

# Cost-benefit Analysis of Ecological Protection in China's Coastal Zone: A Case Study of the Beibu Gulf Coastal Zone

Bowen Cui

The College of Life and Environmental Sciences, Minzu University of China, Beijing, China

Email: cuibowen345@gmail.com

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**Abstract**—The coastal zone, a crucial area for human resources and ecological services, is facing significant ecological damage due to human overexploitation. As economic development shifts towards the ocean, the contradiction between coastal ecosystem protection and economic development intensifies. This paper presents an opportunity cost assessment system for coastal ecological environment protection, focusing on the Beibu Gulf coastal zone. The study reveals that the average annual opportunity cost of the Beibu Gulf coastal ecosystem is  $1.36 \times 10^9$  yuan, with government opportunity costs dominating due to strict environmental protection policies. Residents face  $4.5 \times 10^7$  yuan, mainly due to limited aquaculture and planting industries, and enterprises face  $3.18 \times 10^7$  yuan, mainly due to suspended production and rectification of small and micro enterprises.

**Keywords**—coastal zone, ecological protection, opportunity cost, beibu gulf

## I. INTRODUCTION

Due to the unique attributes of both the sea and land and the unique natural environment, the coastal zone has become one of the most active areas for human activities. Due to the irrational development and utilization of coastal ecosystem resources by humans, the region has faced severe ecological degradation problems. On the one hand, the coastal ecosystem has contributed abundant material resources and diversified ecological services to humans. Several natural attributes of the coastal zone have built a key protective barrier for the coast, including coral reefs, the most extensive, large-scale and effective coastal protection system in the world, and pebble beaches with wave energy absorption function [1]. On the other hand, as the focus of human development has increasingly shifted to the ocean, the coastal zone has developed into a leading area for marine utilization. The discussion of ecosystem functions covers the habitat environment, biological attributes and characteristics or operating mechanisms of the ecosystem in multiple dimensions [2]. This paper evaluates ecological benefits and cost losses in the Beibu Gulf coastal zone using literature, empirical research, and online data aggregation. It calculates the cost and ecosystem service value of Beibu Gulf kelp, providing a theoretical basis for ecological compensation.

## II. CLASSIFICATION AND EVALUATION METHODS OF REGIONAL ECOSYSTEM COSTS

### A. Classification of Regional Ecosystem Costs

There are many different views on the classification of regional ecosystem costs. Based on the perspective of the damaged entity, it can be summarized into three categories: corporate opportunity cost, resident opportunity cost and government opportunity cost; and according to the nature of

the cost, it can be further divided into direct cost and indirect cost. Kosoy *et al.* proposed to use three factors to evaluate opportunity cost: expected change in net income, acceptable price to providers and expected value of land rent [3]. Newton proposed that the size of households, livelihood, community economic growth level, geographical location and population characteristics in different regions jointly shape the diversity of cost changes of ecological compensation mechanisms among regions. When formulating ecological guidelines, local economic attributes, regional population conditions and livelihood patterns should be considered [4].

### B. Cost Assessment Method of Regional Ecosystem

#### 1) Calculation of business opportunity cost (BOC)

The “opportunity cost” chosen is an extremely complex economic principle that runs through almost all areas of activity [5]. Opportunity cost losses for an enterprise include production suspension, restructuring and mergers, and relocation-related costs. The formula for calculating these losses is  $P_i$ , where  $P_i$  represents net profit before closure,  $C$  covers relocation expenses,  $M$  is income from factory sales, and  $B$  is government subsidy.

As shown in Formula 1:

$$BOC = I_1 + I_2 + I_3 = \frac{\sum P_i}{3} + \frac{\sum (I - P_i)}{3} + \sum C_i - M - B \quad (1)$$

#### 2) Calculation of resident opportunity cost (IOC)

Resident opportunity cost losses mainly include four aspects: loss of income from planting industry ( $I_A$ ) · Forestry losses ( $I_B$ ) · Livestock losses ( $I_C$ ) and fishery losses ( $I_D$ ).

In terms of income loss in planting industry ( $I_A$ ), income loss in planting industry ( $I$ )  $R_i$  is the net income per mu of specific crops,  $S_i$  is the reduction in planting area of specific crops,  $b_i$  is the government subsidy given to farmers for returning farmland to farmland;  $q_i$  and  $Q_i$  respectively represent the marginal output of specific crops after using pesticides and fertilizers,  $a_i$  and  $A_i$  respectively indicates the reduction of pesticide and fertilizer application per unit area for specific crops,  $C_i$  is the current market price of crops, represents the purchase cost of pesticides and fertilizers,  $I_0$  and  $I_1$  represents the average income of the land before and after the change of land use. The calculation formula is as follows:

$$I_A = (\sum R_i \times S_i - b_i) + (\sum O_{j \times q_j} \times a_j \times p_j + \sum H_j \times Q_j \times A_j \times p_j - C_t) + (I_0 - I_1) \quad (2)$$

In terms of forestry losses ( $I_A$ ), The average income per unit area of a specific economic forest involves the reduction

of the area of economic forest land, the ecological compensation obtained from public welfare forests, and the income from firewood harvesting. This method is mainly used to assess the losses caused by the conversion of economic forests to public welfare forests, and the reduction of new firewood harvesting income due to natural recovery. The calculation formula is:

$$I_A = \sum r_i \times S_i - u + I \quad (3)$$

In terms of fishery income loss ( $I_B$ ), ( $F_0$ ) and ( $F_1$ ) respectively represent the average fishery income of farmers before and after the fishery ecological environment governance, ( $f_0$ ) and ( $f_1$ ) depicted the average income of fishermen before and after the adjustment of the fishery farming model. The main purpose is to evaluate the effects of the ecological policy of returning farmland to wetlands and the innovative farming model on farmers in specific ecological functional areas. The calculation formula is:

$$I_B = (F_0 - F_1) + (f_0 - f_1) \quad (4)$$

The government's opportunity cost is calculated using a formula that considers tax contributions, return on investment, investment scale, and income tax rate. The product reflects potential entry enterprise tax losses, with relocation to local government often resulting in five-year tax losses. Labor changes also contribute to environmental protection

measures. The calculation formula of the government's opportunity cost is as follows:

$$GOC = (t_0 - t_1) + (R \times I \times t) + \left(\frac{\sum T_i}{5}\right) + b \quad (5)$$

Based on the above discussion, according to the classification of affected objects, the opportunity cost (OC) caused by ecological protection activities is mainly reflected in three aspects: business opportunity cost (BOC), individual opportunity cost (IOC) and government opportunity cost (GOC). Therefore, the opportunity cost calculation formula of ecological environment protection is as follows:

$$OC = EOC + IOC + GOC \quad (6)$$

### III. COST OF ECOLOGICAL PROTECTION IN THE BEIBU GULF COASTAL ZONE - BENEFIT CALCULATION

#### A. Opportunity Cost of Development in the Beibu Gulf Coastal Zone

The Beibu Gulf Economic Zone defines an economic region that includes China's southwestern coastal areas and cities around the Beibu Gulf [6] (Fig. 1). The establishment of the Beibu Gulf coastal zone and its ecological protection measures have resulted in the loss of potential economic and social development opportunities in some areas of the region and its protected areas.

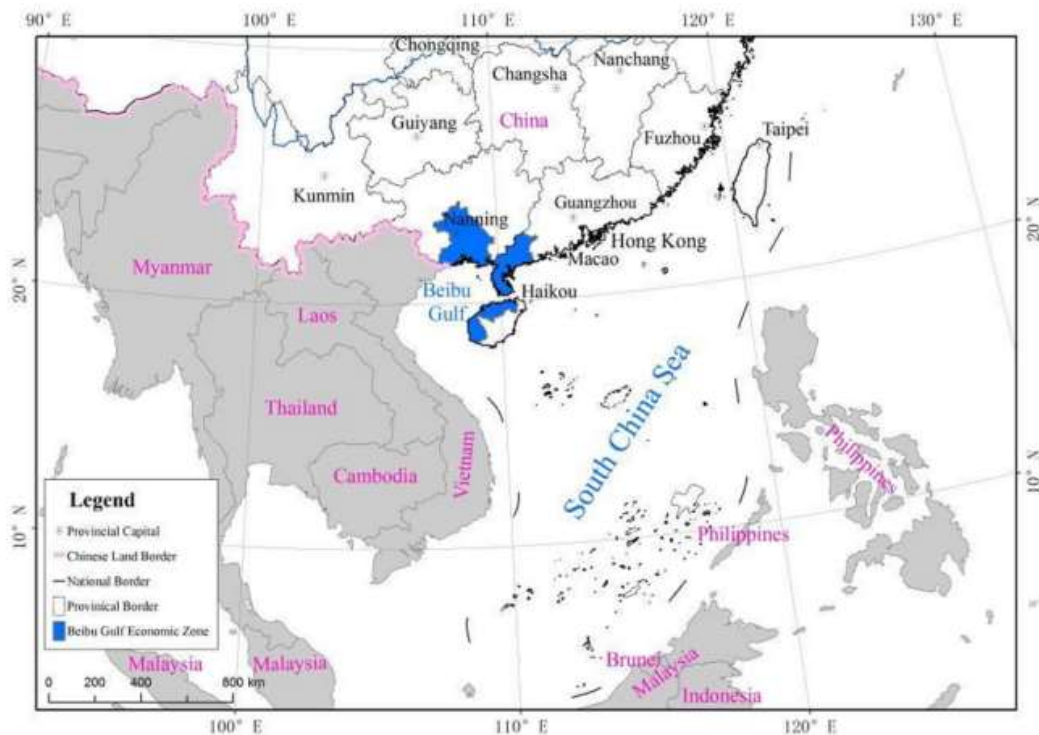


Fig. 1. Beibu gulf coast geographical location.

Based on the above explanation, the opportunity cost (OC) caused by coastal ecological conservation mainly includes the following aspects: the direct opportunity cost (BOC) faced by Beibu enterprises in a specific area, the opportunity cost (IOC) borne by Beibu residents in a specific area, and the opportunity cost (GOC) borne by the government in ecological conservation actions. Coastal ecological

environment protection:

$$OC = EOC + IOC + GOC \quad (7)$$

#### B. Opportunity Cost of Enterprises in the Beibu Gulf Coastal Zone

Economic growth is the main factor driving reclamation

activities in the coastal areas of Beibu Gulf in Guangxi. Path analysis revealed that socioeconomic factors have a significant impact on reclamation activities [7]. From 2016 to 2018, the three municipal governments in the Beibu Gulf region launched and implemented the Blue Sky Defense

Action Plan. In this action, a total of 15 aluminum smelters, 235 illegal sand mining sites and 4 pig farms were closed. The specific situation of the ban, rectification and fine payment in the Beibu Gulf region is shown in Tables 1-3:

Table 1. Number, output and income of eliminated enterprises

| Ceased Production            | Number of Enterprises | Annual Average Production | Market Average Price    | Average Income          |
|------------------------------|-----------------------|---------------------------|-------------------------|-------------------------|
| Illegal Smelting Plants      | 18 (plants)           | 720 (tons)                | 1100 yuan/ton           | $1.4 \times 10^7$ yuan  |
| Illegal Sand Quarries        | 235 (sites)           | 55.5 (cubic meters)       | 150 yuan/m <sup>3</sup> | $2.0 \times 10^9$ yuan  |
| Mechanical Parts Co., Ltd.   | 1 (company)           | 1440 (pieces)             | 800 yuan/piece          | $1.15 \times 10^7$ yuan |
| Building Materials Company   | 1 (company)           | 150 (tons)                | 4000 yuan/ton           | $6.0 \times 10^5$ yuan  |
| Large-scale Poultry Breeding | 4 (farms)             | Loss of 4.5 million yuan  |                         |                         |

Table 2. Number of enterprises undergoing rectification and the amount of rectification

| Enterprise/Company         | Rectification Project                                                                    | Quantity | Funding (10,000 yuan) |
|----------------------------|------------------------------------------------------------------------------------------|----------|-----------------------|
| Brick Factory              | Install desulfurization tower                                                            | 18       | 360                   |
| Coal-fired Industry        | Eliminate coal-fired industrial boilers of 10 steam tons/hour and below, use new boilers | 10       | 180                   |
| Metallurgical Company      | Demolish 70 square meter water crystallizer                                              | 2        | 6                     |
| Iron Smelting Enterprise   | Rectify environmental issues                                                             | 1        | 5.7                   |
| Mechanical Parts Company   | Demolish production equipment                                                            | Several  | 2.2                   |
| Building Materials Company | Demolish production equipment                                                            | Several  | 1.8                   |
| Barbecue Stall Shops       | Oil fume purification rectification                                                      | 100      | 19                    |
| Fishing Recreation         | Underground sewage treatment equipment                                                   | 5        | 7.5                   |

Table 3. Enterprises fined, reasons for fines and amounts

| Enterprise Type                               | Penalty Reason                                                       | Penalty Amount (10K RMB) |
|-----------------------------------------------|----------------------------------------------------------------------|--------------------------|
| Environmental Engineering Company             | Illegal dumping of sludge and environmental violations               | 9                        |
| Comprehensive Development Co., Ltd.           | Exceeding environmental assessment and illegal building construction | 64.7                     |
| Aluminum Smelting Plant & Illegal Sand Quarry | Illegal production operations                                        | 296                      |

The opportunity cost of enterprises in the Beibu Gulf Coast Ecological and Environmental Protection Zone is  $3.18 \times 10^7$  yuan. The specific calculation formula is shown in formula:

$$B0C=I1+I2+I3=(P/3+U)+\Sigma(C+M+B)+T=3.18 \times 10^7 \quad (8)$$

The formula for corporate losses in the Beibu Gulf Coastal Ecological Protection Area reveals economic losses due to forced closures, fines, confiscations, and expenses incurred by enterprises. The opportunity cost of enterprises is  $3.18 \times 10^7$  yuan, with losses in the opportunity cost mainly reflecting the loss of  $2.23 \times 10^7$  yuan due to the closure, rectification expenses of 5.822 million yuan, and fines paid by the enterprise.

### C. Opportunity Costs of Residents in the Beibu Gulf Coastal Zone

In order to restore and maintain the service functions of the coastal ecosystem, some farmers adjusted some of their traditional production and living patterns [8]. From 2016 to 2018, the governments of three Beibu Gulf cities implemented environmental protection plans to improve water quality and ban illegal breeding facilities in coastal waters. This led to the clearing of 476 pig farms, 95 chicken farms, 34 duck farms, and one fish farm. The average price announced by official platforms of “Zhu Price Network” and “Breakfast Price Network” was used as a reference in the calculation process, as specific weight and unit price information of breeding species is difficult to obtain directly. Specific data are shown in Table 4:

Table 4. Data and information on the cleanup and rectification of aquaculture farms in the Beibu Gulf region

| Farm Type    | Number of Farms | Number of Animals/Livestock | Average Weight   | 2018 Average Market Unit Price (Yuan) | Average Income         |
|--------------|-----------------|-----------------------------|------------------|---------------------------------------|------------------------|
| Pig Farm     | 476             | 25,535                      | 105 jin          | 11.3/kg                               | $3.0 \times 10^6$ yuan |
| Chicken Farm | 95              | 227,104                     | 5.5 jin          | 5.21 yuan/jin                         | $6.5 \times 10^6$ yuan |
| Duck Farm    | 34              | 127,558                     | 7 jin            | 6.14/jin                              | $5.5 \times 10^6$ yuan |
| Shrimp Farm  | 1               | 150 mu                      | 800 (animals/mu) | 24.5/jin                              | $2.9 \times 10^6$ yuan |

The opportunity cost of residents is calculated as follows:

$$EOC=(AO-A1)=4.5 \times 10^7 \quad (9)$$

In the formula, A0 and A1 represent the average income of residents from aquaculture before and after the Beibu Gulf cleanup and ecological environment protection, so the

opportunity cost of residents within the Beibu Gulf coastal zone environmental protection area is estimated to be  $4.5 \times 10^7$  yuan.

### D. Government Opportunity Cost in the Beibu Gulf Coastal Zone

Local governments are relaxing environmental regulations to increase tax revenue, aiming to improve air quality.

However, environmental compliance issues forced some companies to cease operations, reducing nickel alloy production to 2.3 million tons and resulting in an estimated 770-million-yuan tax. Two hazardous waste treatment

projects were rejected, generating an additional 235,000 yuan in taxes. A state-owned steel company plans to invest 16 billion yuan, generating 1.2 billion yuan in tax contributions [9]. See Table 5 for details:

Table 5. Information on companies declined due to environmental protection policies in the Beibu Gulf region

| Enterprise Type      | Number of Enterprises | Enterprise Investment Scale | Average Investment Profit Rate | Income Tax Rate | Expected Tax Revenue |
|----------------------|-----------------------|-----------------------------|--------------------------------|-----------------|----------------------|
| Hazardous Operations | 2                     | 10 million yuan             | 23.50%                         | 10%             | 235,000 yuan         |
| Steel                | 1                     | 16 billion yuan             |                                |                 | 1.2 billion yuan     |

The formula for calculating government opportunity cost is as follows:

The study calculates the total tax reduction caused by environmental protection policies in Beibu Gulf municipalities from 2016-2018, resulting in a reduction of 77 million yuan. The impact of relocated enterprises on Qinbei, Beifang, and Fangchenggang municipalities is also considered. The government provides a 35 million yuan living subsidy to affected employees. The study also considers the potential opportunity cost of investment in hazardous waste treatment and steel projects, which could reduce government tax revenue by  $1.28 \times 10^9$  yuan.

#### E. Total Opportunity Cost of the Beibu Gulf Coast

Reguero *et al.* analyzed the flood risk of the Gulf Coast of the United States through a quantitative risk assessment framework and compared the cost-effectiveness of different adaptation measures, including nature-based measures, structural measures and policy measures [10]. The opportunity cost of ecological and environmental protection in the Beibu Gulf Coast region was estimated to be  $1.36 \times 10^9$  yuan, of which the opportunity cost of enterprises was  $3.18 \times 10^7$  yuan, the opportunity cost of residents was  $4.5 \times 10^7$  yuan, and the opportunity cost of the government was  $1.28 \times 10^9$  yuan.

#### IV. CONCLUSION

The study analyzes China's coastal ecological protection in the Beibu Gulf coastal zone, revealing an average annual opportunity cost of  $1.36 \times 10^9$  yuan. The government's opportunity cost is the most significant, at  $1.28 \times 10^9$  yuan, due to its geographical location and policy advantages. Residents' opportunity cost is second, mainly due to limited aquaculture and planting industries. Enterprises' opportunity cost is relatively small, mainly due to production suspension and rectification of small and micro enterprises. However, the study has limitations, including missing output value and unit price data, a short research time span, and inaccuracies in the long-term cost-benefit trend. Future improvements include

expanding the research time span and spatial scope, building a more comprehensive dynamic monitoring system, and improving data collection mechanisms.

#### CONFLICT OF INTEREST

The author declares no conflict of interest.

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