. We built a multi-objective planning model on this foundation, used a grid method for regional planning, and developed an improved policy plan. The findings show that residents of wildlife reserves can be most effectively compensated for the loss of development interests by the government's reasonable social welfare security system. Furthermore, the local area should return farmland to forests, strictly prohibit smuggling, and encourage the development of distinctive low-carbon industries to achieve both ecological and economic benefits.

1. Introduction

1.1 Motivation

Wildlife conservation is an important global issue, and Africa has the richest wildlife resources. In Kenya, about 8% of the country's land area is wildlife-protected areas [1], which are tasked with protecting biodiversity, improving human well-being, and achieving sustainable use of resources [2].

Due to Kenya's natural environment and social background, there has always been a conflict between wildlife and residents. Kenyan residents carry out agricultural production around protected areas, consume large amounts of water resources for irrigation, destroy the original habitat of wildlife and exacerbate the conflict between humans and wildlife [3]. Meanwhile, differences such as distance from protected areas can also contribute to social differences in protected areas and their environs [4].

1.2 The related work

Elske van der Vaart et al. [5] proposed to modify the individual-based model (IBM) through approximate Bayesian computation (ABC) to more accurately analyze the interaction between animals and the natural environment. Kelly R. Finn et al. [6] analyzed multilayer network analysis to study animal sociality, the relationship between individual animals and individuals or populations. Using habitat models, Mélodie Kunegel-Lion et al. [7] calculated and evaluated changes in the natural environment and the human disturbances within them to find changes in animal populations when the habitat environment changes. In 2016, R. S. Reid et al. [8] developed a "continuous engagement" model to balance the relationship between communities and wildlife conservation. Habitat loss is a major driver of biodiversity loss [9], and human-wildlife conflicts are also intensifying [10]. Wildlife conservation efforts that consider habitat conservation and restoration are urgently needed.

1.3 Our work

In this paper, we focus on national wildlife reserves, such as the Masai Mara in Kenya, and try to find effective management approaches that balance the rights of wildlife, natural resources, and local people. We define two indicators, the Human Development Index and the Biodiversity Index, and identify the impact factors of the different dimensions and their weightings. To improve the indicators' credibility and enhance the rationality of scenario planning for different regions, we retrieved a large amount of data and performed data processing. Multiple relationships between impact factors and indicators were established by data-fitting methods such as ridge regression. After the evaluation indicators of the balance effect are clarified, the effect of the policy on each factor can be used to judge the effectiveness of the policy. Considering the differences between different regions, we use a grid treatment method to enhance the generalizability and replicability to provide a global view of the program results to be obtained. The details are shown in Figure 1.

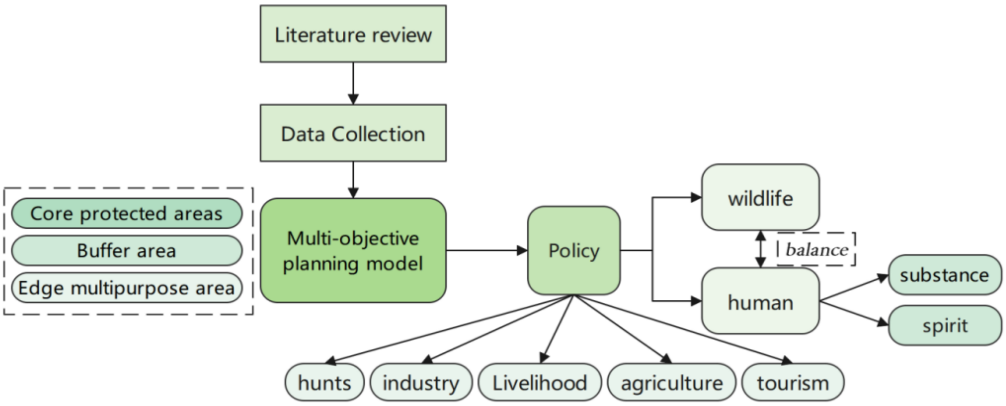

Figure 1: Our work

1.4 The arrangement

Section I of this paper describes the research background and research status of wildlife sanctuaries, as well as briefly introduces the model establishment and analysis process so that readers have a general understanding of the full text. In section II, we described in detail the process of index selection, data fitting, regional division, and the optimal policy results for resolving human-wildlife conflicts. We also extended the analysis framework to the global horizon based on the optimization model. Section III explains the model's sensitivity analysis results, which show that it is stable. Finally, in section IV, we summarize our research and refine and explain the model's main findings.

2. Human-Animal Target optimization model

2.1 Creation and Analysis of Indicators

We quantified the living conditions and needs of the region's people through an extensive literature review to balance the development interests of Kenyan residents with the conservation of wildlife and ecology. The Human Development Index (HI) is introduced to assess the vested interests of the region's inhabitants at various stages of development. Based on the United Nations Development Programme's definition of the Human Development Index (HI) in Figure 2, this study establishes a multi-level analysis structure based on available data to characterize the index from two dimensions: material conditions and spiritual pursuits, including factors such as life expectancy and per capita GDP.

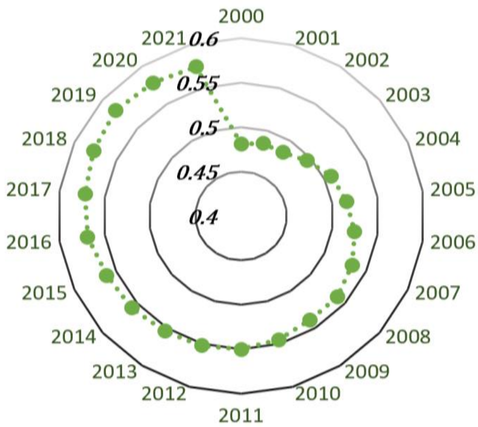

Figure 2: Human Development Index radar chart

We used Kenya's life expectancy and GDP per capita data to characterize the economic and health aspects, obtaining the following Ridge Regression fitting results:

$$HI=f_1(\alpha_1, \alpha_2) \tag{1}$$

$$f_1=0.49+0.067\alpha_1+0.026\alpha_2+\Delta \tag{2}$$

α_1 represents the health (lifespan) indicator, while α_2 represents the economic (GDP) indicator. And Δ represents the error in the function, and its value is close to zero. The R^2 of the model is 0.983, so the fitting effect is effective. We present the fitting effect in Figure 3.

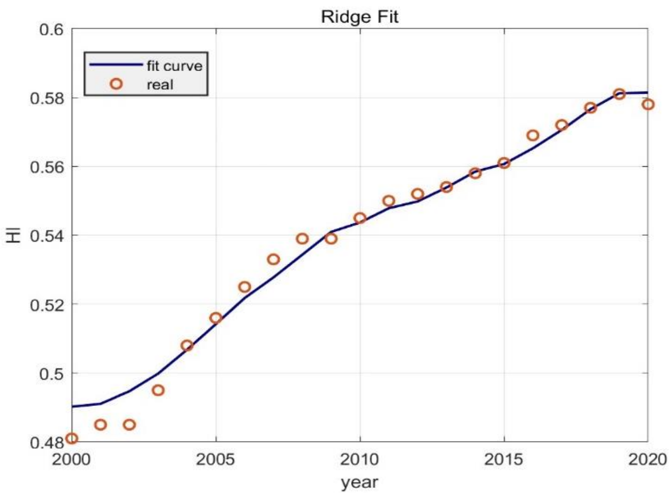

Figure 3: Ridge regression curve

The main water tower in Kenya is located within a wildlife sanctuary. Local agricultural expansion has resulted in the depletion of freshwater resources as well as the loss and alteration of wildlife habitats [8], resulting in a decrease in wildlife species diversity and a scarcity of natural resources. Human society's economic development necessitates a certain supply of natural resources.

Secondly, national protected areas such as the Masai Mara in Kenya attract thousands of foreign tourists every year, which has largely contributed to the growth of the Kenyan economy. For example, in the year ending 30 June 2006, wildlife accounted for 70 % of total tourism revenue, 25% of gross domestic product (GDP), and more than 10% of total formal sector employment [8]. In addition, the reserve is dominated by large mammals, which prey on residents' livestock and thus lead to retaliatory killings of wild animals [11]. As a result, the six observation variables ($x_1 \sim x_6$) of policy measures are used to represent comprehensive factors such as wild animal killing and smuggling in Kenya's wildlife reserves, land development and utilization for industrial and agricultural development, and the government's welfare measures for protected area residents.

$$\alpha_1=g(x_1,x_2,x_3,x_4,x_5,x_6) \quad (3)$$

$$g=0.436+0.199x_1-0.213x_2-0.25x_3+0.264x_4+0.174x_6+\Delta \quad (4)$$

where x_1 represents the number of inbound tourists in Kenya, x_2 represents the area covered by forests, x_3 represents the number of wild animals, x_4 represents the area of agricultural land, x_5 represents industrial water consumption, and x_6 represents the balanced distribution of social well-being. In addition, Δ represents the error in the function, whose value is close to zero. The R^2 of the model is 0.979, and the reserved variables are significant, so the fitting is successful.

Similarly, we want to obtain the influence of relevant policy measures on Kenya's local economic development level - per capita GDP, and we also passed the significance test of the observed variable x_i, screened 4 indicators with P value at the 1% level significant, and obtained the following ridge regression fitting equation:

$$\alpha_2=h(x_1,x_2,x_3,x_4,x_5,x_6) \quad (5)$$

$$h=0.074+0.277x_1-0.155x_2+0.229x_4+0.434x_5+\Delta \quad (6)$$

The results of ridge regression show that the significance P value based on the F test is 0.000***, which shows significance at the level, rejects the null hypothesis, and indicates that there is a regression relationship between the independent variable and the dependent variable. At the same time, the goodness-of-fit R^2 of the model is 0.984, so the fitting effect of the model is good.

Furthermore, the current situation indicates that biodiversity loss is one of Kenya’s most serious threats. Land-use change in favor of agriculture and rural-urban development has resulted in the reduction and modification of wild reserves, resulting in the extinction or endangerment of wildlife species and the natural areas that serve as their habitats. [3]. As an outcome in Figure 4, indicators such as loss of forest cover and wildlife populations are used to describe the decline in Kenyan wildlife biodiversity caused by habitat loss and human killing.

We obtain the polynomial fit of the biodiversity indicator (BI) shown in the figure above, the R^2 of the quadratic polynomial fitting is 0.9525, which has the function formula as follows:

$$BI=f_2(x_2,x_3) \quad (7)$$

$$f_2=-0.015-3.24x_3+1.66x_2-2.35x_3^2+5.42x_2x_3-0.498x_2^2 \quad (8)$$

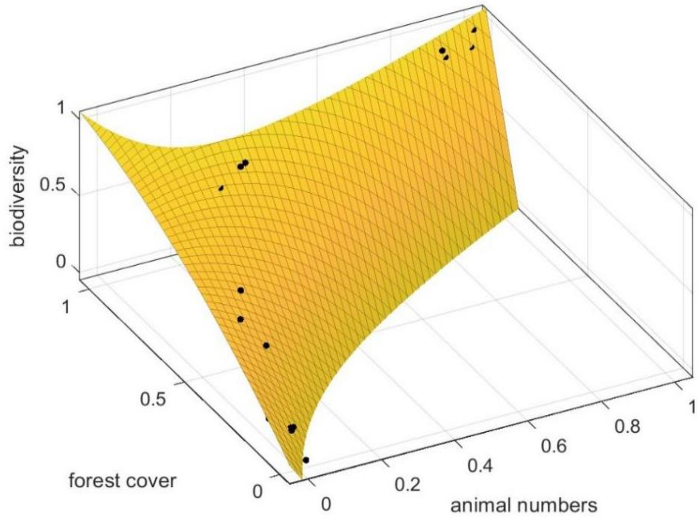

Figure 4: Binary polynomial fitting

2.2 Merit-based Planning of Policies

About the local need to minimize the impact of lost opportunities on people living near protected areas while preserving abundant wildlife, this study employs a multi-objective planning model to optimize and solve problems, as well as to obtain more socially and ecologically effective strategic trends by establishing target functions, constraints, and so on.

$$Z=w_1f_1+w_2f_2 \tag{9}$$

$$\max Z=c^T\cdot\begin{pmatrix}x_1\\x_2\\x_3\\x_4\\x_5\\x_6\end{pmatrix} \tag{10}$$

Among them, Z represents our comprehensive target indicators, which integrate the rights and interests of residents and the protection of wildlife and natural resources through weighted summation, and we require the maximum value of Z and the propensity value of each corresponding indicator, while w_1 and w_2 are the weights of human development rights indicators and biodiversity indicators respectively.

$$\begin{cases} A\begin{pmatrix}x_1\\x_2\\x_3\\x_4\\x_5\\x_6\end{pmatrix}\leq b \\ 0\leq x_i\leq 1,\ i=1,\ldots,6 \end{cases} \tag{11}$$

The above matrix formula represents constraints, where A is the coefficient matrix, we take the protection of natural resources as a constraint on the comprehensive goal, and the convergence of all indicators is between 0 and 1. When the value of the indicator is 1, we are completely inclined to the implementation of the policy in that direction, and when the value of the indicator is 0, we can ignore the implementation of the policy in that direction.

According to UN recommendations, a country should have at least 30% of its total land area to maintain ecosystem stability, but this may vary depending on factors such as the region and the environment. The largest proportion of industrial water use in a country will vary depending on the country's economic structure, industrial development level, water resources, and other factors. In general, industrial water consumption accounts for roughly less than 10% of the total water consumption of a less developed country. In addition, the Food and Agriculture Organization of the United Nations has proposed an indicator that each person needs at least 0.25 hectares of arable land to meet their food needs.

By integrating the above content with Kenya's land area, population, residents' living conditions, and other information, we obtain the coefficient matrix of the constraints of the multi-objective planning model.

$$A=\begin{bmatrix}0&1&0&1&0&0\\0&1&1&0&0&0\\0&1&0&0&1&0\\1&0&1&0&0&0\end{bmatrix} \tag{12}$$

$$b=\begin{pmatrix}1.2\\1.5\\1.5\\1.8\end{pmatrix} \tag{13}$$

We take the largest national reserve in Kenya, the Masai Mara Wildlife Sanctuary, as an example to adjust the corresponding parameters.

2.3 Regional Division and Policy Implementation

Wildlife sanctuaries are classified by the local government as national parks, community reserves, or private reserves. We conducted regional planning for the Masai Mara Wildlife Sanctuary based on the local natural ecological environment, wildlife distribution, and walking in human activity areas to demonstrate the differences between the reserve and the surrounding areas. The topographic distribution map of the Masai Mara Wildlife Reserve in Kenya is drawn in Figure 5.

Figure 5: Map of the Masai Mara Reserve

Then we analyze the density of wildlife, particularly the distribution of large mammals, by spatially rasterizing the Masai Mara area and using a network flow method to divide it into three distinct categories: core wildlife sanctuary, fuzzy marginal area, and multi-use planning area. Figure 6 presents the grid planning results of the wildlife sanctuary in detail.

(1) *Core protected areas*

The area has the strictest protection measures for wildlife and is an important habitat for wildlife and a gathering area for endangered species. Human activities in the area should be as disturbed as possible by wildlife.

(2) *Marginal transition zone*

The buffer zone is a transitional area between the core and surrounding human activities. The area is home to many wild animals that have some migratory activities. The area is a major tourist area, and a community protection mechanism has been established to manage the land.

(3) *Multi-purpose planning zone*

The area is dominated by wildlife corridors, dotted with wildlife that migrates with the seasons. The area can be used for a range of activities, including grazing, farming, and resource extraction, subject to certain limits. The area is more private land for residential and further subsistence development.

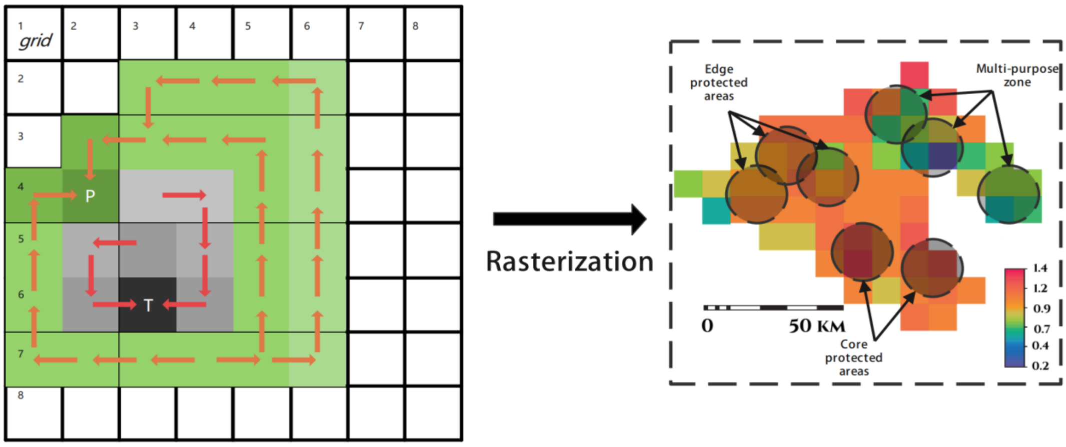

Figure 6: Gridded comprehensive biodiversity distribution map

Based on the above regional planning results, we use the changes of the w_1 and w_2 weight ratios in the objective function of the multi-objective planning model to present the policy directions in the socio-ecological environment of different regions.

$$\begin{cases} Z=w_1f_1(\alpha_1, \alpha_2)+w_2f_2(x_2,x_3) \\ \alpha_1=g(x_1,x_2,x_3,x_4,x_5,x_6) \\ \alpha_2=h(x_1,x_2,x_3,x_4,x_5,x_6) \end{cases} \tag{14}$$

Through the calculation of the MATLAB software, the optimal inclination results of each indicator in different regions can be obtained as follows:

(1) For core protected areas.

$$\begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \end{pmatrix} = \begin{pmatrix} 0.8817 \\ 0.6221 \\ 0.8779 \\ 0.5506 \\ 0.8053 \\ 1.0000 \end{pmatrix} \tag{15}$$

(2) For marginal transition zone.

$$\begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \end{pmatrix} = \begin{pmatrix} 0.9220 \\ 0.6220 \\ 0.8780 \\ 0.5780 \\ 0.8779 \\ 0.9999 \end{pmatrix} \tag{16}$$

(3) For multi-purpose planning zone.

$$\begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \end{pmatrix} = \begin{pmatrix} 0.8018 \\ 0.9118 \\ 0.4782 \\ 0.7882 \\ 0.8982 \\ 0.9481 \end{pmatrix} \tag{17}$$

3. Result and Global Outreach

It can be seen that the rational distribution of social welfare x_6 is the most effective means of government intervention in the Masai Mara region, and macro-control of some of the rights and interests lost due to the division of protected areas by increasing the opportunities for residents to receive education, improving infrastructure and medical security, etc. The tourism industry represented by x_1 should be developed mainly in marginal transition areas, which can increase national income without disturbing endangered wildlife in core areas [12].

Secondly, the greater the need to strengthen the protection of wildlife habitats, reduce deforestation, and achieve ecological benefits. In multi-use zones, the combined development of agriculture and industry can be encouraged, the economic benefits of residents can be increased, residents' dissatisfaction can be alleviated [13], and their support for policies related to protected areas can be improved.

Finally, core areas should strictly enforce anti-poaching laws, restrict human access, and minimize human-wildlife conflicts to better maintain biodiversity in wilderness reserves. Besides, the heart of protected areas should minimize agricultural land occupation and industrial water pollution. The government should maximize social welfare support to protect residents' development rights and interests for the inevitable loss of interests of residents caused by ecological protection.

Differences in climate and geography result in different distributions of organisms with different habits for other wildlife management areas around the world. When formulating management strategies in a targeted manner, we should also consider the economic development and social development of different countries and regions, and conduct in-depth discussions by analogy with the research methods and models used in the above tasks.

Figure 7: Global map of biodistribution

From Figure 7, we can see that the species of wildlife distributed on each continent are different. Since the study of the Kenya Wildlife Sanctuary discusses the conflict between humans and predators, especially those large predators, as long as there is a large predator wildlife reserve, you can use our model to predict and evaluate relevant policies, only need to replace the data in the indicators in the model with the data of the local protected area, and then refer to the relevant strategies of the local government to use our model to better balance the conflict between humans and animals. It also allows for better management of wildlife reserves to maximize benefits.

It is worth noting that no matter which animal sanctuary we are in, we should encourage the development of the tourism industry while making some restrictions to ensure that the survival of wild animals will not be interfered with by tourists. And all regions need to strengthen the upgrading of the tourism industry and increase the income of residents, and resolutely crack down on all illegal activities such as poaching and killing [14].

4. Sensitivity and stability analysis

In terms of the multi-objective programming model, our parameter selection has a certain subjectivity. Therefore, we made fluctuations in the relevant parameters to check the overall stability of the model.

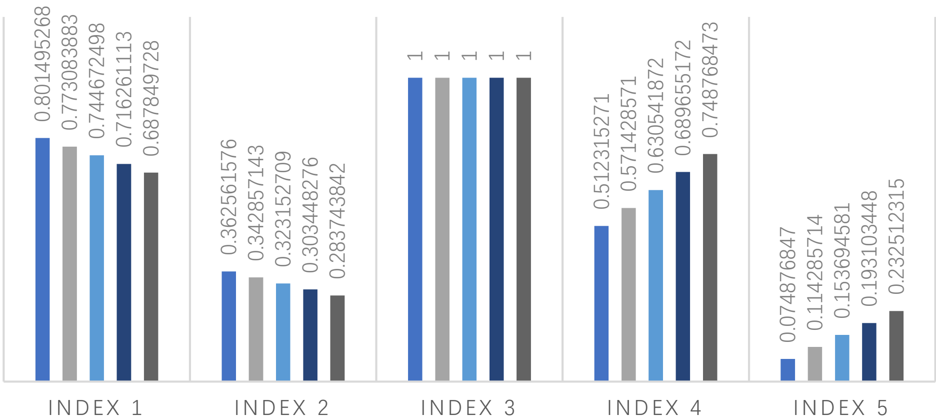

Figure 8: Test of linear programming parameters

As can be seen from Figure 8, the value change of the overall indicator can be controlled within 10% in the case of small parameter changes, and a stable trend is presented. This shows that our parameter setting interval is reasonable, the multi-objective optimization model shows good robustness, and the conclusions obtained have a great reference value.

5. Conclusions

In this study, the correlation between various policy observation indicators is investigated using ridge regression and polynomial fitting, and a full multi-objective planning model is produced by processing regional differences using the grid method. According to the findings, the core protected areas should prioritize biodiversity conservation, strictly prohibit man-made destructive behavior, and compensate residents for their interests through preferential social welfare policies. Ambiguous marginal areas should develop environmentally friendly industries, such as distinctive tourism and low-carbon industries, and take measures such as returning farmland to the forests to protect habitats and reduce human-animal conflicts. Human living areas are separated from wild animals in peripheral multi-functional areas, and rational use of natural geographical advantages is used to develop industry and agriculture, improve infrastructure construction, and raise residents' living standards. Finally, this paper promotes the findings of policy analysis on a global scale.

References

[1] KWS, (2014) Protected areas and status of wildlife. Unpublished.

[2] Srivathsa A, Vasudev D, Nair T, et al. Prioritizing India's landscapes for biodiversity, ecosystem services and human well-being [J]. Nature Sustainability, 2023: 1-10.
[3] Okech R N. Wildlife-community conflicts in conservation areas in Kenya [J]. African Journal on conflict resolution, 2010, 10(2).
[4] Snider, Ryan Austin. (2012). "Land Tenure, Ecotourism, and Sustainable Livelihoods: 'Living on the Edge' of the Greater Maasai Mara, Kenya."
[5] Van der Vaart E, Beaumont M A, Johnston A S A, et al. Calibration and evaluation of individual-based models using Approximate Bayesian Computation [J]. Ecological Modelling, 2015, 312: 182-190.
[6] Shah P, Mukhovi S M. Benefits of Protected Areas to Adjacent Communities: The Case of Maasai Mara National Reserve in Kenya [J]. Africa Journal of Physical Sciences ISSN: 2313-3317, 2019, 3.
[7] Kunegel-Lion M, Neilson E W, Mansuy N, et al. Habitat quality does not predict animal population abundance on frequently disturbed landscapes [J]. Ecological Modelling, 2022, 469: 109943.
[8] Reid R S, Nkedianye D, Said M Y, et al. Evolution of models to support community and policy action with science: Balancing pastoral livelihoods and wildlife conservation in savannas of East Africa [J]. Proceedings of the National Academy of Sciences, 2016, 113(17): 4579-4584.
[9] Newbold T, Hudson L N, Hill S L L, et al. Global effects of land use on local terrestrial biodiversity [J]. Nature, 2015, 520(7545): 45-50.
[10] Dickman A J. Complexities of conflict: the importance of considering social factors for effectively resolving human–wildlife conflict [J]. Animal Conservation, 2010, 13(5): 458-466.
[11] Broekhuis F, Cushman S A, Elliot N B. Identification of human–carnivore conflict hotspots to prioritize mitigation efforts [J]. Ecology and evolution, 2017, 7(24): 10630-10639.
[12] Venter O, Magrach A, Outram N, et al. Bias in protected-area location and its effects on long-term aspirations of biodiversity conventions [J]. Conservation Biology, 2018, 32(1): 127-134.
[13] Copeland C, MacKerron G, Foxon T J. Futures for Findhorn: Exploring challenges for achieving net zero in an ecological intentional community [J]. Futures, 2023: 103155.
[14] Mubarok Z. Illegal, unreported and unregulated fishing and transnational organized fisheries crimes: Perspectives of legal and policy measures of Indonesia [J]. 2019.