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Original Research

Research on the Synergy Measurement for Wetland Ecological-Economic -Social Composite System Based on Order Parameter

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Abstract

As the composite system of wetland ecology, economy and society is divided into wetland ecological subsystem, wetland economic subsystem and wetland social subsystem, this paper did the research on the measurement of the synergy degree between the three subsystems. First, we built the index system for measuring the order degree of each subsystem by PSR model and calculated the weight of each index. On this basis, this paper built a model for measuring the synergy degree. Then this paper did the empirical research using the data from 29 provinces, and the results showed that: the order degrees in different areas and subsystems are different; the synergy degrees in different areas are different; the wetland composite system in western China is evaluating to be more harmoniously, while in the east it's evaluating to be less harmoniously and in central China it evaluated from disharmoniously to harmoniously and to disharmoniously.

Keywords: wetland composite system, order degree, synergy degree, PSR model, improved DEAHP model

Proposal and Construction of Wetland Ecological-Economic-Social Composite System

General Secretary Xi Jinping has repeatedly proposed and stressed that "clear water and green mountains are as valuable as mountains of gold and silver", "ecology is resources and productivity". In fact, forests, grasslands, rivers and wetlands are green wealth bestowed on human beings by the nature. Wetlands, which enjoy the reputation of "kidney of the Earth", together with forests and oceans constitute three major ecosystems in the world, and play irreplaceable ecological functions such as resisting floods, regulating runoff, controlling pollution and regulating climate. However, the reckless destruction of wetland resources and ecology by human production and life around wetlands has not only led to the loss of ecological functions of wetlands, but also posed a serious threat to the prevention and protection of natural disasters

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and the safety of industrial and agricultural production in wetland areas.

In such cases, This study believes that the interactive coercive feedback mechanism of wetland ecology, production and life should be fully considered. On this basis, a model and scheme for effective protection of wetland ecology, rational allocation of wetland resources and reasonable arrangement of production and life around wetlands should be established to couple protection and utilization of wetland resources coordinately. Only by this way can achieve sustainable and healthy development of wetland ecological economy, and realize organic unity of economic, social and ecological civilization construction in wetland areas. Therefore, This study proposes to integrate ecology, production and life in wetland areas into a composite system by referring to the notion and research framework of ecological economic system [1, 2], which is called " wetland ecological-economic-social composite system".

Based on the definition of "social-economic-natural composite ecosystem" proposed by Ma Shijun and other scholars [3], combined with basic features of wetland ecology, economy and society, This study defines "wetland ecological-economic-social composite system" as follows: wetland ecological economic system is a special composite system with certain structure and function, which is composed of wetland ecological system, wetland economic system and wetland social system interacting, interweaving and interpenetrating. Dominated by human behaviour in wetland regions, Wetland ecological-economic-social composite system takes wetland environment as a basis, wetland resource as lifeblood, wetland regional social system as the channel. In essence, the operation of this composite system is the process of human protection, development and utilization of wetland resources, in order to make wetland factors of production allocate reasonably and utilize scientifically.

Fig. 1 shows the basic structure of the wetland ecological-economic-social composite system, from which it can be seen that this system is a special composite system composed of wetland ecology, regional economy and social development interacting, interweaving and interpenetrating, and contains three subsystems: wetland ecological economy, regional economic system and social development system, with energy, materials and information exchanging and value streams circulating and transforming. These three subsystems influence each other and evolve.

Wetland Ecological Subsystem

Wetland ecosystem refers to the organic whole that can achieve internal interaction and self-regulation between wetland organisms and environment through energy flow and materials circulation. In this system, biotic and abiotic components form the hierarchical spatial structure [4].

Wetland ecosystem plays an important role in human production and life because it can provide biotic and abiotic components such as wetland plants and animals, microorganisms, energy, materials and hydrology. In wetland ecosystem, the ecological materials and ecological services provided can be transformed into effective resources when they become part of wetland

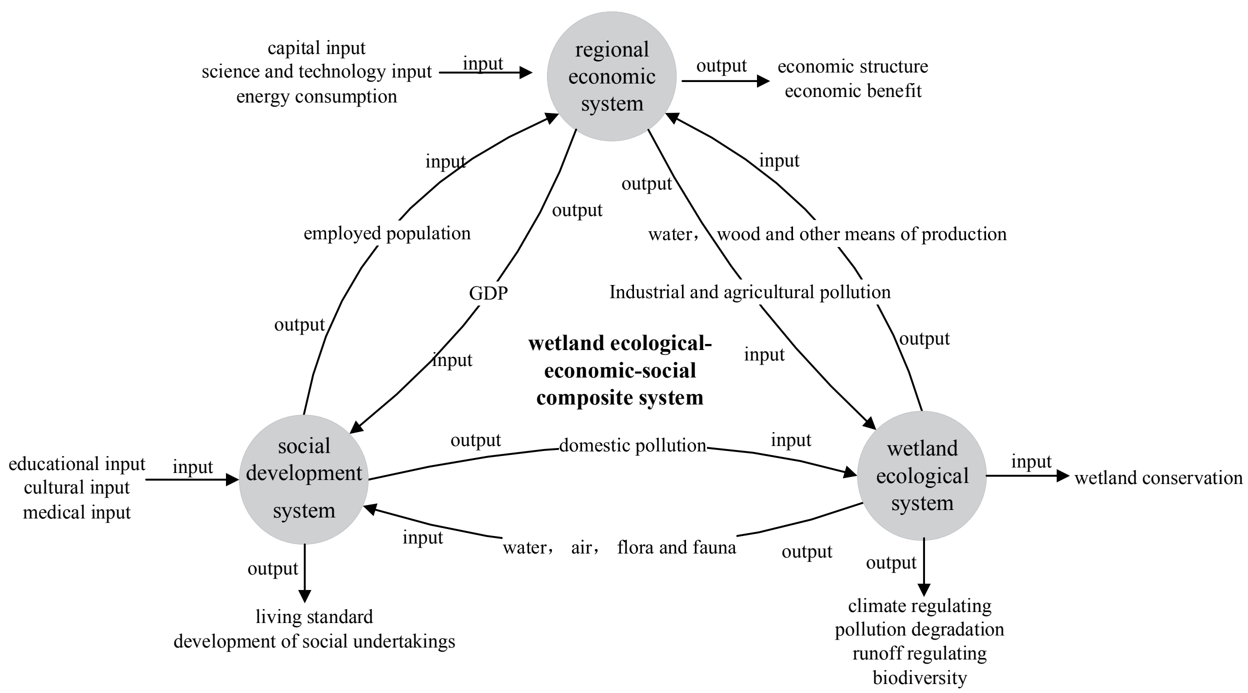

Fig. 1. Wetland ecological - economic - social composite system structure diagram.

regional social system and wetland economic system [5].

Wetland Regional Economic Subsystem

Economic system is a special whole consisting of productivity and production relations in a special environment or system. Wetland economic system is a kind of economic system under special environment (wetland) [6], the core of which is the matching and interactive influence mechanism of wetland productivity and wetland production relations in wetland environment [7]. Wetland productivity system and wetland production relations system will form special structures of production, circulation, distribution, consumption and ownership through the development, utilization, protection and service of wetland resources. Wetland productivity derived from wetland resources supply is the materials guarantee and driving force of wetland economic system.

In the interaction and match between wetland productivity and wetland production relations, wetland regional economy can create and accumulate value, which will reflect in the economic entity, that is, the formation of wetland industry. Wetland industry, refers to the general term for all kinds of material productions and service sectors that make use of wetland productivity brought by wetland resources. To be specific, wetland industry is an effective extension of existing industries, which is more green and ecological, including various forms such as wetland agriculture, peat industry, wetland tourism, wetland education, wetland scientific research.

Wetland Social Development Subsystem

Wetland social development system refers to the social communities and their interaction mechanism that gather within wetland regions and live on wetland economic productions and ecological services [8]. This system is human-centered and integrates ideology, moral spirit, culture and art, education, technology, law and regulations formed and accumulated in the wetland areas. Wetland social systems provide labor and intellectual support to wetland economic systems and wetland ecosystems.

Wetland is the origin of life and culture, known as “cradle of life”, “gene bank of species”, “birthplace of civilization”. The thoughts, beliefs, arts, science and regulations deposited in human evolution in the wetland areas are results of mind activities in wetland social system, constituting wetland spirit, history and culture, and playing specific functions in wetland composite system. These specific functions are manifested as follows: to provide spiritual guarantee and intellectual support for the operation of wetland economic system as well as the restoration and transformation of wetland ecosystem; to provide values and methodology for people to understand, utilize and transform wetland; to meet the spiritual and cultural needs of people in wetland areas; to cultivate people’s spiritual realm in wetland areas and promote their comprehensive quality development.

Construction of Evaluation Index System Based on PSR Model

The Pressure-State-Response (PSR) model was first proposed by the OECD to evaluate environment in the world[9]. As a relatively effective ecological evaluation and management model PSR has been widely used in the field of ecosystem evaluation in recent years [10-12].

As a complete natural geographical unit, wetland system is a composite system under the hydrological cycle. In wetland ecology-economy-society composite system, PSR model is based on cause-effect, reflecting the interaction between human production, life and wetland environment, that is, human activities exert certain pressure on wetland environment, resulting in the wetland environment changing its original nature or the quantity of natural resources, then people in turn response to these changes through environmental, economic and management measures to restore environmental quality or prevent environmental degradation. In other words, the pressure variable describes the impact exerted by human activities on wetland environment, that is the cause of wetland environmental problems; the state variable describes the physical measurable characteristics of wetland environmental problems caused by pressure variable; the response variable describes degree of social response to environmental problems, which can affect the state variable directly or indirectly, constituting the Pressure-State-Response model between human and environment. Based on above analysis, this paper construct a three- level evaluation index system for the order degree of each subsystem.

Calculation of Index Weights Based on Improved DEAHP Model

The weights of each index need to be set reasonably after establishing the above subsystem. At present, there are various subjective/objective index weighting methods about the determination of the weights of the order parameter index system, such as AHP Method [13, 14], Entropy Weighting Method [15, 16], CRITIC Method [17, 18], Correlation Matrix Weighting Method [19, 20], etc., but all of them have certain defects. Against this background, a popular method in decision-making is that combined with the subjective judgment matrix of experts, each index is regarded as a decision-making unit (DMU) and optimized by Data Envelopment Analysis (DEA) Method to determine the index weights. Ramanathan proposed the Data Envelopment Analysis of Hierarchy Process

Table 1. Index system of order degree of wetland composite system.

System Layer	State Layer	Basic Index Layer	Data Sources
Wetland ecological subsystem	Condition	Wetland area	*China Forestry Development Report, China Wetland Science Database*
		Wetland biodiversity	*China Forestry Development Report, China Wetland Science Database*
		Proportion of contaminated water area	*China Environmental Statistics Yearbook*
	Pressure	Amount of industrial wastewater discharged per unit land area	*China Statistical Yearbook, China Environmental Statistics Yearbook*
		Industrial solid waste generation per unit land area	*China Statistical Yearbook, China Environmental Statistics Yearbook*
	Response	Number of wetland parks or reserves	*China Forestry Development Report, China Wetland Science Database*
		Wetland conservation input ratio	*China Wetland Science Database*
		Investment in environmental protection accounted for GDP	*China Statistical Yearbook*
Wetland economic subsystem	Economic scale	Proportion of the total output of wetland industry in GDP	*China Wetland Science Database, China Statistical Yearbook, China Environmental Statistics Yearbook*
		Fixed asset investment per capita	*China Statistical Yearbook*
		Wetland GDP per capita	*China Wetland Science Database, China Statistical Yearbook, China Environmental Statistics Yearbook*
		Energy consumption	*China Energy Statistics Yearbook*
	Economic structure	Degree of industrial diversification	*China Statistical Yearbook*
		Proportion of wetland service industry	*China Wetland Science Database, China Statistical Yearbook*
		Proportion of wetland agriculture	*China Wetland Science Database, China Agricultural Yearbook*
Wetland social subsystem	Social-demographic	Population density	*China Demographic Yearbook*
		Urbanization level	*China Statistical Yearbook*
		Education level	*Chinese Education Statistical Yearbook*
		Proportion of employed person in wetland industry	*China Wetland Science Database, China Statistical Yearbook*
	Living standard	Per capita disposable income of urban residents	*China Statistical Yearbook*
		Per capita consumption of urban residents	*China Statistical Yearbook*
		Engel Coefficient	*China Statistical Yearbook*
		Medical beds per 10000 people	*China Statistical Yearbook*
	Scientific and technical	Density of scientific research institutions	*China Statistical Yearbook*
		Capacity of scientific research projects	*Chinese Education Statistical Yearbook, China Statistical Yearbook*
		Number of newly established enterprises	*China Statistical Yearbook*

(hereinafter referred to as DEAHP)[21], based on which Wang and Chin proposed Improved DEAHP Model, which compensates the defect of not being able to get reasonable weights in the case of discontinuity of comparison matrix [22]. In this paper, DEAHP Model will be used to determine the index weights of the three subsystems of wetland ecology, regional economy and social development. The basic idea is as follows.

Note that the complementary comparison matrix of the wetland subsystem index system is *A*:

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & \dots & \vdots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix}$$

Thus, $a_{ij} = 1/ a_{ij}$ ($i \neq j$). The DEAHP Model considers each row of A as a DMU and each column as an output index, while assuming that the inputs of all DMUs are 1. At this point, each DMU corresponds to a virtual constant input index and numerous output indexes. The weights of A can be obtained by using the input-output oriented CCR Model by defining $W = (w_1, w_2, ..., w_n)^T$ as the weight vector. The process is as follows.

$$Maximize \quad z_0 = \sum_{j=1}^{n} a_{ij} w_j \quad j = 1, 2, \cdots, n$$

$$s.t. \begin{cases} \sum_{j=1}^{n} \left(\sum_{i=1}^{n} a_{ij} \right) w_j = 1, \\ \sum_{j=1}^{n} a_{ij} w_j \geq n w_j, \quad i = 1, \ldots, n, \\ w_j \geq 0, \quad j = 1, \ldots, n. \end{cases} \tag{1}$$

The optimal solution of the above linear programming model w_0^* will be the weights of the DMUs$_0$. The corresponding weight vectors $W^* = (w_1^*, w_2^*, ..., w_n^*)^T$ can be obtained by solving all DMUs in A.

Furthermore, Wang and Chin realized that the weights of indexes will be judged by multiple experts, so they constructed the following group decision model: let $A^{(k)} = (a_{ij}^{(k)})_{n\times n}$ be the complementary comparison matrix given by the experts k(k = 1, 2, ..., m), and h_k be the relative authority among the experts, in which $\sum_{k=1}^{m} h_k = 1$ [23]. The model can be summarized as follows.

$$Maximize \quad z_0 = \sum_{j=1}^{n} \left(\sum_{k=1}^{m} h_k a_{ij}^{(k)} \right) w_j \quad j = 1, 2, \cdots, n$$

$$s.t. \begin{cases} \sum_{j=1}^{n} \left(\sum_{k=1}^{m} \sum_{l=1}^{n} h_k a_{ij}^{(k)} \right) w_j = 1, \\ \sum_{j=1}^{n} \left(\sum_{k=1}^{m} h_k a_{ij}^{(k)} \right) w_j \geq n w_j, \quad i = 1, \ldots, n, \\ w_j \geq 0, \quad j = 1, \ldots, n \end{cases} \tag{2}$$

Thus, the weight of order index system of each subsystem can be obtained, as shown in Table 2 below.

Modeling of the Synergy Degree in Wetland Composite System

After constructing the index system and setting the weights, the order degree of each subsystem of the wetland composite system need to be measured. In this system, μ_i(i = 1, 2, 3) is regarded as the order parameter of the wetland ecological subsystem, regional economic subsystem and social development subsystem, μ_{ij}(j = 1, 2, ..., m) represents the Number j index of the Number i order parameter, whose specific value is X_{ij}; If a_{ij}, β_{ij} are the upper and lower limits of the

Table 2. Calculation Results of Index Weight.

Sequence Number	Index Layer	Weight	Sequence Number	Index Layer	Weight
X1	Wetland area	0.0873	X14	Share of wetland services industry	0.0340
X2	Wetland biodiversity	0.0373	X15	Share of wetland agriculture	0.0340
X3	Proportion of area of contaminated water bodies	0.0540	X16	Population density	0.0240
X4	Volume of industrial wastewater discharged per unit of land area	0.0307	X17	Urbanization level	0.0273
X5	Industrial solid waste generation per unit land area	0.0607	X18	Education Level	0.0240
X6	Number of wetland parks/reserves	0.0373	X19	Share of people employed in wetland industries	0.0273
X7	Percentage of wetland conservation inputs	0.0540	X20	Per capita disposable income of urban residents	0.0240
X8	Environmental investment as a share of GDP	0.0707	X21	Per capita consumption of urban residents	0.0240
X9	Wetland industry GDP as a percentage of GDP	0.0507	X22	Engel coefficient	0.0307
X10	Per capita fixed asset investment	0.0407	X23	Medical beds per 10,000 population	0.0240
X11	Per capita gross wetland product	0.0373	X24	Density of scientific research institutions	0.0387
X12	Energy consumption	0.0240	X25	Capacity to undertake scientific research projects	0.0267
X13	Degree of industrial diversification	0.0387	X26	Number of new business start-ups	0.0300

order parameter respectively at the critical point of system stability, the contribution coefficients u_{ij} can be measured as follows.

$$u_{ij} = (X_{ij} - \beta_{ij}) / (\alpha_{ij} - \beta_{ij}), u_{ij} : benefit - oriented\ index$$
$$u_{ij} = (\alpha_{ij} - X_{ij}) / (\alpha_{ij} - \beta_{ij}), u_{ij}: cost - oriented\ index \tag{3}$$

In the above equation, u_{ij} reflects the degree of satisfaction of each index in reaching the target, with u_{ij} approaching 0 reflecting the least satisfaction and u_{ij} approaching 1 reflecting the greatest satisfaction. Negative outputs are recorded as cost-oriented indexes, including the proportion of polluted water bodies in the system, the volume of industrial wastewater discharged per unit land area and the volume of industrial solid waste per unit land area. Thus, the order parameter of each subsystem u_{ij}, also known as the order degree, can be calculated as follows:

$$u_i = \sum_{j=1}^{n} \lambda_{ij} u_{ij}, \sum_{i=1}^{m} \lambda_{ij} = 1 \tag{4}$$

After calculating the order degree of each subsystem, the synergy degree of the wetland composite system can be calculated. Fist of all, let a given initial moment be t_0, and the systematic order degree of each subsystem ordinal parameter be u_i^0. In this condition, noting the order degree of each subsystem u_i^1 at the moment of t_1, the synergy degree of the wetland composite system can be calculated as follows:

$$H = \theta \sqrt[3]{\left| \prod_{i=1}^{3} \left[u_i^1 - u_i^0 \right] \right|} \tag{5}$$

Of which $\theta = \dfrac{\min_i \left[u_i^1 - u_i^0 \right]}{\left| \min_i \left[u_i^1 - u_i^0 \right] \right|}$

Empirical Study

This chapter develops an empirical study based on an inter-provincial data sample. Due to the statistical discontinuity of wetland data, the time samples for the empirical study were identified as 1978, 1990, 2000, 2008 and 2019 based on the availability of data. With a total number of 145, observation samples contain provinces, autonomous regions and municipalities directly under the Central Government, among which Chongqing, Tibet Autonomous Region, Hong Kong, Macao and Taiwan regions were excluded because of the missing data. Data sources are detailed in Table 1.

For a better comparative analysis, this paper divides the data sample into three sub-samples: eastern, central and western samples, according to the criteria for dividing the three major domestic economic belts (Fig. 2), where the eastern samples include 12 provinces/autonomous regions/municipalities, including Liaoning, Hebei, Beijing, Tianjin, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Guangxi and Hainan; the central samples include nine provinces/autonomous regions/municipalities, including Heilongjiang, Jilin, Inner Mongolia, Shanxi, Henan, Hubei, Hunan, Anhui and Jiangxi; the western samples include 8 provinces/autonomous regions/municipalities in Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Ningxia, Qinghai and Xinjiang.

The first step is to calculate the order degree of ecological, economic and social subsystems of the wetland in different provinces/autonomous regions/municipalities. On this basis, the synergy degree of the wetland composite system can be calculated according to equation (5). The results are as follows.

Fig. 2. Division of Data Sample.

Table 3. Order Degree of Wetland Ecological Subsystem.

	1978	1990	2000	2008	2019
Liaoning	0.629	0.491	0.437	0.454	0.421
Beijing	0.687	0.593	0.568	0.631	0.583
Tianjin	0.676	0.597	0.575	0.628	0.592
Anhui	0.482	0.439	0.430	0.460	0.478
Shanghai	0.666	0.555	0.536	0.563	0.595
Jiangsu	0.663	0.561	0.543	0.590	0.629
Zhejiang	0.640	0.531	0.542	0.573	0.608
Fujian	0.604	0.511	0.489	0.509	0.551
Shandong	0.621	0.525	0.486	0.553	0.587
Guangdong	0.691	0.583	0.561	0.602	0.644
Guangxi	0.500	0.453	0.431	0.463	0.474
Hainan	0.493	0.385	0.372	0.395	0.435
Average of the Eastern Samples	0.613	0.519	0.497	0.535	0.550
Shanxi	0.574	0.477	0.450	0.469	0.468
Jilin	0.560	0.496	0.469	0.503	0.541
Heilongjiang	0.580	0.489	0.515	0.550	0.493
Anhui	0.572	0.528	0.476	0.492	0.532
Jiangxi	0.540	0.493	0.524	0.518	0.523
Henan	0.514	0.437	0.409	0.463	0.464
Hubei	0.590	0.515	0.474	0.491	0.510
Hunan	0.571	0.511	0.495	0.520	0.548
Inner Mongolia	0.549	0.496	0.449	0.459	0.488
Average of the Central Samples	0.561	0.493	0.473	0.496	0.507
Sichuan	0.645	0.555	0.534	0.572	0.567
Guizhou	0.445	0.389	0.387	0.414	0.424
Yunnan	0.564	0.477	0.478	0.501	0.523
Shaanxi	0.566	0.483	0.464	0.502	0.537
Gansu	0.579	0.471	0.487	0.523	0.561
Qinghai	0.679	0.597	0.567	0.623	0.668
Ningxia	0.547	0.469	0.449	0.484	0.507
Xinjiang	0.567	0.492	0.476	0.503	0.536
Average of the Western Samples	0.574	0.492	0.480	0.515	0.540
National Average	0.583	0.501	0.484	0.515	0.532

Table 4. Order Degree of Wetland Economic Subsystem.

	1978	1990	2000	2008	2019
Liaoning	0.273	0.367	0.496	0.616	0.790
Beijing	0.236	0.319	0.382	0.430	0.484
Tianjin	0.241	0.326	0.414	0.477	0.567

Table 4. Continued.

Anhui	0.154	0.218	0.271	0.299	0.308
Shanghai	0.195	0.269	0.341	0.360	0.439
Jiangsu	0.234	0.305	0.367	0.417	0.474
Zhejiang	0.227	0.295	0.353	0.374	0.453
Fujian	0.141	0.167	0.231	0.272	0.294
Shandong	0.183	0.253	0.335	0.375	0.416
Guangdong	0.225	0.298	0.372	0.400	0.454
Guangxi	0.297	0.427	0.548	0.605	0.723
Hainan	0.317	0.423	0.548	0.625	0.769
Average of the Eastern Samples	0.227	0.306	0.388	0.437	0.514
Shanxi	0.253	0.348	0.482	0.594	0.763
Jilin	0.263	0.350	0.468	0.587	0.717
Heilongjiang	0.268	0.384	0.512	0.579	0.738
Anhui	0.258	0.342	0.475	0.615	0.729
Jiangxi	0.276	0.413	0.521	0.584	0.694
Henan	0.260	0.386	0.524	0.620	0.817
Hubei	0.277	0.393	0.532	0.631	0.777
Hunan	0.284	0.415	0.552	0.606	0.728
Inner Mongolia	0.275	0.371	0.508	0.648	0.776
Average of the Central Samples	0.268	0.378	0.508	0.607	0.749
Sichuan	0.348	0.540	0.642	0.704	0.845
Guizhou	0.306	0.413	0.505	0.551	0.716
Yunnan	0.374	0.498	0.624	0.698	0.838
Shaanxi	0.317	0.430	0.532	0.605	0.775
Gansu	0.367	0.496	0.626	0.654	0.860
Qinghai	0.364	0.492	0.612	0.689	0.858
Ningxia	0.374	0.496	0.554	0.644	0.832
Xinjiang	0.333	0.447	0.555	0.665	0.819
Average of the Western Samples	0.348	0.477	0.581	0.651	0.818
National Average	0.281	0.389	0.495	0.568	0.666

Table 5. Order Degree of Wetland Social Subsystem.

	1978	1990	2000	2008	2019
Liaoning	0.168	0.288	0.347	0.402	0.567
Beijing	0.387	0.547	0.649	0.722	0.904
Tianjin	0.348	0.540	0.642	0.704	0.845
Anhui	0.306	0.413	0.505	0.551	0.663
Shanghai	0.374	0.498	0.624	0.698	0.893
Jiangsu	0.380	0.509	0.620	0.679	0.881
Zhejiang	0.367	0.496	0.626	0.654	0.860

Table 5. Continued.

Fujian	0.364	0.492	0.612	0.689	0.858
Shandong	0.374	0.496	0.554	0.644	0.832
Guangdong	0.396	0.526	0.643	0.721	0.925
Guangxi	0.195	0.269	0.311	0.391	0.394
Hainan	0.191	0.241	0.284	0.304	0.451
Average of the Eastern Samples	0.321	0.443	0.535	0.597	0.756
Shanxi	0.248	0.348	0.421	0.464	0.541
Jilin	0.263	0.350	0.407	0.466	0.494
Heilongjiang	0.226	0.384	0.451	0.458	0.515
Anhui	0.260	0.342	0.414	0.494	0.507
Jiangxi	0.244	0.334	0.459	0.463	0.472
Henan	0.292	0.386	0.463	0.499	0.595
Hubei	0.233	0.314	0.382	0.472	0.511
Hunan	0.259	0.336	0.402	0.480	0.506
Inner Mongolia	0.218	0.292	0.358	0.434	0.447
Average of the Central Samples	0.249	0.343	0.417	0.470	0.510
Sichuan	0.241	0.326	0.414	0.477	0.567
Guizhou	0.154	0.218	0.271	0.299	0.308
Yunnan	0.195	0.269	0.341	0.360	0.439
Shaanxi	0.234	0.305	0.367	0.417	0.474
Gansu	0.227	0.295	0.353	0.374	0.453
Qinghai	0.141	0.167	0.231	0.272	0.294
Ningxia	0.183	0.253	0.335	0.375	0.416
Xinjiang	0.225	0.298	0.372	0.400	0.454
Average of the Western Samples	0.200	0.266	0.336	0.372	0.425
National Average	0.257	0.351	0.429	0.480	0.564

Table 6. Synergy Degree of Wetland Composite System.

Synergy	1978	1990	2000	2008	2019
Liaoning	-0.25881	-0.12573	0.092883	0.121945	-0.22865
Beijing	0.273657	0.142855	-0.15936	-0.17455	-0.23706
Tianjin	0.247745	0.149178	-0.13565	-0.13753	-0.11987
Anhui	0.206493	0.104183	-0.14099	-0.15474	-0.22292
Shanghai	0.291344	0.154765	-0.16902	-0.21034	-0.27632
Jiangsu	0.261071	0.140235	-0.15132	-0.15941	-0.25148
Zhejiang	0.250859	0.117777	-0.16297	-0.1651	-0.25149
Fujian	0.291406	0.101701	-0.17605	-0.19824	-0.1853
Shandong	0.273983	0.124194	-0.1306	-0.16374	-0.25961
Guangdong	0.286457	0.155104	-0.1615	-0.19754	-0.29338
Guangxi	-0.18468	-0.09166	0.149674	0.129917	0.186538

Table 6. Continued.

Hainan	-0.18857	0.09973	0.15977	0.188536	-0.11803
Average of the Eastern Samples	0.219423	0.126107	-0.08047	-0.09393	-0.09578
Shanxi	-0.08084	0	0.038768	0.044252	-0.16867
Jilin	0	0	-0.01535	0.072048	0.122269
Heilongjiang	-0.16722	0	-0.02242	0.068765	-0.10577
Anhui	0.062771	0	-0.01688	-0.03164	0.103523
Jiangxi	-0.13482	-0.10014	-0.02342	0.075952	0.125198
Henan	0.121265	0	-0.07274	-0.08817	-0.21704
Hubei	-0.17013	-0.12444	0.092597	0.07379	-0.04585
Hunan	-0.13122	-0.11026	0.09242	0.076057	0.119419
Inner Mongolia	-0.17285	-0.12649	0.092793	0.099621	0.157193
Average of the Central Samples	-0.12016	-0.08486	0.05622	0.073348	-0.04973
Sichuan	-0.234	-0.09122	0.14399	0.141665	-0.02259
Guizhou	-0.18307	0.09283	0.147459	0.158298	0.189352
Yunnan	-0.23279	0.101112	0.177894	0.211195	0.175898
Shaanxi	-0.19035	-0.10586	0.103229	0.117984	0.120499
Gansu	-0.21889	0.095989	0.17183	0.176119	0.187554
Qinghai	-0.33561	-0.24458	0.179305	0.213302	0.249525
Ningxia	-0.22924	0.113147	0.137405	0.167828	0.18684
Xinjiang	-0.20531	-0.10938	0.114669	0.164123	0.158766
Average of the Western Samples	-0.23225	-0.08938	0.15317	0.176091	0.181287
National Average	-0.13376	-0.08674	0.034823	0.055125	-0.07517

From the above results, we can see that: 1) The order degree of both wetland economic subsystem and wetland social subsystem show an increasing trend year by year, but the order degree of wetland ecological subsystem has experienced the process of first decreasing and then increasing. This indicates that both wetland economy and society are developing in a more balanced and orderly way, while wetland ecology has experienced disorderly development after the reform and opening up, and then moved towards orderly development after entering the 21st century; 2) The order degree of different subsystems in the same geographical area is different. The order degree of the ecological subsystem is maintained between 0.40 and 0.65, while that of the economic and social subsystems is from 0.2 to 0.8, a larger range; 3) The order degree

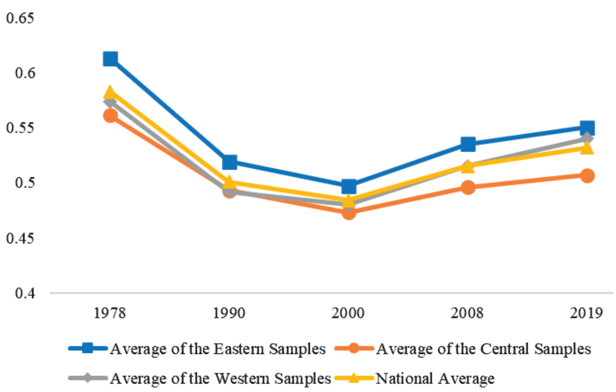

Fig. 3. Order Degree of Wetland Ecological Subsystem.

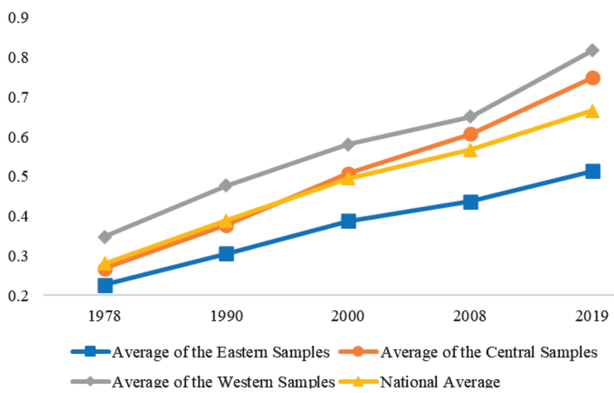

Fig. 4. Order Degree of Wetland Economic Subsystem.

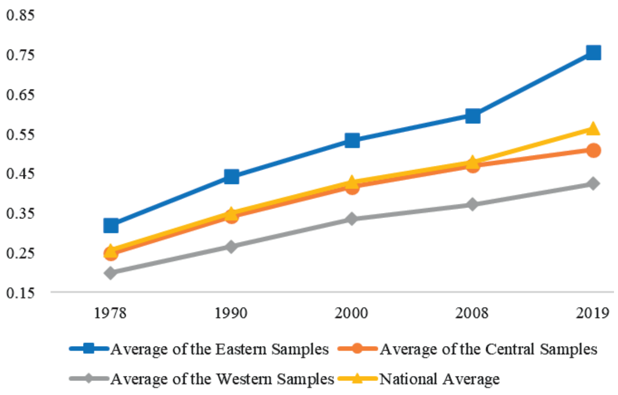

Fig. 5. Order Degree of Wetland Social Subsystem.

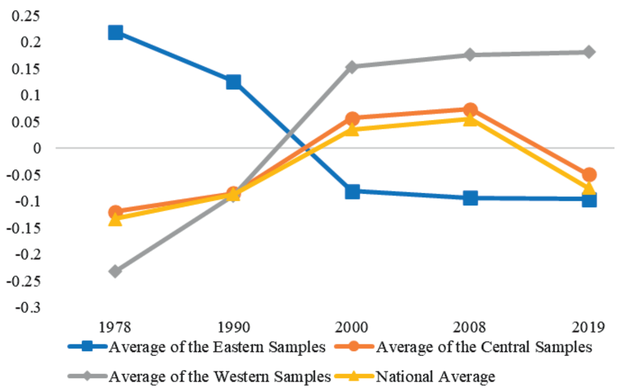

Fig. 6. Synergy Degree of Wetland Composite System.

of different regions under the same subsystem also varies. In terms of the order degree, for the ecological subsystem, the order is east, west and central; for the economic subsystem, the order is west, central and east; for the social subsystem, the order is east, central and west; 4) In terms of synergy degree, eastern, central and western regions show obvious differences: although the synergy degree is still very low in the west, ecological-economic-social composite system of wetland is growing more synergistic; the eastern region changed from positive synergy to negative synergy, indicating that with the development of economy and society, the ecology, production and life of wetlands in the region were deviating from harmonious unity; the central region has experienced the development from deviation to harmony and then to deviation again.

Conclusion

This paper proposes the concept of wetland composite system of ecology, economy and society, and constructs a metric model for the synergy of the composite system on the basis of measuring the order degree of the three subsystems. The empirical results based on 29 provinces/autonomous regions/municipalities across China show that: differences exist not only in the order degree of different regions and subsystems, but also the synergy degree of the wetland composite system in the east, central and western regions. Specifically, in terms of wetland ecology, economy and society, western region is growing more synergistic; eastern region is getting more divergent; and central region have experienced a evolutionary process of getting divergent at the beginning, growing synergistic afterwards, and currently getting divergent again. The research have strong guiding significance for how to build a harmonious and synergistic ecological-economic-social composite system of wetland.

Conflict of Interest

All the authors declare that they have no conflicts of interest.

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