

The Progress of Chinese Researches on Social-ecological System and Its Enlightenment to Relevant Researches in Arctic-alpine Ethnic Region

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Abstract—With the deepening of national ecological civilization construction in China, it is urgently needed to study the "taking mountains, rivers, forests, farmlands, lakes, and grasslands composed life community" from the perspective of complex adaptive system. The theory of social-ecological system provides the basis for making an interdisciplinary integration research on the complex adaptive systems, and has certain theoretical significance to sort out the progress of social-ecological system researches in China. Based on the social-ecological research literatures in China, this paper combs Chinese progress in this theoretical research. It is concluded that the theory of social-ecological system has different connotations, and Chinese geographical circle's practice in research on human-land complex system is more prone to the composition of social-ecological system from the perspective of ecological, economic and social subsystems. In the field of public management, Ostrom's social-ecological system diagnostic analysis framework was used to study the complex adaptive systems of mining areas, lake basins and grasslands. This paper further combs the vulnerability, resilience, adaptability and cohesion research progress in social-ecological system sustainability researches, proposes to study the composition of the social-ecological system in arctic-alpine ethnic region from aspects of ecology, economy, society and culture based on the existing researches and the regional characteristics of the arctic-alpine ethnic region, and puts forward a socio-ecological analysis framework for arctic-alpine ethnic region based on Ostrom's social-ecological system diagnostic analysis framework.

Keywords—social-ecological system; research progress; arctic-alpine ethnic region; enlightenment

I. INTRODUCTION

At the 18th National Congress of the Communist Party of China, General Secretary Xi Jinping proposed the principle of "taking mountains, rivers, forests, farmlands, lakes, and grasslands as a life community" from the macroscopic view of natural resources and ecosystem management in the new era and emphasized that it is necessary to use systemic thinking methods to manage natural resources and

ecosystems and treats and deploys the overall governance of the "mountains, rivers, forests, farmlands, lakes, and grasslands" system as a key content of ecological civilization construction [1]. Therefore, using complex system theory to study the natural, social and economic complex system has important practical theoretical needs. At the same time, with the deepening of urbanization in China, the interaction mechanism of human-land relationship becomes more and more complex, faces the interference of multi-scale and multi-pressure disturbance factors; the natural, social and economic complex system is always in the process of dynamic evolution. Social-ecological system theory is an important theory for studying complex adaptive systems. Therefore, combing the current progress in researches on Chinese social-ecological system theory has important practical and theoretical significance for further understanding the scientific discourse of "taking mountains, rivers, forests, farmlands, lakes, and grasslands as a life community".

Based on the social-ecological system research literatures in China, this paper combs the progress of theoretical researches on social-ecological system in China. Firstly, it analyzes the concept and research content of social-ecological system theory in different disciplines; secondly, it analyzes the difference between the theoretical research tradition of human-land complex system and the social-ecological system theory; thirdly, it analyzes the characteristics of researches on the composition of social-ecological system that are made by Chinese geographical circles based on the theory of human-land complex system from the perspectives of ecological, economic and social subsystems; meanwhile, it also combs the researches that Chinese public administration field of researchers make on specific complex adaptive system by using Ostrom's social-ecological system diagnostic analysis framework; fourthly, this paper further combs the vulnerability, resilience, adaptability and cohesion of social-ecological system sustainability research; fifthly, it proposes to study the composition of the social-ecological system in arctic-alpine

ethnic region from aspects of ecology, economy, society and culture based on the existing researches and the regional characteristics of the arctic-alpine ethnic region, and puts forward a socio-ecological analysis framework for arctic-alpine ethnic region based on Ostrom's social-ecological system diagnostic analysis framework.

II. IDENTIFICATION OF THE CONCEPT OF SOCIAL-ECOLOGICAL SYSTEM

A. Definition of the Concept in Different Research Fields

In the field of sociology research, social-ecological system theory, hereinafter referred to as the ecosystem theory [2], is a basic theory that closely combines system theory, sociology and ecology and is different from the social-ecological system theory in management and geography research fields. According to the ecosystem theory in the field of sociology research, the social environment (family, group, organization, institution, community, etc.) in which human beings live is an ecosystem with social nature; it is divided into micro, meso and macro types respectively corresponding to individuals, small groups and larger social systems [3], and emphasizes the relationship between individuals and their growing environment, namely the development of individuals is in an environment that interacts with them and constantly changes; at the same time, this environment is hierarchical, and has four levels such as micro system, intermediate system, outer system, and macro system according to the frequency and close extent of their interaction with individuals, constituting a concentric structure [4]. According to the ecosystem theory, individuals' ability to interact with the environmental system is innate, and the relationship between people and the environment is reciprocal [5].

In the field of Chinese geography research, with respect to the interaction relation between nature and society, Ma Shijun and Wang Rusong proposed that the survival and development of the three different systems of society, economy and nature are constrained by other system structures and functions, constituting a social-economic-natural complex ecosystem [6]. Therefore, human society is a kind of socio-economic-natural complex ecosystem taking human behavior as the leading factor, natural environment as the basis, resource flow as the lifeline and social culture as the meridian [7]. Zhou Xiaofang believed that, in concept, the human-land complex system concerned by Chinese geography scholars is very similar to the social-ecological system, but they are fundamentally different in the consideration of the system background and system environment issues. The theory of human-land complex system in China pays attention to the contradiction between human and land and finally takes sustainable development as the highest form, while the social-ecological system pays more attention to the interference factors in the environment and is characterized by uncertain future [8].

B. The Concept of Social-ecological System

The social-ecological system analysis framework was extended from the economics research of fisheries management to the cross-disciplinary research fields of

ecology, geography, sociology and political science for the first time, and provides scholars with a basic carrier that can accommodate and integrate complex variables and knowledge system, involving ecology, economy, society and other aspects [9]. The socio-ecological system theory was introduced into ecosystem research field by Ecologist Holling in 1973 on the basis of complex adaptive system theory; Holling maintained that social-ecological system was a typical complex adaptive system, having nonlinearity, unpredictability and self-organization features [10]. There are complex interactions between social system and ecology, such as nonlinearity, circular feedback, time lag, genetic effects, thresholds, heterogeneity and mutation. The analytical frameworks for researching the peace mechanism between social system and ecosystem include the human-environmental system framework, management-transformation framework, and social-ecological system framework; wherein, the social-ecological system framework specifically deconstructs the peace structure between social system and ecosystem, has multi-level network structure and thus can be used for making multi-scale analysis [11].

III. THE COMPOSITION AND ANALYSIS FRAMEWORK OF SOCIAL-ECOLOGICAL SYSTEM

A. Analysis Framework of Social, Economic and Natural Subsystems

Based on the research tradition of human-land complex system, it is proposed, from the perspective of complex system, that the social-ecological system is composed of social subsystem, economic subsystem and natural subsystem, and emphasizes the nonlinear interaction between the three subsystems [6]. Fu Qiang and Fan Dongping believed that the social-ecological system was a complex adaptive system, and the social subsystem, economic subsystem and natural subsystem constituted the adaptive action subject of this complex adaptive system [12]; Wang Xingyu, Wang Jun and et al constructed a social-ecological system model with Farm household scale from social, economic and ecological perspectives [13]; Wang Jun, Yang Xinjun and et al selected the water sensitive factor from social, economic and ecological perspectives, and constructed a socio-ecological system model of semi-arid area [14]; Jiang Wei, Wang Jun, Yang Xinjun and et al constructed a rural social-ecological system model of the Loess Plateau from the perspective of social, economic and ecological sub-systems [15]; Wang Qun, Lu Lin and et al took social, economic and ecological subsystems as the measurement units and constructed a social-ecological system analysis model of tourist destinations [16]; Wang Zijiao, Yang Xinjun and et al constructed a rural society-ecological system assessment framework from social, economic and ecological perspectives, selected the system indicators in Delphi method, and finally constructed a rural society-ecological system composed of three components such as social subsystem, economic subsystem, and ecological subsystem, and nine indicators [17]; Wu Haoyi, Li Wenjun and et al proposed that the grassland ecosystem was a complex social, economic, and ecological system, and put forward a conceptual model grassland social-ecological

system based on the idea of "soil-grass interface, grass-animal interface, and grass-animal-human interface" [18].

B. Ostrom's Social-ecological System Analysis Framework

Chinese scholars introduced Ostrom's social-ecological system analysis framework and also made empirical research on the basis of this framework. Tan Jiangtao analyzed this framework: Ostrom believed that the social-ecological system included four core subsystems such as resource system, resource unit, management system and users. Those four subsystems may directly affect the final interaction result of the social-ecological system, and may also receive the counter-action of the interaction results. Ostrom further made an expansive research on this framework and introduced action scenarios as the dynamic basis of the analytical framework [19]; Yang Tao discussed the framework from the factors influencing governance actions of public affairs, and made detailed analysis on the variables in the framework from individual, micro and macro levels respectively [20].

In aspect of applying Ostrom's socio-ecological analysis framework to make empirical research, some research progress has been achieved in recent two years. The socio-ecological system analysis framework was used to refine the list of key variables having effect on specific social-ecological systems; and complex variable indicators were incorporated into a systematic, multi-level analytical framework for diagnostic analysis. This research approach is currently a common practice of applying Ostrom's social-ecological analysis framework to make diagnostic research. Wang Xiaoli used this method to analyze the key variables of the governance system, actor system and resource system in the social-ecological system of three coastal fishing grounds in the California Bay [21]; Wang Yahua applied this framework, identified ten key variables affecting the possibility of independent governance of public pond resources: scale of resource system, the productivity of the system, predictability of dynamic changes of the system, liquidity of resource units, number of users, leadership, social capital, knowledge, the importance of resources to users and the rules for collective choice, and tested the second-level variables that may be related to independent governance of irrigation in the social-ecological system framework one by one combined with historical data [22]; Yang Ting took chemical park as the resource system, the chemical park management committee as the governance system, and the chemical product as a resource unit, enterprises and the public as users, and constructed a social-ecological system framework for China's chemical industry park [23]; Shang Zhimin constructed a mining area social ecosystem complex structure composed of the mining economy, workers culture, industrial policy, natural ecology, legal systems and other elements specific in mining area, taking mineral resources, mineral enterprises, management departments and users as the main bodies, and used analytical comparison method to measure the resilience of the mine social-ecological system [24].

IV. STUDY ON THE SUSTAINABILITY OF THE SOCIAL-ECOLOGICAL SYSTEM

A. Vulnerability

Chen Yaling, Yang Xinjun and et al used the relationship between vulnerability and resilience "two sides of a coin" and introduced tourism pressure and sensitivity index to research the vulnerability and resilience of tourism society-ecological system [25]; Yu Zhongyuan combined the "stress-state-response" model and "exposure-sensitivity-response ability" model of utilization and sustainable development of the evaluation resources, and constructed a driving mechanism model with respect to the vulnerability of the social-ecological system [26], and made research on the vulnerability of the social-ecological system and its driving mechanism, and analyzed the spatial and temporal evolution characteristics of vulnerability of the social-ecological system in Dianchi region within 1990-2010 [27]; lake basin became the key area of research on vulnerability of the system due to its high coupling with natural society, relatively complete ecosystem structure and function and risk to external world especially the relative sensitivity toward human activities. Yu Zhongyuan used the "exposure-sensitivity-response ability" model and constructed the social-ecological system vulnerability analysis framework to analyze the spatial and temporal evolution of lake basin's vulnerability and the driving mechanism formed by the vulnerability [28]; Yu Zhongyuan and Li Bo combined the "stress-state-response" model and "exposure-sensitivity-resilience" model, and constructed the analysis framework and evaluation model of social-ecological system vulnerability of lake basins [29]; in regional dimension, Li Jie and Zhao Ruifeng studied the vulnerability of Gansu provincial social-ecological system, took exposure-sensitivity-adaptability as the basic elements of vulnerability, and got natural factors, human stress, natural environment, social economy, economic response, and social measures constituted an evaluation indicators system for evaluating vulnerability of provincial social-ecological system [30]; Wen Xiaojin, Yang Xinjun and et al used the exposure-sensitivity-adaptability evaluation method to study the vulnerability of social-ecological systems in mountainous cities under multi-adaptive targets, analyzed the spatial and temporal evolution of the vulnerability in county field, and put forward the vulnerability scenarios under different adaptation targets [31]; Chen Jia, Yang Xinjun and et al used the VSD framework to study the evolution of socio-ecological system vulnerability in semi-arid areas, got the vulnerability divided into exposure, sensitivity and adaptability, and analyzed the spatial and temporal distribution characteristics and evolution trend of socio-ecological system vulnerability in semi-arid areas [32]; Wang Linfeng maintained that the vulnerability of socio-ecological system in agro-pastoral transition zone referred to the sensitivity of the social ecosystem in the face of multiple disturbances such as drought, land desertification, and policy changes, and the lack of response ability so that the system structure and function are easy to be changed, emphasized the sensitivity and response ability of socio-ecological system, and constructed a socio-ecological system

vulnerability indicator system from the perspectives of ecology, resources, society and economy [33].

B. Resilience

Resilience research has gone through a research process of shifting from an ecosystem to a socio-ecological system. Holling introduced resilience into social-ecological system, and defined resilience as the ability of social-ecological system to withstand disturbances and maintain its functions. The social-ecological system resilience measurement index system was constructed through the social, economic and ecological subsystems [34]. At present, the measurement of the resilience of social-ecological system in China is mainly made on the basis of the relationship of "two sides of a coin", namely "the opposite side of vulnerability is resilience" and then an analytical model was constructed. Wang Xingyu, Wang Jun and et al selected the water sensitive factor of farm household scale from the perspectives of society, economy and ecology, and constructed the evaluation model of the resilience of the socio-ecological system against the drought weather at the farm household scale [13]; Wang Jun, Yang Xinjun and et al constructed a social-ecological system resilience measurement model for semi-arid region on the basis of the relationship of "two sides of a coin" between vulnerability and resilience, and the water sensitive factor selected from the three perspectives of society, economy and ecology, and analyzed the time-order characteristics of the resilience change by using time-order data [14]; Chen Yaling, Yang Xinjun and et al researched the vulnerability and resilience of social-ecological system in tourism by using the relation between vulnerability and resilience and introducing in the indexes of tourism pressure and sensitivity [25]; Wang Fuqiang and et al researched the drought resilience of social-ecological system in provincial level on the basis of the relation between vulnerability and resilience [35]; Yang Xinjun and Shi Yuzhong took road construction as the disturbance factor, analyzed the road construction's influence on the social-ecological system in Qinling Mountainous areas, and researched the social-economic connectivity and rural community resilience of the system [36]; Wang Qun, Lu Lin and et al took the three subsystems of society, economy and ecology as the measurement units, analyzed the vulnerability and response capacity of each unit, and then constructed a resilience measurement index system for the social-ecological system of tourist destination [16]; Li Dezhi conducted a review research on the resilience of social-ecological system in foreign countries, identified the concept of resilience, analyzed the research objects of the current social-ecological system from the aspects of cities, communities, social groups, and so on, and summarized the current resilience measurement method from the perspectives of survey research and math model [37]; Shang Zhimin established a social ecological system composite structure for mining area constituted by four subjects such as mineral resources, mineral enterprises, management departments and users and many special elements of mining area such as mining economy, worker culture, industrial policy, natural ecology and legal system, and measured the resilience of the social-ecological system of mining area in analytical comparison method [24].

C. Adaptability

The social-ecological system of lake-type tourism destination has three adaptive circulation circles, one poverty trap and several adaptive cycle stages. Engineering construction and tourism development are the direct driving forces for the social-ecological system transformation of tourist destinations; the regional development thrust and tourism market demand are the main external disturbances; the internal economic development desire and resource protection restriction are the internal driving forces of evolution of the social-ecological system of tourist destination [38].

D. Cohesion

In view of measurement of the anti-interference ability of social-ecological system, Hu Xiaobing, Shi Peijun and et al proposed the concept of cohesion based on the connectivity of complex network, and believed that cohesion is a more universal connection, while network cohesion provide brand-new contents for optimizing network system, not only can describe the anti-interference ability of the system, but also can represent more extensive practical meaning [39]; Shi Peijun and et al analyzed the general concepts of sustainability of the social-ecological system, including vulnerability, resilience and adaptability. As for the design of structure and functions carrying the subsystems, the coordinated operation between the elements in the economic, social, institutional and other subsystems, and further effective changing of the vulnerability, resilience, adaptability, reducing sensitivity and exposure and improving the response ability of the system, Shi Peijun put forward the concept of "cohesion" of the social-ecological system; it is an ability to explain the adjustment and optimization of the system structure and functions and the reduction of the vulnerability [40].

V. ENLIGHTENMENT FROM RELEVANT RESEARCHES ON ARCTIC-ALPINE ETHNIC REGION

A. Regional Characteristics of Arctic-alpine Ethnic Region

Arctic-alpine ethnic region has vulnerable ecological environment, is an important ecological function area of China, and bears the important ecological functions of conserving water sources and replenishing rivers; such region is a concentrated area for ethnic minorities. The livelihood of people here is mainly based on traditional animal husbandry, and has significant local cultural characteristics. This paper takes Gannan Tibetan Autonomous Prefecture as the research region; this region is one of the deep poverty areas, with vulnerable ecological environment, and the economic industry here faces a large escalating transformation pressure. In the process of ecological economy, society and culture, such region faces environmental pressures such as drought, snow disaster and grassland degradation, as well as disturbance brought by economic factors such as changes in livelihoods, resource exploitation, and tourism development. It also experiences the influence of social management factors such as grassland management methods and public utilities and facilities, as well as the influence of the impact and integration of foreign culture. Therefore, making research on the social-ecological

system of arctic-alpine ethnic region represented by the Gannan Tibetan Autonomous Prefecture is of certain practical significance and can provide a theoretical basis for formulating scientific and rational comprehensive development policy for such region.

B. Recognition Based on Human-land Complex System

Duan Yifu believed that "The theme of humanism expresses a deep-rooted desire which is to understand the complexity and subtlety of human experience, so as to pay more attention to quality, adjectives and psychology than quantity, nouns and economics". [41] Natural system and human experience system both show complex characteristics. Geography studies the relationship between human and land; it reveals the laws of natural science of "land", and also attaches importance to the complexity of "people" which cannot be simply summarized in the term "human beings". Research on the social-ecological system of arctic-alpine ethnic region should pay particular attention to the "collective unconsciousness" of ethnic group, namely a stable cultural and psychological structure constructed jointly by primitive religion, Tibetan Buddhism, love of the land, and behavioral habits. Through research on the cultural subsystem of the social-ecological system of arctic-alpine ethnic region from the perspective of complex science, it is possible to comb the rational content within which has reference meaning for current ecological civilization construction and policy formulation, and appropriately adjust the environmental and resource concepts of the current utilitarianism. Therefore, the research on the composition of social-ecological system of arctic-alpine ethnic region based on the theory of human-land complex system should emphasize the importance of researching the cultural subsystem of the region, expand the three subsystems of ecology, economy and society in existing researches, and

form an ecological-economic-social-cultural composite system analysis model in line with the local characteristics of arctic-alpine ethnic region.

C. Applying Ostrom's Analysis Framework

The grassland-colony system of arctic-alpine ethnic region is essentially a social-ecological system. Ostrom's social-ecological system analysis framework includes four sub-systems: "resource system", "resource unit", "governance system" and "user/actor"; meanwhile, those subsystems are also affected by extensive social, economic, political, and ecological environmental context variables. The scale of resource system, the productivity of the system, predictability of dynamic changes of the system, liquidity of resource units, number of users, leadership, social capital, knowledge, the importance of resources to users and the rules for collective choice are ten key variables proposed by Ostrom against the independent governance of public pond s.

Rural community in arctic-alpine ethnic region is a complex, diverse system taking grassland as the environment and livelihood background, has high unpredictability and is typical social-ecological system. The resource subsystem of rural social-ecological system in arctic-alpine ethnic region refers to grassland; the resource unit refers to pasture and cattle and sheep; the governance system refers to the relevant institutional arrangements and policy systems from the central to the local level; the actor refers to pastoralists, experts and scholars, non-governmental organizations, tourists and other individuals or organizations relevant to the utilization and governance of grassland; the economic, social and political environments and ecological system research area contain different scales of social, economic, climatic, geographic and other background factors, as shown in "Table I".

TABLE I. RURAL SOCIAL-ECOLOGICAL SYSTEM ANALYSIS FRAMEWORK IN ARCTIC-ALPINE ETHNIC REGION

Resource system	Actor	Social, economic and political backgrounds
Resource type	Herder	Economic development
Clear resource boundaries	Experts and scholars	— Regional economic level
Scale of the resource system	NGO	Population trend
— available grassland area	Tourist	— Total population
— per capita grassland area	Socioeconomic attribute	Political stability
Artificial facility	History or previous experience	— importance attached to by the central government
— grassland fence	Position	— extreme events
— breeding greenhouse	Leadership	Other governance systems
Output of the resource system	Social capital	Market
Average grass yield/mu	Social ecosystem view / mental model	Media organization
— Average grazing capacity/mu	Dependence on resources	Technology
Balance	— Economic dependence	
System dynamic predictability	Available technology	
Storage feature		
Position		
Resource unit	Interaction process	Characteristics of relevant ecosystem
Mobility of resource units	Harvest yield of different actors	Climatic characteristics
Updating or growth rate	Information sharing between actors	Type of pollution
Interaction between resource units	Negotiation process	Flow of resources
Economic value	Conflict between actors	
Scale	Investment activity	
Significant mark	Lobbying activity	
Time and space analysis	Self-organized action	
Governance system	Result	
Government organization	Social performance assessment	
NGO	Ecological performance assessment	

Resource system	Actor	Social, economic and political backgrounds
Network structure	Externalities to other SES systems	
Property structure		
Operational rules		
Collective selection rule		
Constitutional rules (country)		
Supervision and sanction rules		

VI. CONCLUSION

Through a literature review research, it is found that the current social-ecological system researches in China reflect the research tradition and characteristics of the "human-land complex system", and the research methods tend to reveal the overall characteristics of the social-ecological system through subsystem analysis. This is somewhat different from the social-ecological system concept proposed by Ostrom. In the field of public management research, Chinese scholars are more likely to accept Ostrom's socio-ecological diagnostic analysis framework. In recent years, researches on fishing ground, industrial parks, mines and other research objects have achieved some progress. Nevertheless, Chinese scholars have carried out active researches in reflecting the various attributes of the social-ecological system, achieved many results of research on the vulnerability, resilience and adaptability of the system, and proposed the concept of cohesion of the social-ecological system cohesion in combination with actual conditions in China and interpreted the concept.

In the future, on the basis of carrying forward the tradition of research on "human-land complex system" in Chinese geographical field, there is certain research space for making clear the operational mechanism of subsystems and the interaction between various subsystems, and further revealing the overall operational characteristics of the social-ecological system. At the same time, it is of certain research value to make systematic analysis from the perspective of public resources by using Ostrom's socio-ecological analysis and diagnosis framework. Especially in arctic-alpine ethnic region, the interaction between "human-grass-animals" has profoundly affected the changes of rural social-ecological systems in the region. It is of practical significance to research the function of different stakeholders in the operation process of social-ecological systems from the perspective of the utilization of grassland public resources.

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