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ORIGINAL RESEARCH ARTICLE

Construction of evaluation system for land and sea resources and environmental carrying capacity

Shimin Ma[1,2*], Xinyang Xu[2], Jin Ni[1], Jing Zhang[1], Hengfei Huan[1]

[1] *Shenyang Center of China Geological Survey, Shenyang 110034, China.*

[2] *School of Resources and Civil Engineering, Northeastern University, Shenyang 110004, China. E-mail: xamashimin@126.com*

ABSTRACT

Ocean and land are inseparable components of the global ecosystem. It is necessary to study the evaluation system of land and sea resources and environmental carrying capacity. The study selects evaluation index of land and sea resources and environmental carrying capacity, which is mainly reflected in five aspects: the importance of ecological protection, the suitability of agricultural production, the suitability of urban construction, the impact of marine environment, socio-economic conditions and the current situation of marine economic development. The PSR model is used to effectively connect the land and the sea, which reflects the inseparable overall relationship of mutual restriction, mutual promotion and common development between the two.

Keywords: Land and Sea Coordination; Evaluation Index; PSR Model; Ecosystem; Resources and Environment Carrying Capacity

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1. Introduction

Land-sea integration is to analyze land and sea as two independent systems in the process of social development, comprehensively considering their economic, ecological and social functions, involving resources, economy, society, ecology and safeguarding sovereignty, which is related to national development and national security.

In the 1930s, American scholars in related fields proposed to take the coastal zone as a composite element to manage marine resources and land resources in a unified manner. In October, 1972, the concept of "coastal zone management" was clearly put forward for the first time in the United States coastal zone management act, which means that under the guidance of sustainable development strategy, reasonable spatial planning is adopted to reduce the excessive development and utilization of sea and land resources and the damage degree of marine space resources[1]. In February, 1975, 17 Mediterranean countries approved the "map" at the meeting of governments of Mediterranean coastal countries convened by the United Nations Program, and the integrated coastal zone management (ICZM) was upgraded from the original closed and independent management mode to intergovernmental joint management[2]. Since then, the concept of Agenda 21 adopted at the United Nations Conference on environment and development (UNCED) has been formally put forward.

The implementation of land and sea integrated planning in China has entered the national strategic level, opening up a new situation of land and Sea comprehensive development. Therefore, there is an urgent need to study the evaluation system of land and sea resources and environmental carrying capacity.

Ocean and land are two major components of the global ecosystem, but these two systems are not completely independent. They affect and depend on each other, and they are an inseparable whole. For the discussion on the exact meaning of “land and sea coordination”, experts and scholars in many fields understand it from different angles, with different emphasis. At present, a unified conclusion has not been formed. Wang *et al*.[3] made a detailed discussion on land and sea coordination from the national and coastal levels, and gave the narrow meaning of “land and sea coordination” on the basis of ensuring the normal operation of regional ecological environment and social economy; Sun *et al*.[4] believed that land and sea integration is a complex system that takes the land subsystem and the sea subsystem as a whole, forming an interaction and having a certain unique structure and function; Ye[5] said that the purpose of land and sea integration is to maintain the stable development of the region, take into account the unique environment of marine and land resources, coordinate the development planning of the two regions, and fully consider the interaction between the sea and land systems; Wang[6] regarded land and sea coordination as coordinating the use of land and marine resources from the two aspects of ocean and land; Yang[7] believed that land and sea planning refers to macro-control of the industrial layout of land, marine resources and land resource development, so as to maximize the overall efficiency of the utilization of land and sea resources on the basis of ecological protection; Cai *et al*.[8] believed that the land system and the marine system should be regarded as a whole, with the sea and land regional planning policy as the guide and the regional carrying capacity as the core, so as to ensure the coordinated development between the social and economic system, the marine system and the land system; Cao *et al*.[9] believed that unified land and ocean planning, starting from the specific national conditions, promoted the comprehensive development from land to sea, and accelerated the development of land and ocean integration. He explained the strategic connotation of land and sea integrated development, deeply analyzed the current difficulties of land and sea integrated development in China, and then put forward strategic ideas and relevant countermeasures and suggestions for the future land and sea integrated development in China; Zhou *et al*.[10] constructed four target layers of land, ocean, water and geological environment, including nine criteria layers of cultivated land, construction land, resource supply, resource utilization, water environment, marine resources and marine environment, crustal stability, ground stability and mine geological environment, with a total of 37 evaluation indicators, and put forward the idea of five-level early warning for the monitoring of the carrying capacity of resources and environment in the overall planning of land and sea in Guangxi, put forward targeted suggestions and relevant countermeasures against the background of land and sea coordination.

At present, the research on land and sea planning is only a theoretical theory on the development of land and sea resources, environmental protection, ecological status and regional policy planning. From different perspectives, scholars in different fields hold different views on the interpretation of the connotation of land and sea planning and the construction of evaluation index system. Regarding the land area and the sea area as a composite system, how to establish the interaction and transformation relationship between the land area system and the sea area system is a problem that needs to be solved in the land and sea integrated research.

This study believes that the land and sea integration is to take the land system and the sea system as a whole, and plan the allocation of resource elements, the cultivation of advantageous industries, infrastructure construction and ecological environment improvement of the two systems in a unified manner, so as to achieve the coordinated development of the sea area and the land economy. The evaluation indicators of land and sea resources and environmental carrying capacity are mainly reflected in five aspects: the importance of ecological protection, the suitability of agricultural production, the suitability of urban construction, the impact of marine environment, socio-economic conditions and the current situation of marine economic development. The pressure state response (PSR) model is adopted, and the pressure index, state index and response index are used to build the framework of the evaluation system, so as to effectively connect the land system and the sea system, and reflect the inseparable overall relationship of mutual restriction, mutual promotion and common development between the two[11,12].

2. Evaluation index system of land and sea resources and environmental carrying capacity

The Ministry of Natural Resources has organized and formulated the *Guidelines for the Evaluation of the Carrying Capacity of Resources and Environment and the Suitability of Land and Space Development* (Trial), in which the carrying capacity of resources and environment mainly includes the importance of ecological protection, the suitability of agricultural production, and the suitability of urban construction. Referring to the corresponding technical guidelines and planning outline, this study complements the marine environmental impact, socio-economic conditions and the current situation of marine economic development, and jointly constructs the evaluation index system of land and sea integrated resource and environmental carrying capacity from five aspects: the importance of ecological protection, the suitability of agricultural production, the suitability of urban construction, marine environmental impact, socio-economic conditions and the current situation of marine economic development.

3. Construction principles

3.1 Systematic principle

This study refers to the *Technical Guidelines for the Evaluation of the Carrying Capacity of Resources and Environment and the Suitability of Territorial Space Development* (Trial) issued in June, July, November and December 2019, the *Compilation Guidelines of Provincial Land Space Planning* issued in January 2020, as well as refer to the *Technical Guidelines for Environmental Impact Assessment of Marine Engineering*, *GBT19485−2014*, *Technical Guidelines for Marine Functional Zoning* (*GB/T17108−2006*), *Outline of the National Ecological Demonstration Zone Construction Planning (1996−2050)* and *13th Five Year Plan of Ecological Protection in Dalian.* The article collected and referred to various technical specifications. The selected indicators are independent and linked with each other, with hierarchy, and form an evaluation index system from top to bottom.

3.2 Scientific principle

The evaluation of land and sea resources and environmental carrying capacity is a comprehensive study with many factors and aspects, including resources, environment, ecology and marine ecological environment. From the perspective of professional knowledge, we can have an in-depth understanding of the evaluation object. The selection of index system should be objective and reasonable, and can objectively reflect the utilization of regional resources, ecosystem structure, marine environment and other aspects. Combined with the preparation of territorial spatial planning, based on the systematic analysis of the relationship and role of regional water, land, ocean, climate, ecology, environment, disasters and other elements of resources and environment, the overall resource and environment carrying capacity of regional land and sea is objectively evaluated. The selection of evaluation indicators must be based on scientific theories to ensure the authenticity and reliability of evaluation results and provide scientific basis for decision-making.

3.3 Principle of representativeness

The evaluation indicators should be representative to reflect the characteristics of the overall resource and environmental carrying capacity of land and sea as far as possible, and should not be separated from the relevant data and information of the study area. Try to choose those comprehensive and representative indicators.

3.4 Principle of conciseness

Closely combined with the compilation of territorial spatial planning, the selection of evaluation indicators should comprehensively reflect the relationship and status of water, land, ocean, climate, ecology, environment and disasters. On the basis of ensuring science, grasp the essence and key, and select the most representative indicators.

3.5 Feasibility principle

The selection of evaluation indicators of land and sea resources and environmental carrying capacity should not only meet the theoretical requirements, but also consider the difficulty of data acquisition, whether the required data and statistical data are true and practical; the evaluation method adopted should be simple, easy to accept and easy to apply in the field of practical evaluation according to the actual research situation of the region.

3.6 Comprehensive principle

The evaluation index system of land and sea resources and environmental carrying capacity is a complex composed of resources, environment and other elements. There are many influencing factors and various indicators. Moreover, it is difficult to determine the qualitative and quantitative indicators. Therefore, the selected indicators should be considered comprehensively, take into account the overall situation, and comprehensively reflect all aspects affecting the land and sea resources and environmental carrying capacity in combination with the preparation of land and space planning.

4. Build a classification framework

Based on the establishment principle of index system to construct the evaluation index system: target layer–system layer–element layer–index layer–establish the index system.

4.1 Establishment of target level

The target level of the index system is a comprehensive description and overall reflection of the overall objective of the evaluation object. In order to maintain the sustainable development of resources and environment in the study area, the overall resource and environment carrying capacity of land and sea in the study area is taken as the target layer this time.

4.2 System level establishment

The system is composed of several interacting and interdependent elements, which is an organic whole with a certain level of specific functions, and this organic whole is subordinate to a larger system.

With reference to the technical guidelines and planning outlines such as the *Technical Guidelines for the Evaluation of the Carrying Capacity of Resources and Environment and the Suitability of Territorial Space Development* (Trial), *Technical Guidelines for Eenvironmental Impact Assessment of Marine Engineering GBT19485–2014*, *Technical Guidelines for Marine Functional Zoning GB/T17108–2006*, *Outline of the National Ecological Demonstration Zone Construction Plan (1996–2050)*, and *13th Five Year Plan for Ecological Protection of Dalian*. This study takes the importance of ecological protection, the suitability of agricultural production, the suitability of urban construction, the impact of marine environment, socio-economic conditions and the current situation of marine economic development are the system level. Each system is composed of a group of indicator elements. The index elements of each system are independent and linked to each other. They are hierarchical and form an evaluation index system from top to bottom.

4.3 Establishment of element level

The connotation of the system level is decomposed, and the corresponding indicators are selected according to different attributes to make a subsystem evaluation on the importance of ecological protection, the suitability of agricultural production, the suitability of urban construction, the impact of marine environment, socio-economic conditions and the current situation of marine economic development in the study area. The importance of ecological protection consists of the importance of ecosystem service function and the element layer of ecological sensitivity; agricultural production suitability and urban construction suitability are composed of land resource evaluation, water resource evaluation, environmental evaluation, disaster evaluation and other elements; marine environmental impact is composed of marine hydrodynamics, seawater quality, marine ecology and other elements; social and economic conditions and the current situation of marine economic development are composed of pressure indicators, state indicators, response indicators and other elements. Each element layer is composed of a group of indicators.

4.4 Establishment of index level

Analyze and evaluate the natural resources, landform and geological conditions of the area in depth, consult a large number of references on the overall carrying capacity of land and sea, conduct scientific analysis and statistics, and adopt feasible evaluation indicators based on technical guidelines and planning outline.

This study refers to the *Technical Guide for Evaluating the Carrying Capacity of Resources and Environment and the Suitability of Land Space Development* (Trial), and selects three related research index systems: the importance of ecological protection, the suitability of agricultural production, and the suitability of urban space development; with reference to the *Technical Guidelines for Environmental impact Assessment of Marine Engineering (GBT19485−2014)*, select the relevant research index system of marine hydrodynamics, seawater quality, marine ecology, etc.; with reference to the *Technical Guidelines for Marine Functional Zoning GB/T17108−2006*, select relevant research indicators such as socio-economic conditions and analysis of the current situation of marine economic development; with reference to the *13th Five Year Plan for Ecological Protection in Dalian*, relevant research indicators such as environmental quality indicators, pollution control indicators, environmental basic public service indicators, and ecological security pattern are selected; with reference to the *National Ecological Demonstration Zone Construction Planning Outline (1996−2050)*, based on the above indicators, the evaluation indicators of public participation in construction and poverty alleviation policies are selected.

5. Build an index system

5.1 Relevant research indicators of ecological protection importance evaluation

(1) The importance of ecosystem service function: including the importance of water conservation function, water and soil conservation function, biodiversity maintenance function, wind and sand prevention function, coastal protection function and other index elements.

(2) Ecological sensitivity: including index elements such as water and soil loss sensitivity, desertification sensitivity, rocky desertification sensitivity, coastal erosion and sand source loss sensitivity.

5.2 Relevant research indicators of agricultural production suitability evaluation

(1) Land resource evaluation: including slope and soil texture;

(2) Water resources evaluation: including the control index modulus of precipitation and total water consumption;

(3) Climate evaluation: ≥0 ℃ active accumulated temperature;

(4) Environmental assessment: soil environmental capacity;

(5) Disaster evaluation: meteorological disasters, including drought, rain and waterlogging, high temperature and heat damage, low temperature and cold damage, and strong wind disasters.

5.3 Relevant research indicators of urban construction suitability evaluation

(1) Land resource evaluation: slope, elevation and topographic relief.

(2) Water resources evaluation: precipitation and total water resources modulus.

(3) Climate evaluation: comfort.

(4) Environmental assessment: atmospheric environmental capacity and water environmental capacity.

(5) Disaster evaluation: geological disaster risk and storm surge disaster risk.

(6) Evaluation of location advantage degree: evaluation of location advantage degree at provincial level and evaluation of location advantage degree at municipal level.

5.4 Relevant research indicators of marine environmental impact assessment

(1) Relevant research indicators of marine hydrodynamics: bay tide level, tidal capacity of large, medium and small tidal bays, changes in flow field, water exchange capacity of large, medium and small tidal bays, physical self-purification capacity of bays, distribution of suspended sand fields, and changes in beach and seabed erosion and deposition.

(2) Research indicators related to seawater quality: bay sediment quality, bay biological quality, pollution source investigation and evaluation, bay pollution carrying capacity and pollutant purification capacity,

(3) Marine ecological related research indicators: bay chlorophyll, primary productivity, phytoplankton, zooplankton, benthos, intertidal organisms, fish eggs, larvae and juveniles, species composition and spatial distribution pattern, rare and endangered species and fishery biological evaluation.

5.5 Relevant research indicators of socio-economic conditions and marine economic development status

(1) Relevant research indicators of social and economic conditions: location condition analysis, population condition analysis, infrastructure analysis, regional economic analysis.

(2) Relevant research indicators for the analysis of the current situation of marine economic development: the analysis of the overall development level of marine economy, the analysis of marine industrial structure, the analysis of the basic characteristics of regional marine economy, the analysis of the overall development level of marine resources, and the main problems of marine economic development[13].

(3) Relevant research indicators of the *13th Five Year Plan for Ecological Protection in Dalian*: environmental quality, pollution control, basic environmental public services, and ecological security pattern.

(4) Indicators related to the construction of ecological demonstration areas: the level of public participation in the construction, poverty alleviation policies.

PSR is used to build the evaluation index system of socio-economic conditions and the current situation of marine economic development. This model was originally proposed by Canadian statisticians David J. Rapport and Tony Friend in 1979. In the 1980s and 1990s, the United Nations Environment Program (UNEP) and the Organization for Economic Cooperation and Development (OECD) used PSR to build a framework for the study of environmental issues from an economic perspective, reflecting the interconnection and interdependence between human beings and the environment[12,14]. At present, this model has been widely used in the fields of economy, environment, ecology and so on. This study uses this model to effectively link the land system and the sea system, so as to reflect the inseparable overall relationship between them, which is interdependent, mutually restrictive, mutually reinforcing and common development. This study analyzes the elements of relevant research indicators. The pressure indicators represent human beings’ demand for resources and consumption materials from the natural environment through various activities. Five indicators are adopted, including the analysis of the overall development level of marine economy, the analysis of marine industrial structure, the analysis of the basic characteristics of Regional Marine economy, the analysis of the overall development level of marine resources, and the main problems of marine economic development; status indicators represent environmental status and environmental changes, and four indicators are adopted, including location condition analysis, population condition analysis, infrastructure analysis, and regional economic analysis; response indicators refer to the response to negative environmental impacts through changes in consciousness and behavior, using six indicators, including environmental quality, pollution control, basic environmental public services, ecological security pattern, public participation in construction level, policies and regulations. Among them, the environmental quality includes 9 indicators, including the number of days when the air quality in the central urban area reaches good or above, the concentration of inhalable particles, the concentration of fine particles, the excellent proportion of river water quality, the water quality compliance rate of centralized drinking water source, the water quality compliance rate of offshore environmental function area, the soil environmental quality compliance rate of cultivated land, the soil environmental safety assurance rate of new construction land, and the total noise compliance rate in the functional area of the central urban area; pollution control includes six indicators, such as the total emission of sulfur dioxide, the total emission of nitrogen oxides the emission of chemical oxygen demand, the emission of ammonia nitrogen, the utilization and disposal rate of industrial solid waste, and the harmless treatment rate of hazardous waste; basic environmental public services include six indicators, including the domestic sewage treatment rate in the main urban area, the domestic sewage treatment rate in the county, the reclaimed water reuse rate in the urban area, the harmless treatment rate of domestic garbage in the main urban area, the harmless treatment rate of domestic garbage in the county, and the popularization rate of central heating in the main urban area; the ecological security pattern includes five indicators, including the proportion of the ecological protection red line area in the national territory area, the ecological environment quality index, the urban greening coverage rate, the urban per capita public green space area, and the forest greening rate. The evaluation index system of land and sea resources and environmental carrying capacity is shown in **Table 1**.

Table 1. Evaluation index system for the resources and environment carrying capacity of sea-land coordination

Target layer	System layer	Element layer	Index layer
Evaluation index system of land and sea resources and environmental carrying capacity	Evaluation of the importance of ecological protection	Importance of ecosystem services	Importance of water conservation function, water and soil conservation function, biodiversity maintenance function, wind prevention and sand fixation function, coastal protection function
		Ecological sensitivity	Sensitivity to water and soil loss, desertification, rocky desertification, coastal erosion and sand source loss
	Suitability evaluation of agricultural production	Land resource evaluation	Slope, soil texture
		Water resources evaluation	Control index modulus of precipitation and total water consumption
		Climate assessment	≥0 °C active accumulated temperature
		Environmental assessment	Soil environmental capacity
		Disaster evaluation	Meteorological disasters, including drought, rain and waterlogging, high temperature and heat damage, low temperature and cold damage, and strong wind disasters
	Suitability evaluation of urban construction	Land resource evaluation	Slope, elevation and topographic relief
		Water resources evaluation	Modulus of precipitation and total water resources
		Climate assessment	Comfort
		Environmental assessment	Atmospheric environmental capacity, water environmental capacity
		Disaster evaluation	Geological disaster risk and storm surge disaster risk
		Evaluation of location advantage	Evaluation of regional advantage at provincial level and municipal level
	Marine environmental impact assessment	Marine hydrodynamics	The tidal level of the Bay, the tidal capacity of the large, medium and small tides Bay, the changes of the flow field, the water exchange capacity of the large, medium and small tides Bay, the physical self-purification capacity of the Bay, the distribution of the suspended sand field, and the erosion and deposition changes of the beach and seabed.
		Seawater quality	The quality of sediment in the Bay, the biological quality of the Bay, the investigation and evaluation of pollution sources, the pollution carrying capacity of the Bay and the purification capacity of pollutants
		Marine ecology	Species composition and spatial distribution pattern of chlorophyll, primary productivity, phytoplankton, zooplankton, benthos, intertidal organisms, fish eggs, larvae and juveniles, rare and endangered species and fishery organisms in the Bay

6. Conclusion

At present, the academic community has not unified the understanding of the evaluation index system of land and sea resources and environmental carrying capacity. The difficulty lies in how to establish an influence relationship of mutual restriction, mutual promotion and common development between land and sea, which are not completely independent systems. As there are still deficiencies in the scientific understanding of land and sea planning, this study believes that at this stage, an index system can be established in five aspects: the importance of ecological protection, the suitability of agricultural production, the suitability of urban construction, the impact of marine environment, socio-economic conditions and the current situation of marine economic development, making the evaluation more complete and operable. In terms of the evaluation of social and economic conditions and the current situation of marine economic development, the PSR model is used to effectively connect the land and the sea, so as to reflect the inseparable overall relationship between the two, which restricts, promotes and develops together, so that the evaluation of the overall resource and environmental carrying capacity of the land and sea is more scientific and instructive. There are several aspects that need further research. (1) since there is still little research on the indicators of land and sea integrated resource and environmental carrying capacity, and the selection of indicators is also very different, it is necessary to strengthen the research on indicators in this area in the future. (2) The PSR model is used for analysis, which reflects the relationship between social and economic conditions and the current situation of marine economic development. However, there are also mutual influences and interactions between the importance of ecological protection, the suitability of agricultural production, the suitability of urban construction, and the marine environmental impact system. To express these connections clearly, it is also necessary to establish a model to simulate their mutual relations and dynamic changes[15-18]. (3) In terms of improving the independence and representativeness of indicators, and the selection of general indicators and regional characteristic indicators, research work should be further strengthened[19-23].

Conflict of interest

The authors declare no conflict of interest.

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