Regional Sustainable Development

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Abstract

This chapter first reviews major trends and popular research topics in the field of regional sustainable development, and then summarizes major progress in the study area in China by focusing on five sub-topics, that is, how to understand the coupling relationships between human and nature, how to delineate the carrying capacity of natural resources and the environment, how to evaluate the status of sustainable development of a region, how to utilize natural resources in a sustainable way, and how to achieve regional sustainable development with better governance. Lastly the section calls for multi-disciplinary studies for guiding practice of regional sustainable development and for more attention to the role of regional governance.

Keywords

Human-land system • Carrying capacity • Regional governance • Natural resources utilization • Evaluation

A total of 4178 SCI/SSCI-indexed articles were collected from 94 international journals from 2000 to 2014 in the research area of regional sustainable development. Of these journals 54 published no fewer than 15 articles each on this topic (see Appendix J). The articles were selected by searching for the keywords "sustainable development*", "natural resources*", "carrying capacity*", "sustainable development assessment*", "man-land system*", "man-land relationship*", "ecological economy*", "ecological security*". However, the articles published with the words "global" and "community" and "social" in titles, abstracts, and author keywords were excluded.

13.1 Overview

13.1.1 Contributions by Scholars from Different Countries

The 4178 research articles on regional sustainability are unevenly distributed geographically. More specifically, they are concentrated in several leading countries, including the United States (the USA), China, the United Kingdom (the UK), Australia, Canada, Netherlands, Germany, Turkey, Spain and India. The USA, China and the UK accounted for 15.8, 11.9 and 11.5 %, respectively, of the total articles. Since 2010, the number of articles published by Chinese scholars each year has exceeded that of the USA, and China has ranked the first in the list of countries. In 2010–2014, 340 articles were contributed by China, 35 % more than that by the USA. In 2014 alone Chinese scholars published 84 articles, 50 % more than their counterparts in the USA.

According to Table 13.1, the top 10 countries in terms of the number of articles published are on the whole the most cited. In terms of the total number of citations, the USA, UK and China are the top 3, accounting for 19.4, 16 and 7.7 %, respectively, of the global total. Although China's total number of citations in 2000–2010 was lower than those of UK and the USA, the figure rose to 1706 in 2010–2014, making China the first in the citation list, higher than the USA and UK.

In terms of the number of the most highly cited articles, China ranked the third in 2000–2014, accounting for 10.8 % of the world total, lower than that of the USA (16.9 %) and UK (15.7 %). In the most recent four years (2010–2014),

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Table 13.1 Top 20 countries (regions) with the number and citations of SCI/SSCI-indexed articles on "Regional Sustainable Development" during the period 2000–2014

	Number of articles						Cited frequency						Number of highly cited articles					
	Countries (Regions)	2000	2014	2000-2004	2005-2009	2010-2014	Countries (Regions)	2000	2014	2000-2004	2005-2009	2010-2014	Countries (Regions)	2000	2014	2000-2004	2005-2009	2010-2014
Rank	World	116	428	709	1,434	2,035	World	2,968	255	15,831	23,483	10,891	World	12	0	52	92	105
1	China	2	84	33	125	340	China	32	42	502	1,651	1,706	China	0	0	2	6	19
2	USA	34	55	168	241	252	USA	768	25	4,678	3,912	1,154	UK	5	0	11	19	12
3	UK	25	32	138	195	149	UK	935	51	3,301	3,711	1,038	USA	4	0	16	14	9
4	Australia	9	20	35	76	99	India	22	1	410	286	617	Malaysia	0	0	0	3	9
5	Canada	5	12	34	65	79	Malaysia	0	26	0	331	589	Turkey	0	0	6	8	7
6	Netherlands	3	11	24	40	69	Turkey	2	0	721	1,195	491	India	0	0	1	2	7
7	Germany	6	15	17	30	69	Australia	179	10	579	1,670	463	Germany	1	0	3	2	4
8	Spain	0	12	3	36	62	Germany	200	5	439	468	459	Canada	0	0	0	4	4
9	Malaysia	0	13	0	7	59	Spain	0	2	63	514	453	Spain	0	0	0	1	4
10	Turkey	1	5	16	37	57	Canada	74	4	455	1,096	411	Netherlands	0	0	1	5	3
11	Brazil	1	12	6	25	57	Netherlands	107	7	730	899	397	Sweden	0	0	1	2	3
12	India	2	7	19	24	53	Brazil	14	6	173	244	242	Australia	0	0	1	10	2
13	Italy	2	17	10	17	48	Sweden	57	4	520	753	236	Brazil	0	0	1	0	2
14	Sweden	1	7	18	43	42	Italy	18	10	561	259	198	Taiwan, China	0	0	1	0	2
15	Japan	2	7	9	18	34	Taiwan, China	0	0	177	250	122	Italy	0	0	3	1	1
16	Finland	0	6	14	27	31	Finland	0	1	211	407	116	Switzerland	0	0	0	3	1
17	France	1	5	5	19	31	Austria	0	1	264	354	110	Austria	0	0	2	1	1
18	Greece	2	3	9	27	28	Switzerland	29	1	98	599	78	Slovenia	0	0	0	2	1
19	Austria	0	3	11	19	21	Denmark	50	0	184	576	53	France	0	0	0	1	1
20	Switzerland	1	3	8	31	18	Norway	0	3	91	434	27	Norway	0	0	0	3	0

Note Countries (Regions) ranked by the number of articles, cited frequency and number of highly cited articles during the period 2010–2014

however, China ranked the first in terms of the most highly cited articles with 19 articles in total.

13.1.2 Key Research Topics

The highly cited articles are from journals in such research fields as energy, environmental management, production, development, global environmental change, and planning (see Table 13.2). Major topics addressed by these articles include energy, land, forests, carbon (climate change), and water.

According to the keywords co-occurrence network analysis for regional sustainable development research (Fig. 13.1), the high frequency keywords appeared since 2000 can be divided into five research clusters. Sustainable, development, energy and renewable energy form the first cluster. Among them, energy and renewable energy have become high frequency keywords since 2008. The second cluster includes environmental, governance, community, political and strategy, and the third includes sustainability, system, and urban. The frequency of sustainability and system has steadily increased since 2005. The keywords in the fourth cluster are management, climate change and agriculture, and model. Among them, management has been one of the highest frequency keywords since 2000, and the frequency of climate change has risen rapidly since 2008. The fifth research cluster consists of such keywords as natural resources, policy, conservation and environment, among which policy, however, has been a high-frequency keyword since 2000, increasing in frequency year by year. The frequencies of natural resources and resource policy have declined since 2008.

In addition, model, impact and index (indicator) are also high-frequency keywords. Apart from energy, elements like land, water, and forests are also high frequency keywords. Among these elements, the keywords which are highly associated with global climate change, such as energy, forests, and land, have risen in frequency in recent years, while the frequency of water has declined. Among all the keywords, governance, system, energy, assessment, climate change, ecology, and research methods have high frequencies, which still keep rising; economic and environmental are high-frequency keywords, but their frequencies remain relatively stable. This reflects the fact that more attention has been paid to governance issues related to climate change in the international academic community.

13.1.3 The Role of NSFC in Supporting the Research on Regional Sustainable Development

Regional sustainable development has been an important area of study supported by NSFC since its foundation. Sub-research fields include human-land relationships, resource utilization and carrying capacity, and the regional sustainable development situation. In 2000–2014, the total number of various research projects funded by NSFC on

Table 13.2 The journals with highly cited SCI/SSCI-indexed papers on "Regional Sustainable Development" during the period 2000–2014

Field	Main journals	Number of highly cited articles	Proportion (%)
Energy	Renewable and Sustainable Energy Reviews	39	22.5
	Renewable Energy		
	Energy		
Environmental management	Journal of Environmental Management	32	18.5
	Environmental Management		
Production	Journal of Cleaner Production	15	8.7
Development	World Development	14	8.1
Global environmental changes	Global Environmental Changes: Human and Policy Dimensions	10	5.8
Planning	Landscape and Urban Planning	10	5.8
Geography	Political Geography	19	11.0
	Progress in Human Geography		
	Antipode		
	Annals of the Association of American Geographers		
	Economic Geography		
Sum		139	80.3
Total		173	100.0

regional sustainable development was 197, among which about 60 % were funded after 2010. These projects have contributed a lot to the academic advance of regional sustainable development research in China, enabling China to occupy an increasingly important position in the field in the international academic community. However, due to the location-specific features of regional sustainable development research and language issues (i.e., English proficiency), early NSFC-funded research projects yielded few English articles.

Since 2003, with the rapid increase in the number of scholars with a good command of English and the institutionalization of publishing SCI/SSCI-indexed articles, the number of articles published in 99 major SCI/SSCI-indexed journals by Chinese scholars on regional sustainable development has grown rapidly. In 2000, only 2 papers were published, but the figure rose to 7 in 2003, and further to 20 in 2007. In 2010, the figure reached 66, and climbed to 84 in 2014. In 2010–2014, the number of articles published by Chinese scholars in this research field accounted for one sixth of the world total (Table 13.1). In the meantime, the number of articles funded by NSFC increased rapidly. In 2000–2004, NSFC-funded articles accounted for 15.2 % of the total number of papers published by Chinese authors while the figure rose to 30.4 % in 2005–2009, and to 41.5 % in 2010–2014 (Table 13.3).

Due to differences in development stages, governance structures and natural conditions, different countries and

Table 13.3 NSFC-funded projects and SCI/SSCI-indexed articles on "Regional Sustainable Development" during the period 2000–2014

SCI/SSCI-indexed articles					NSFC-funded projects			
Periods	Number of articles	% of articles by Chinese authors	% of articles with NSFC funding by Chinese authors	% of articles funded by MOST among those with NSFC funding	Number of projects	Funding (10,000 yuan)	Number of PIs	Number of institutions
2000–2004	709	4.7	15.2	0.0	39	1,459.0	39	26
2005–2009	1,434	8.7	30.4	34.2	48	2,301.0	46	31
2010–2014	2,035	16.7	41.5	32.6	110	6,982.5	108	73
2000–2014	4,178	11.9	36.9	32.1	197	10,742.5	179	93

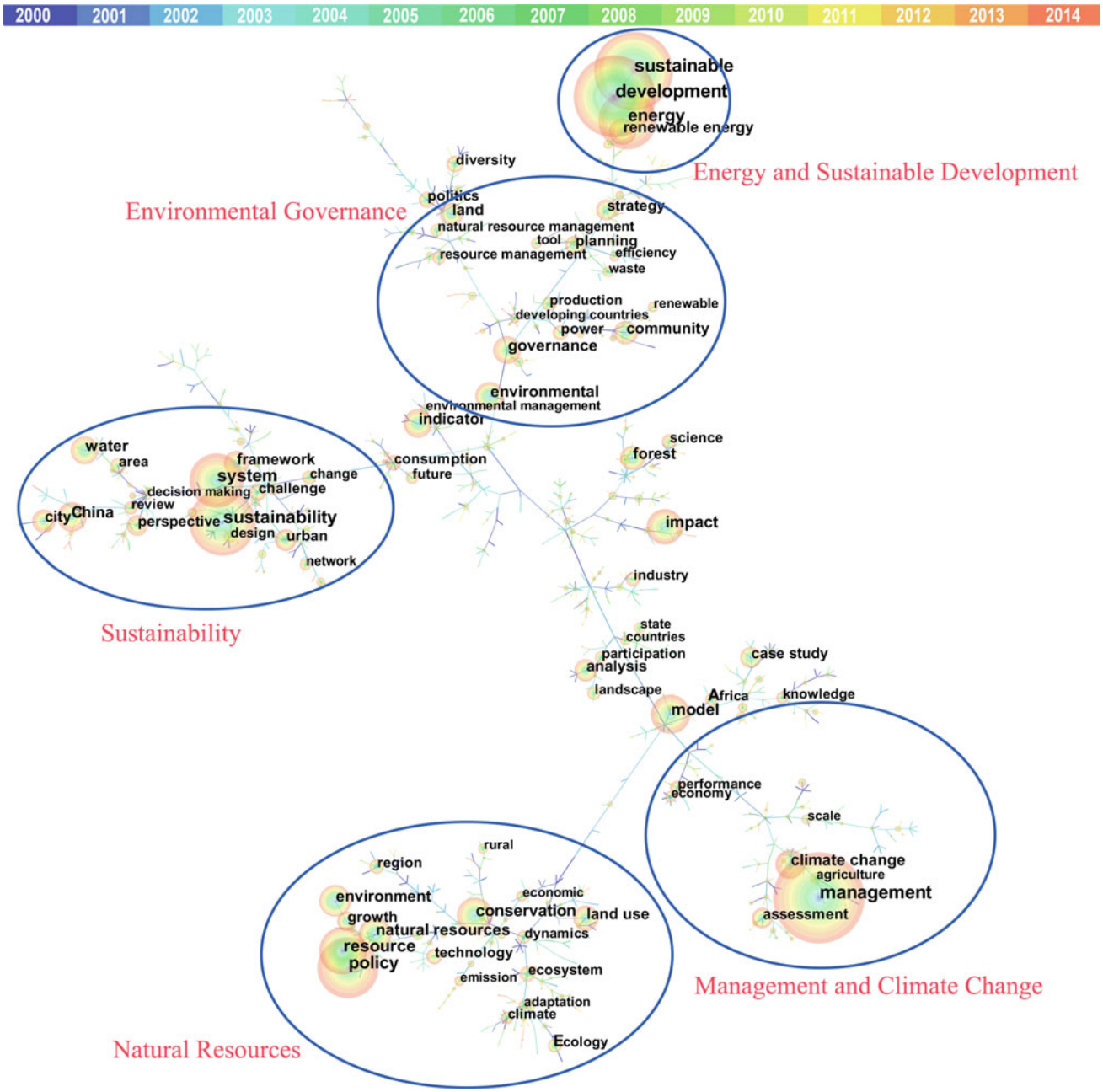

Fig. 13.1 Co-occurrence network of SCI/SSCI-indexed article keywords on "Regional Sustainable Development" during the period 2000–2014

regions face different sustainable development problems. This leads to differences in frequent keywords used by scholars from different countries (Figs. 13.2 and 13.3). Management, energy, natural resources, policies, systems, land, water, sustainability, and impact are the commonly used high-frequency keywords by both Chinese and foreign scholars. Foreign scholars pay more attention to protection, governance, forest, community, strategy and assessment, while Chinese scholars study more about urban, regional, urban, growth, and ecological system. These differences reflect to a certain extent the development stage of China. In addition, there is a strong correlation between the high-frequency keywords used in articles published and the keywords used in the application documents for NSFC projects. The difference is that NSFC-funded projects put more emphasis on ecological carrying capacity, the human-land relationship and decision support systems. In addition, changes in the high-frequency keywords in applications for NSFC projects (Fig. 13.3) show that a concern with human-land relationships, decision support systems, and dynamic mechanism declined, while model, simulation, land, ecological carrying capacity, urbanization,

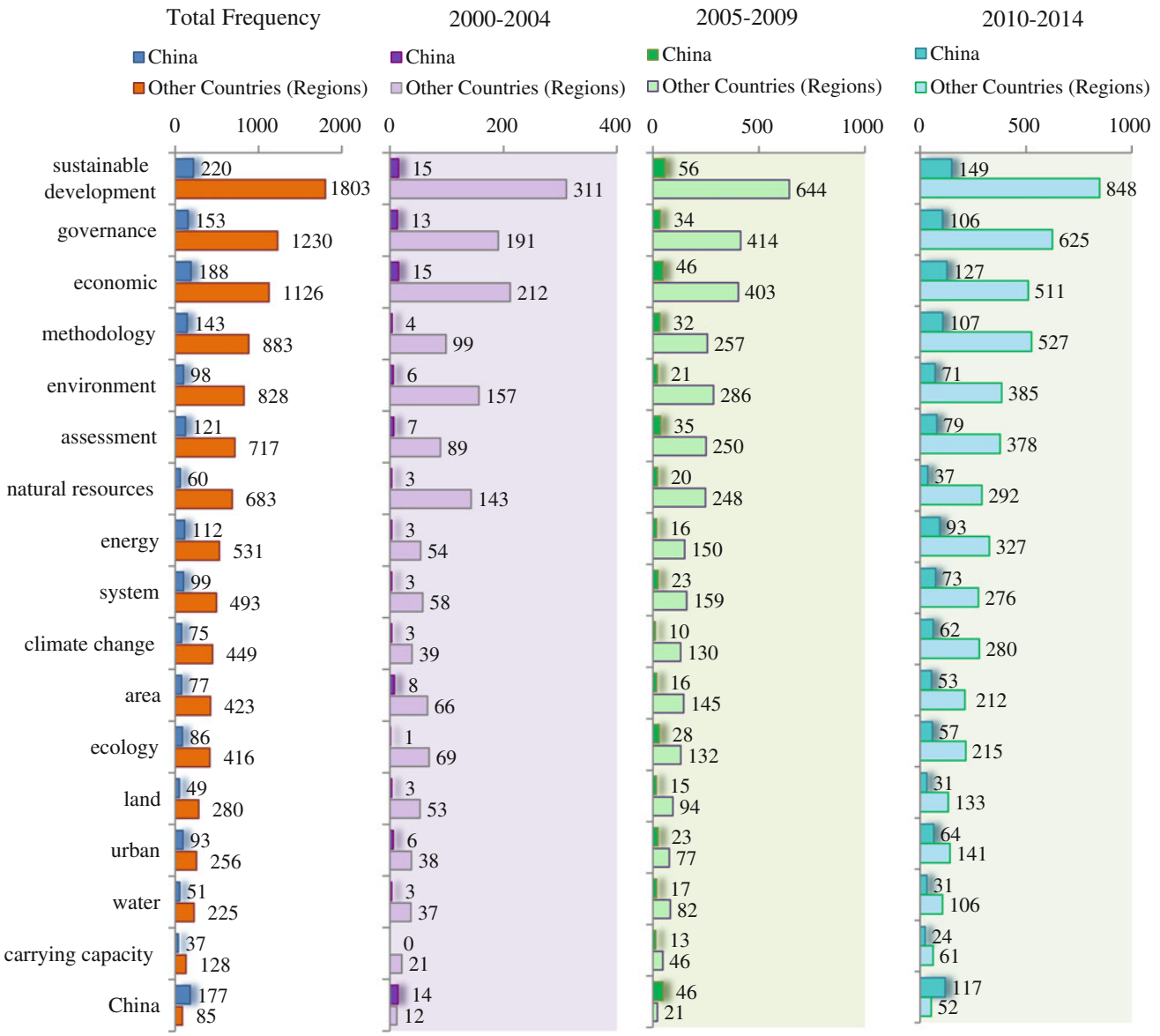

Fig. 13.2 Keyword temporal trajectory graph for SCI/SSCI-indexed articles on "Regional Sustainable Development" during the period 2000–2014

environmental effects, and resource utilization received increasing attention.

13.1.4 The Role of the Geographical Sciences in Regional Sustainable Development

The geographical sciences emphasize integration and regional differences, are relatively strong in syntheses and spatial visualization of knowledge, and play a leading role in regional sustainable development theory and practice (NRC 2010). Of the top 10 articles on regional sustainable development, five articles have a first author majored in human geography (Ph.D.), and other two articles have a first author majored in geography-related disciplines. This indicates that geographers can be leaders in the field of sustainable development research.

The sustainable development of a region is related not only to its ecological environment and natural resources, but also to its economic conditions like industrial structure and technology as well as its social, cultural and political conditions. Therefore, scientists from both the natural and social sciences have been widely engaged in this field of research. Natural scientists study the natural laws of sustainable development while economists and social scientists examine relevant economic and social rules. As a result of increasing subdividing of modern sciences, it is difficult from the perspective of a single discipline to reveal comprehensively and

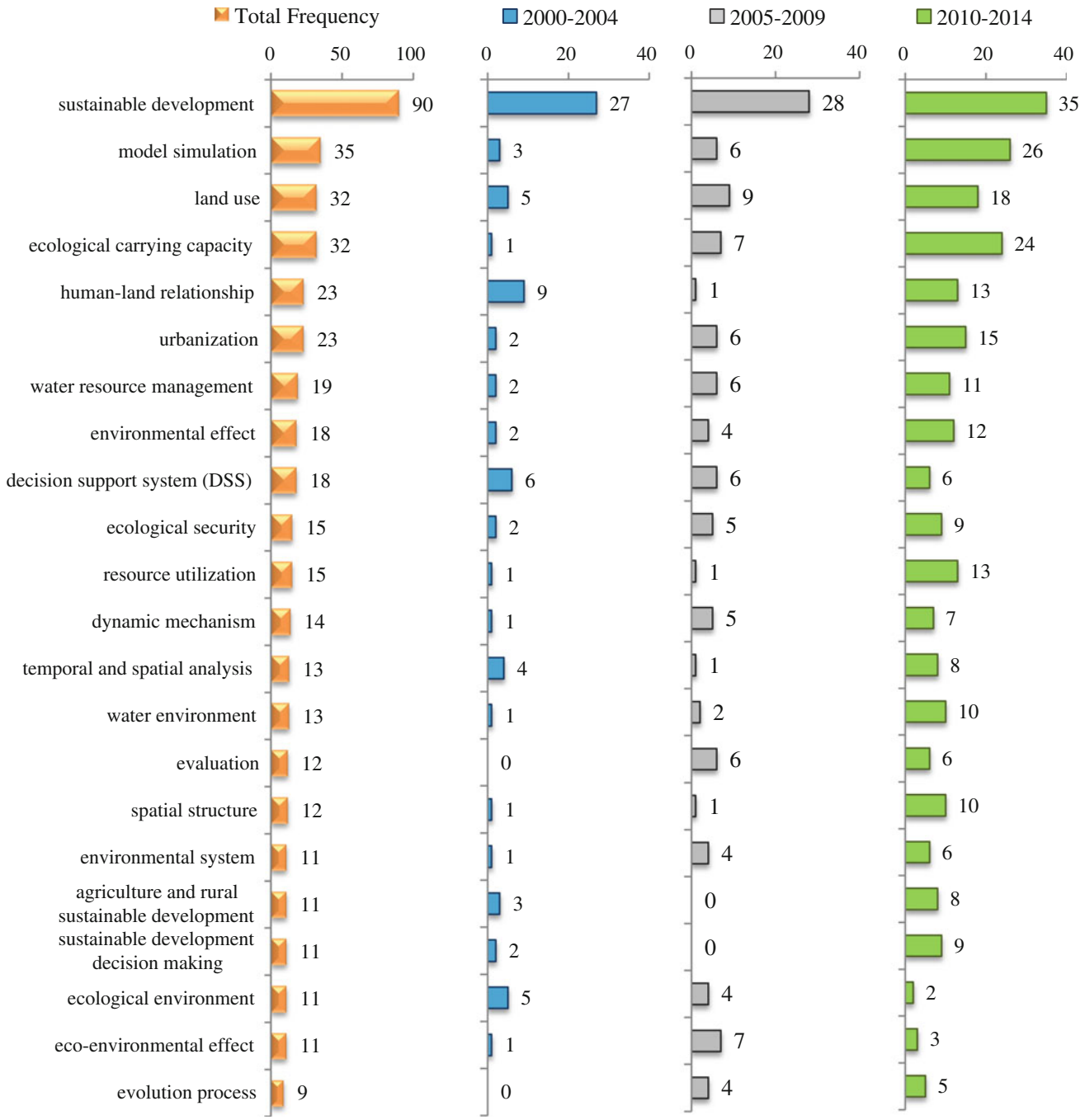

Fig. 13.3 Keyword temporal trajectory graph for NSFC-funded projects on "Regional Sustainable Development" during the period 2000–2014

profoundly the complexity of sustainable development. Therefore, integration thinking is needed when studying regional sustainable development. The geographical sciences, including physical geography and human geography, adhere to the principle that "the whole is greater than the sum of the parts" and emphasize "considering and solving problems from the whole" (Cai et al. 2012).

Geographers borrow concepts from biology such as resilience and adaption to construct a framework to understand the adaptation of territorial systems in increasingly complex environments (Adger 2000). In addition, geographers began a dialogue with economists and political scientists, and employ the concepts of spatial agglomeration (Rosenthal and Strange 2001) and social capital (Pretty and Ward 2001) to deepen understanding of the efficient utilization of natural resources and the operating rules of economic activities. The geographical sciences do not simply apply concepts from other disciplines, but transform them

creatively and endow them with spatial connotations. At the same time, they put more emphasis on the interactive relations and temporal and spatial variations in the outcomes of natural laws, economic laws and government actions and conventions (Bulkeley 2005).

In recent years, geographers have paid more attention to the application of new technologies and new methods, especially spatial analysis and visualization techniques (Verburg et al. 2002), input-output models (Liu et al. 2012) and modeling (Yu and Lu 2003). At the same time, regional development databases have been constructed for natural-human coupling process research (Tang et al. 2010). The employment of these techniques has improved the quality of research into sustainable development on the one hand, and has increased the competitiveness of geographical scholars in supporting national strategic decision-making on the other hand.

Many geographical scholars have been actively involved in national and local consultancy with regard to sustainable development and played an important role. Professor Adger Neil, one of the world's top 10 most highly cited authors, is a contributor to the third and fourth IPCC scientific assessments. Professor Bulkeley Harriet has offered advice on the sustainable development of agriculture and the rational use of water resources in the UK. Professor Pretty Jules is an important member of the UK government environment and resources advisory board.

Since the 1990s, geographers in China have tried to continuously develop scientific understanding of national and regional sustainable development (Lu 2003; Fan 2011; Liu et al. 2006), and have provided important technical supports for major national spatial planning projects, e.g., major function-oriented zoning, national territorial planning, Northeast Region revitalization planning, Western Region development, planning for the rise of Central China, planning for resource-exhausted cities, eco-region development planning, and the planning for key regions including the Yangtze River Delta region, Beijing-Tianjin-Hebei, Chengdu-Chongqing region, Tianshan Economic Belt, post-earthquake reconstruction planning, and planning for the Silk Road Economic Belt and the 21st Century Maritime Silk Road.

13.2 Questions and Research Progress

13.2.1 How to Understand the Coupling Relationship Between Man and Nature?

With the rapid development of industrialization, urbanization and globalization, the pressure and impact that human activity exerts on the geographical environment has increased. More and more research focused on the relationship between regional human activity and the geographical environment, especially on the resource and environmental change caused by land use and land cover change, the relationship between population and economic growth and resource and environment, and the human-environment relationship in typical regions.

International Research Progress

Land use/land cover change is one of the important contents of regional environmental change and sustainable development researches, whose main aim is to model and monitor human-land system. In the report "The Emergence of land use change sciences for global environmental change and sustainability", Turner et al. (2007) point out that the dynamics of land use and land cover should be understood as a coupled human–environment system to address theory, concepts, models, and applications relevant to environmental and societal problems. In the past two decades, research progress in land use change has been mainly made in the observation, monitoring, and understanding of the coupled system—causes, impacts, and consequences, modeling, and synthesis issues.

As the major reflection of human-land system, the relationship between population and economic growth and resource environment is studied by numerous scholars. In 1972, Club of Rome studied the stress situation of water and land resource, corn production and mineral resource caused by rapid development of population and industrialization, and put forward the pessimistic conclusion of zero growth. Moreover, some economists probed into the conditions and process of the coordinated development of economy and environment and the interrelationship among factors based on economic growth theory. For example, Solow (1974) and Stiglitz (1974) analyzed the optimized situation and path of resource exploitation. Leontief (1970) applied the input-output model to the correlative research of economic behavior and environment. In 1990s, Grossman and Krueger (1991), Shafik and Bandyopadhyay (1992), and Selden and Song (1994) put forward the "Inverted U Type" curve of economic development and environmental quality, i.e., *Environmental Kuznets Curve* (EKC). Although subsequent researchers have carried out a number of empirical researches to verify the existence of EKC in different conditions with different environmental pollution indices and samples at different temporal scales and drawn different conclusions, the EKC has been a good reference to the harmony between the human-land system. As for the analysis of specific factors, relative researches are focused on the effect of economic growth on energy consumption, and the relationship between economic growth and environmental pollution.

The studies of human-land system in typical regions are mainly concentrated on coastal areas, resource based cities,

rural-urban fringe areas, islands and communities, and are mostly concerned about the impact of global climate change on sustainable development in coastal areas and the countermeasures (Prandle 1991; Juhasz 1991), transformation of resource-based cities (Lockie et al. 2009), and rural-urban fringe areas.

In sum, foreign research on human-land relationship was initiated earlier, starting from basic theoretical research to empirical research with the progress of technology and methods, and finally formed several research fields around human-land relationships. A great part of the research was concentrated on regional, systematic and integrative research, the main research topic of which is the impact mechanism of human activity on natural environment. At the same time, more attention has been paid to observational data accumulation in typical regions over long periods of time, analysis of social and economic statistics, and integrative research of multi-factors in order to better reveal the mechanism and process, pattern and regulation of the effect of human activities on the natural environment.

Research Progress in China and Representative Achievements

Geographical and environmental factors and human-land relationship are the major research fields of geography and geographers in China. Huang (1999) pointed out that the relationship between the two major categories (groups)—"human" and "land", is the most important relationship in the terrestrial system. Wu (1991) introduced the system theory into geography, and put forward that the human-land relationship refers to the interaction and feedback effect between human and nature on the earth's surface. The two elements of "human" and "land" are intertwined in a certain way and form an intricate, complicate and opening system with a certain structure and function in a certain territorial area. Therefore, it can be called a "Human-land Territorial System", abbreviated as "human-land system". This system consists of human beings' dependence on nature and the active role of human beings. It is an open, contingent and unstable system (Lu 2002).

The central objectives of human-land system research are to explore the spatial and temporal patterns of the interaction between human activities and the natural resources and environment factors, to analyze and model the differential effect and strength of different factors, to reveal the dominant factors and their relationships with regional development, to find the basic characteristics of the human-land system in different types of regions, and to evaluate and forecast the evolution of the system. The ultimate goal of human-land territorial system research is to achieve regional sustainable development (Zheng and Cheng 2001).

The study of "human-land system" in China was firstly seen at the end of 1980s. It mainly focused on the concept and contents of human-land system, the relationship between system optimization and regional sustainable development, and the dynamics of the system. The research outputs were about 10 papers per year. By 2000, the research outputs of "human-land system" had seen explosive growth. Afterwards, the number of published articles in this topic has gone back to a steady growth while the research field has been diversified. Especially with the integration of natural science and social science, the research on human-land system has been expanded with focuses on sustainable development theory, vulnerability evaluation, coupling mechanism, structure and regulation, and typical regions studies (Fig. 13.4).

The sustainable development of human-land system is mainly discussed through theoretical and typical regional studies (Pan 2000; Fang 2002). The compatible coexistence of human-land system is the theoretical basis for regional sustainable development. Only in a specific human-land system can regional sustainable development be realized. Action and reactions are initiated by human activity and realized by conjugate evolution, and the ultimate result is dynamic balance between the two subsystems (Zhang and Zheng 2000).

Human-land system is a complex system composed of social, economic, resources and environmental factors. The study on the coupling mechanism of human-land system is a study of the interaction of different factors in the system, and the factors affecting this interaction process, which mainly include human needs (Yang 2002), science and technology (Cai 1995), and globalization and urbanization (Luo and Chen 2003), property system (Luo 2007b). In addition, the assessment and evaluation on the coupling state and degree of human-land system are the main contents, which can be done using gray correlation analysis method or the entropy weight gray correlation method, etc. As for the system structure, it is mainly analyzed from the spatial (Fan 2014a), systematic (Li 2008), classification and flowing (Ren and Ren 2006) perspectives.

The study on the vulnerability of human-land system was initially analyzed from the qualitative perspective. It is pointed out that the cause of human-land system vulnerability lied in the initial turbulence as a result of the interaction between natural and social systems, and was enlarged by positive feedback and deviated from the equilibrium state eventually (Cai et al. 2002). The main analysis objects are mainly concentrated in the areas of desertification, mining cities, oil cities and so on. Afterwards, the research method has gradually been quantitative, and the researches have

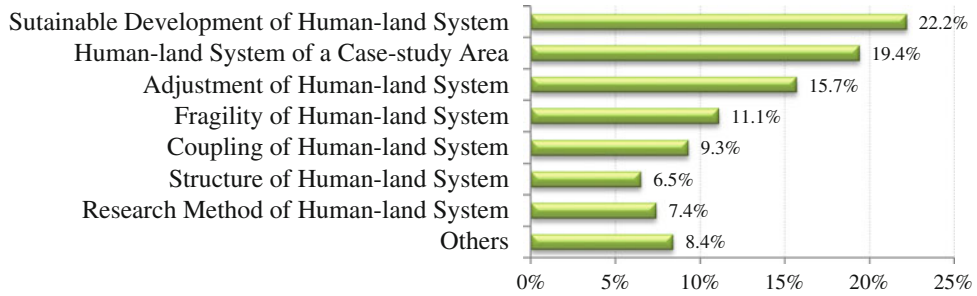

Fig. 13.4 Distribution of the keywords on "Human-land Coupling System Research" in CNKI journals during the period 2000–2014 (*Data source* Based on the result of grouping of "Chinese Keywords" in China Knowledge Resource Integrated Database (CNKI))

mainly been focused on analyzing the main factors leading to fragility of human-land system with the establishing of vulnerability assessment index system.

The typical areas for Chinese human-land system research are mainly concentrated in two types of regions: one is areas with rapid social and economic development and significant effects on the natural environment, such as coastal areas; the other is in areas with fragile natural environments easily influenced by human activities, such as Wei River Basin, Guanzhong Plain, Minqin Basin, mining city, farmland-pastoral ecotones, etc.

An important output of Chinese human-land system research is to provide advisory services to the government. Thus, the optimization control of the human-land system has become the focus of regional sustainable development. The analytical research on the focuses of regulating and controlling mainly concerns response and interaction mechanism (Zhao 2000), fairness (Wang 2010), coordinated development (Yang 2002) and system optimization (Fang 2003) and so on. The objects to be optimized involve population, resources, environment, development and related systems, which mainly focuses on the input and output relationship between the human society subsystem and the natural material subsystem (Cheng 2006).

China's representative achievements in recent years are as follows:

First, exploration on the factors and coupling mechanism of human-land system in the view of impact of industrialization, urbanization and globalization on local land, water and ecological environment (Liu and Jin 2006; Zhang et al. 2004; Luo 2007a). For example, NSFC Key Programme (KP) "The Urbanization Process and Its Ecological Impact of North-West Arid Area Under the Water Resource Restriction", which probes into the mechanism and main driving factors of the coupling process between water resource change and urbanization process (Fang and Yang 2006; Qiao and Fang 2005).

Second, analysis of the process and factors of human-land relationship evolution in a temporal view. For example, land use and land cover change is one of the main topics, which probed into the droving action and mechanism of human economic exploitation and urbanization activity on the scale and structure of land use based on long term data (Li et al. 2006; Yang 2004). Another topic is the study on the relationship between human settlement relocation with natural environmental change, such as Huang's research (2001) on the relationship between the resources degradation of man-natural relation in Weihe River Basin 3100 years before, which found that the climate drought trend and water-soil degradation had facilitated the replacement of the agricultural culture to nomadic culture and led to the great changes in land use patterns.

Third, the quantitative measurement of the coupling relationship between human and nature mainly uses the concept of "vulnerability", "coupling" and others. Many Chinese scholars carried on the coupling degree research between industrialization, urbanization and environmental pollution, such as the Key Programme (KP) of NSFC "Vulnerability and Sustainability of Human-land System of the Mining Cities in Northeast China", which made a quantitative evaluation of the economic development vulnerability of mining cities (Li and Zhang 2008).

Future Research

Compared with foreign studies, domestic research focuses more on the mechanism, process and spatial patterns of human-land system, and is concerned with the difference in different spatial scales and the dynamic optimization model of typical regions. As for research methods, it has made quantitative assessment on the coupling degree of human and nature system, resource and environment carrying capacity and ecological footprint based on social and economic data, combined with the observation data at a long period of time and sequence data of large spatial scale. Therefore, in China, human-land system theory has been widely applied to the cognition and resolution of sustainable development problem in national and regional scale. As for research methods, much emphasis has been placed on data analysis and simulation while little has been placed on theoretical development. In

the future, it should strengthen the theory research on the mechanism, process and pattern of human-land system regulation. For research methods, it should pay more attention to the study of integrated technical support system, combination of qualitative and quantitative, scientific and technological methods and the "3S" technology.

13.2.2 How to Delineate the Carrying Capacity of the Resource-Environment System for Human Activities?

International Research Progress

The concept of resource-environment carrying capacity derives from the thought of carrying capacity in early ecology. Recently, it has evolved into a comprehensive concept focusing on the reasonable exploitation of resources, the sound cycles of ecological environment, and the carrying capacity of resource-environment conditions for population size and economy scale. As a scientific concept for reflecting the relationship between resource-environment background and social-economic activities, resource-environment carrying capacity is one of the important scientific themes in current regional sustainable development research. It is significant for regions to cope with changes in resources and environment and achieve sustainable development.

International research on resource-environment carrying capacity originated from the book entitled "Road to Survival" by American scholar Vogt in 1949. He firstly named the over-exploitation of natural resources and environment by human beings as "ecological unbalance", and defined the concept of regional carrying capacity to reflect the population and economic development capacity of regional resources and environment (Vogt 1949). Afterwards, system dynamics models were used for the research on resource-environment carrying capacity. By analyzing the interrelations among the multiple factors in the system, identifying system structure and the correlations among factors, and considering the relationship between population, resources, environment, and development, relationship changes under different development strategies could be simulated, and optimized scheme of regional development under long-term goal could be determined (Sleeser 1990). The article of theoretical discussion by Arrow (1995) in Science aroused tremendous attention to related issues of resource-environment carrying capacity. Since 2000, the international research focusing on resource-environment carrying capacity has rarely appeared. On the one hand, the research on resource-environment carrying capacity is affected and restricted by multiple factors, which cause uncertainty. On the other hand, research focus has started to shift onto environment and energy fields due to the relatively abundant resource reserve in developed countries.

In recent years, there has been little research taking resource-environment carrying capacity as a direct subject in the highly cited articles in the field of sustainable development. Most of them address environment, energy, ecology, or sustainable development issues. From the perspective of hot keywords, carrying capacity has not appeared, while resources, natural resources, environment, land use, energy, sustainability, sustainable development, and related words could be found.

Research Progress in China and Representative Achievements

China's research on resource-environment carrying capacity first originated from land carrying capacity based on the relationship between land, food, and population. The quantitative research could date to the study of productive potential of grain crops in China in 1964 (Zhu 1964). With the introduction of carrying capacity in the 1980s, a large amount of research on land carrying capacity based on food security appeared. In regard to water carrying capacity, the water resources research team of Xinjiang autonomous region of Chinese Academy of Sciences led by academician Yafeng Shi firstly developed the concept of water carrying capacity in 1989 (Shi and Qu 1992). Afterwards, a lot of research on water carrying capacity emerged in China, especially those focusing on the arid areas in northern China. In the late 20th century, the environmental issues attracted more concerns as regional environmental problems arose in China. Since then, China's scholars have started to carry out intensive research on environment carrying capacity, mainly focusing on atmosphere environment, water environment, and soil environment. Besides, ecological capacity has been gradually developed based on the concept of carrying capacity and the understanding of the population-resource-environment-society-economy system (Gao 2001). As a usual descriptive concept of restrictive extent of regional development, the carrying capacity evaluation has been extended to various fields of population, resources, environment, society, and economy. Ocean carrying capacity, lake carrying capacity, tourism resource carrying capacity, and mineral resource carrying capacity have also been studied.

With continuous development of research on resource-environment carrying capacity, more and more scholars have realized the limit and partiality of single factor carrying capacity research in resource or environment fields. It is an important trend to discuss theories and methodology of the integrated research on resource-environment carrying capacity. Since 2000, taking the coordinated development of

"nature-economy-society" combined system as the goal, the integrated research on resource-environment carrying capacity has prevailed, of which the research on resource-environment integrated carrying capacity has become a hot topic (Fan 2009, 2010, 2014b).

China's representative achievements in recent years are as follows:

First, the status space method of regional carrying capacity. By summarizing the international and China's research methods of regional carrying capacity, Mao and Yu (2001) and Yu and Mao (2003) put forward the idea that the status space method could be used for measuring regional carrying capacity. The deviation value between real carrying status and theoretical capacity could be used as basis for quantitative measurement of regional carrying capacity. By establishing an evaluation indicator system which included the pressure-bearing, pressure, and interregional exchange categories, the regional carrying capacity in Bohai-Rim area was quantitatively evaluated. With the help of system dynamics models, the changing trends of regional carrying capacity and carrying status were also simulated and predicted. The empirical studies prove that the status space method is an effective method of measuring regional carrying capacity or resource-environment carrying capacity.

Second, evaluation of resource-environment carrying capacity for post-disaster reconstruction planning. Based on China's five emergency disaster relief programs including those for Wenchuan, Yushu, Zhouqu, Lushan, and Ludian, taking geological disasters as major factors, water and land resource conditions, ecological environment, engineering and hydrological geology as important factors, industrial economy, urban development, infrastructure as auxiliary factors, Fan (2009, 2010, 2014b) established an indicator system of basic evaluation, carried out single factor and integrated evaluation, revealed spatial differences of resource-environment carrying capacity for post-disaster reconstruction, and identified the boundary and scope of areas with different carrying capacity from 3 aspects including geological conditions and hazard risks, physical geographic conditions, and population and economic base. Besides, by analyzing the influence mechanism of water and land resources conditions, regional economic development level, and urbanization level on carrying population, the simulation method of measuring population capacity was established, and the reasonable population size in the earthquake stricken area was calculated. The research on resource-environment carrying capacity effectively guided the reconstruction work after disasters, proving that it has significant practical value.

Third, research on ecological footprint and ecological capacity. The methodology of ecological footprint was introduced into China in the early 21st century based on which some empirical research were conducted. For instance, taking Gansu province and 12 provincial administrative regions in western China as case study areas, Xu et al. (2000) and Zhang et al. (2001) conducted an empirical research on the calculation of ecological footprint. Using high-resolution remote sensing data of land-use and land-cover change, Yue et al. (2009, 2011) calculated the ecological footprint and ecological capacity in the five provinces in northwestern China. In addition to the three common indicators including ecological footprint per capita, biological capacity per capita, and ecological surplus/deficit per capita, three new indicators e.g., biological capacity per unit area, ecological footprint per unit GDP, and biological capacity pressure index were also adopted.

Fourth, research on land carrying capacity. It is a typical way of geographic research to clarify the spatial differences of capacity in different regions from the perspective of land resources and provide suggestions accordingly. Using Agro-Ecological Zone (AEZ) model and Geographic Information System (GIS) technology, Feng et al. (2007, 2008) calculated grain productive potential at a 1 km × 1 km grid and county levels in China. By classifying the resource endowment of grain productivity, the resources potential of grain yield in China's different regions was revealed. Based on the man-grain relationship, the model of land resources carrying index was established, and the spatial-temporal dynamic patterns of land carrying capacity from 1949 to 2005 in China were quantitatively evaluated at country, province, and county levels. Also, the land carrying capacity of pasturing areas, urban areas, and poverty-stricken counties were discussed.

Future Research

With the gradual extension of its content, the concept of carrying capacity has naturally extended from ecology to other disciplines. The decisive variables of carrying capacity include not only natural resources and environment basis, but also social-economic factors, such as social-economic development level, social consumption mode, technology development status, social institution arrangement, and social value system. The carrying objects include not only the quantity of population or the economic volume, but also the content of economic activities. Therefore, completing and developing the concept and content of resource-environment carrying capacity has become urgent work to do. At present, China's research on resource-environment carrying capacity is mainly based on single factors and static and closed systems, and the standards and criteria of evaluation methods are still to be established. In the future, the

quantitative research on resource-environment carrying capacity which integrates multiple factors should be determined as development direction, and a scientific and reasonable evaluation indicator system is to be explored. We need to conduct indicator evaluation on subsystems including economic system, ecological-environmental system, resources system, sustainable development system, and analyze the interactive relationship among the factors of resource-environment carrying capacity. In this way, a set of operable and consistent evaluation methods and models of resource-environment carrying capacity will be formed.

13.2.3 How to Evaluate the Status of Regional Sustainable Development

International Research Progress

Sustainable development strategy is a common objective for the development of human beings, and the assessment of the state and capability of regional sustainable development is the means to make such target explicit. In other words, once an index system and research methods are established, we can identify whether the development of a region is sustainable or not, what the degree of sustainable development is, and how to strengthen the capacity of sustainable development. And a judgment on whether the development mode of the region has facilitated its realization of sustainable development strategy can be made. In brief, such assessment is the essential tool and the significant premise for the implementation, evaluation and establishment of a sustainable development strategy. Thus, selecting reasonable index system is of great significance for the understanding of the sustainability of human-land relationships (Mccool and Stankey 2004). Decision makers can make such judgments as which behaviors are beneficial for building a sustainable society from both global and local, natural and social, short-term and long-term perspectives (Ness et al. 2007). In this way, sustainable development is no longer a concept (Robinson 2004).

First, research on the evaluation index system of sustainable development is deepening. The assessment should contain multi-dimensional objectives. It not only refers to the sustainability of the environment, biodiversity, protection of natural resources, and pollution etc. but also includes economic and social aspects, such as economic efficiency, social fairness, rural-urban integration, and regional equalization (CSD 2006; Moldan et al. 2012). According to different emphases, the index system can be mainly divided into three types: the first one is environment-oriented, like environmental pressure index (European Commission and Eurostat 1999), environmental performance index (World Economic Forum 2002), the environmental-friendly index (Statistics Finland 2003), and ecological index (Pré Consultants 2001); the second one is economy-oriented, like sustainable economic welfare index (Daly and Cobb 1989); the third one is society-oriented, which mainly includes human development index (UNDP 1990), happiness index system (Prescott-Allen 2001), and so on. Based on a comprehensive research, UNCSD put forward the index of sustainable development, which included foundational well-being and economic well-being, identifying its present situation and change (Stock and Flow). Specifically, life expectancy, education level, clean water, residence and 28 other indicators are covered (UNCSD 2008).

Second, new approaches to evaluate sustainable development are emerging. Wackernagel et al. (2002) published a paper on PNAS about evaluating the capability of sustainable development based on ecological footprint, which tried to measure the ability for humans to meet their demands, like food. The results showed that the demands had exceeded the regeneration ability of the earth itself. To be more specific, the human ecological footprint of the total global biosphere ecological bearing capacity increased from 70 % in 1961 to 120 % in 1999. In addition, there are many newly-emerging methods, like energy analysis, lifecycle assessment, energy analysis, DPSIR analysis framework, and energy analysis and so on.

Third, the capacity of dynamic monitoring of sustainable development status has been enhanced. Since the 1980s, with the development of 3S techniques, i.e. remote sensing, geographical information systems, and global position system, the dynamic monitoring platform has been established gradually in the world. Researches on “digital earth” and “digital city” are also in full swing in many countries and regions of the world.

Topics of international research on the evaluation of regional sustainable development include sustainable development, sustainability, assessment methodology, evaluation model, the human development index, sustainable economic welfare index, green net GNP, performance of sustainability, ecological sustainability index, ecological footprint, energy analysis, energy sustainability, comprehensive index of sustainable development, sustainable asset management, sustainable development enterprises, product lifecycle, urban sustainability, environmental quality, environmental sustainability and vulnerability, cleaner production technologies, happiness index, the performance of national health system, sustainable society and sustainable communities, and so on.

Research Progress in China and Representative Achievements

In recent decades, research on the state and capability of regional sustainable development in China has made great progress, one of which is fundamental research on the formation process, structure and theories of the human-land territorial system, new factors and patterns of regional sustainable development, the concept and mode of circular economy, and the coordinated development among population, resources, environment and economy. Moreover, current researches focus on the construction of the evaluation index systems of the sustainable development capability. They can be divided into the sustainable development index systems of states, provinces, regions, cities and certain themes according to their research scales and objects. The third progress is in the model and methods for evaluation of the capability of sustainable development. Quantification is the major method of evaluation research. Commonly used methods are: Entropy Method, Delphi Method, Data Envelope Method, Analytic Hierarchy Process, Fuzzy Mathematics and Neural Network Method, etc. In recent years, ecological footprint, energy analysis, system dynamics, and recycling economy have become new approaches of evaluation research. The representative achievements are as follows:

First, evaluation of regional sustainable development state. Researches in this sub-field started relatively early and have yielded fruitful achievements. Mao (1996) applied multi-index comprehensive analysis method, and established an index system concerning four aspects, i.e. economic growth, social progress, resources and environment support, and the sustainable ability, to evaluate the sustainable development state of Shandong Province. The weights of these indicators, a total of ninety, were determined by analytic hierarchy process. The Research Group on Sustainable Development of the Chinese Academy of Sciences (1999) also put forward a set of comprehensive evaluation index systems of sustainable development. The systems were divided into five grades with 45 indexes and 208 specific indicators. Later on, according to the requirements of ecological civilization, the index systems were revised. Moreover, comprehensive evaluation of sustainable development in regions has been carried out in China (Sustainable Development Strategy Research Group 2014).

Second, evaluation on regional sustainable development capacity. Quantitative evaluation is conducted on regional sustainable development capacity based on multidisciplinary analyses, like ecological footprint, energy synthesis, and scenario prediction based on system dynamics model. Based on the method of ecological footprint, Qin and Xu (1998) analyzed the spatial structure and dynamic changes of Henan input-output potential. Geng et al. (2013) published an article in *Science*, presenting a new method to discuss the feasibility of evaluating the performance of China's circular economy based on the method of energy analysis. As for the method of system dynamics model, taken Huangling County, Shaanxi Province as an example, Cheng et al. (2004) established three economic growth scenarios, i.e. natural growth, high-speed growth and moderate-speed growth. Predictions of the growth state of indicators like economy, population, water consumption and three wastes emission in 2050 were made under different scenarios, which have provided decision-making support for the selection of regional sustainable development modes.

Future Research

Taking regions as research objects, the evaluation of the capability and state of regional sustainable development involves natural elements like water and soil, and human elements like population, economy, and their interaction and relationship, showing that geography is a comprehensive discipline. Another trend is the combination of natural science and social science which embodies the interdisciplinary characteristics of geography. Researches on the evaluation of the capability and state of regional sustainable development in China have three characteristics: First of all, it has strong practicality. In order to meet the real needs for the sustainable development, geography is of great significance and value; secondly, the priority is given to innovation. Main methods of evaluation are derived from foreign theories, and researches fully oriented to China's own conditions still lack originality and innovativeness; thirdly, it is highly connected with natural science. Due to the research funding system in China, the role of human factors in sustainable development has still not received sufficient attention. An emphasis on human factors is a feature of international research.

13.2.4 How to Utilize Natural Resources in a Sustainable Way?

International Research Progress

Natural resources are not only the material basis for maintaining human existence, activities and development, but also the support conditions for balanced operation of regional spatial structures. The sustainable exploitation and utilization of natural resources are crucial components of sustainable development strategies. To fully, reasonably, economically and efficiently utilize the existing resources and in the meantime develop new substitute resources constantly is a new value for human beings to exploit and utilize resources, which can ensure the consistent and sustainable

utilization of natural resources for human beings, and meet the needs of the development of both contemporary and future generations.

Scholars from different countries have been paying high attention to researches on sustainable use of natural resources, including rational exploitation, conservation and management of conventional resources, such as water, land, organism and energy, as well as the exploitation and use of clean resources (Hepbasli 2008). The scope of researches involves several topics, e.g., approaches of sustainable use of different natural resources, assessment of resource use efficiency etc. Due to the growing shortage of global water resources, multi-objective optimization research on multiple-use of water resources is increasingly valued. Safavi et al. (2010) developed principles and methodology of multi-objective and multi-stage optimal management on multiple uses of surface water and groundwater. A trained artificial neural network model was developed as a simulator of surface water and groundwater interaction while a genetic algorithm was developed as the optimization model. In recent years, against the background of global change, numerous researches about the impacts of global climate change on sustainable use of resources have been conducted, including how climate change affects water and biotic resources, how to address climate change by reducing greenhouse gases emission with reasonable energy production and use (Bilgen et al. 2008) and how land use and land cover changes feed back to climate system. Meanwhile, international academic community highly emphasizes the importance of social study and management on sustainable natural resources use, and considers that sustainable management should be transformed into sustainable governance (Plummer and Fitzgibbon 2004).

Research Progress in China and Representative Achievements

In recent years, research progresses in the sustainable use of resources in China include management of sustainable water resources use and construction of water-saving society, intensive and efficient use together with optimal allocation of land resources, approaches and efficiency assessments for sustainable use of energy, global environment changes and sustainable use of resources, etc. For instance, the dualistic natural-social water cycle theory (Wang et al. 2007, 2013) dialectically identified the relationship between development of human socioeconomic system and sustainable development of the ecological environmental system, which could provide a scientific basis for coordinating human society water use and ecological water use as well as a theoretical basis for rational exploitation and use of water resources. Process model of intensive agricultural land use based on material flow analysis (MFA), and sustainable land use patterns with input reduction and low environmental risk are able to provide scientific basis for improving environmental quality of high-intensive farming areas and sustainable development of agriculture and rural areas (Yin et al. 2015). China's representative achievements in recent years are as follows:

First, sustainable water resources use and management and water-saving society. In recent years, Chinese scholars have made significant progress in several aspects including theories of dualistic water cycle system, high efficiency water use, water resources management, etc. (1) The theoretical framework of compound water cycle system with nature-artificial dualistic driving force and structure was proposed. It holds that watershed water cycle has nature-social dualistic evolution effect under the influences of human activities, which presents an explicit "nature-social" dualistic feature (Wang et al. 2007, 2013; Qin et al. 2014). (2) Based on integrated research of watershed ecology, hydrology, and economy, agricultural water-saving technologies were developed and integrated. And integrated management schemes to improve benefits of basin water under the changing environment were proposed, including hydrology-ecology basic researches, engineering and biological water-saving technologies, and development of watershed integrated management (Cheng et al. 2008). (3) Virtual water strategy was redefined by employing extended analytical framework. The core of virtual water strategy is to select an approach route to develop the secondary and tertiary industries that leads water resources flow to industry and service sectors by dint of positive feedback ring (Xu et al. 2013). (4) According to the features of watershed in arid region, a quantification framework for the sustainable management of water resources was proposed. This framework highlights quantitative criteria, index systems, fundamental models and quantitative methods (Zuo et al. 2006).

Second, intensive and efficient use and optimal allocation of land resources. The major contributions include efficiency assessments of land use in Chinese cities, process simulations of intensive land use in rural areas and optimal allocation of land resources. For instance, based on data envelope analysis of the input-output and scalable efficiency of land use in 655 cities across China, Wu et al. (2011) reported that the input-output efficiency of urban land use in China is low by and large and ascends by the level of city scales, high in Eastern China and low in Central and Western China. In addition, Song and Liu (2010) used the theories and technology of ecological construction and urban-rural areas integration to analyze coupling mechanism of suburban areas from multiple dimensions. Moreover, they took Beijing as an example to find out the main

contents and methods of modern suburban agricultural program on environmental construction.

Third, is energy sustainable utilization mode and efficiency assessment. (1) According to the theory and method of life cycle assessment, a model of cleaner production was built for enterprises to achieve sustainable development. From the aspects of scoping definition, inventory analysis, data processing, program determining and program implementation, the model was used for determining the objects of developing cleaner production audit in enterprises, analyzing material and energy losses of the audit object, discussing the causes of pollutants generation and discharge, thus the foundation was built for seeking opportunities to develop cleaner production and implement programs (Cao and Jin 2010). (2) According to the basic demand of economic and social development, as well as the core conception of energy sustainable development, an evaluation index system of China's energy sustainable development was designed. Based on this index system, the 2000–2010 sustainable development level of energy in China, and the energy scenarios in 2020 were quantitatively evaluated (Miao et al. 2012). (3) Research on spatial patterns and heterogeneous characters of sustainable energy development constructed a framework of sustainable energy development zoning of China, especially at the national and regional scales (Shen and Liu 2011). (4) Researches on how to cope with the impacts of global climate changes on energy have been conducted. Wang et al. (2014) reported that new factors including distribution and competition of international carbon emission, competition of low carbon technology and new energy technology, low carbon finance and carbon market system, and carbon tariff and low carbon trade barrier are significantly affecting current patterns of geopolitics.

Future Research

Compared with international researches on sustainable energy use, researches made by Chinese scholars are mainly focused on formations, variations and spatial patterns of energy, and impacts of human activities on natural resources, such as water cycle in natural-social system, changes and drivers of land resources, etc. Considerable researches on approaches, patterns and management of sustainable use of resources have been conducted, but current researches still focus on qualitative analysis while little attention has been given to quantitative researches, especially to researches on integrated analytical models, resulting in a huge gap between international leading researches and Chinese researches. Moreover, there is a shortage of researches on fundamental theory and technical methods. It is beneficial for Chinese scholars to use international researches which investigate sustainable energy use from the viewpoint of sociology, management science and economics for reference. Furthermore, how to guide policy makers to effectively strengthen the sustainable exploitation and use of resources through scientific research is still an urgent issue which needs to be solved by Chinese scholars at present.

13.2.5 How to Achieve Sustainable Development Through Regional Governance?

International Research Progress

Regional governance is the important foundation of achieving sustainable development. There have been a lot of studies on regional sustainable development since 1987 when the concept of sustainable development was put forward. However, regional governance was not a popular concept in regional sustainable development research until the last decade. From 2000 to 2013, the frequency of the word "policy" in literature increased from 56 to 188 ranking second among all of the hot words in sustainable development research domain. The frequency of the word "planning" in literature increased from 42 in the year of 2000 to 134 in 2014 and ranked 11th in terms of total frequency. After 2005, the frequency of "governance" in literature has been increasing very quickly. In 2005, the word only appeared 4 times, whereas in 2013, the frequency of it increased to 36 times and ranked 38th.

Regional governance research in the world can be consolidated into two core meanings: one is theoretical/analytical and the other more empirical. At present, the vast majority of contributions are empirical ('governance as an empirical phenomenon') studies. Few attempts have been made to produce a dedicated theory of sustainable development governance (Jordan 2008), and the integrated theoretical system has yet to be established. In European countries, regional governance in practice has a relatively long history. The most representative works are the spatial planning of Germany, the spatial planning of Dutch, and the regional planning of French. In recent years, the European Union has carried out a large number of practices on cross-region environmental management and constructed a series of new concepts on regional governance. At the same time, the focuses of regional governance have been shifted. On the one hand, environmental governance has become a more and more important content of spatial planning (Bulkeley 2005; Opdam et al. 2006; Adger et al. 2003); on the other hand, urban region or network society has turned into an important object or unit in regional planning and regional governance studies (Deas and Ward 2000). Along with the rapid development of computer technology, GIS has been utilized more and more broadly in spatial planning, especially in simulation of urban space evolution (McCall 2003; Barredo et al. 2003).

Jordan (2008) conducted an in-depth analysis of the meanings of sustainable development and governance. He argues that sustainable development is a political concept to replace governance, and the UN's Agenda 21 is a flexible international law to carry out sustainable development by means of governance. He thinks that governance includes not only governmental system but also non-governmental institution. Governance cannot be restricted in a specific period of time or a specific geographic area. It should be applied to totally different geographic scales, such as global system, state, and region, etc. or cross different spatial scales and generate a hierarchical governance.

Bulkeley (2005) configured a new spatial grammar of environmental governance, i.e. to construct a geographic space of "scale" and "networks", to coordinate relationship between vertical connection in scales and horizontal relation in networks, and to shape a new geographic space for environmental governance. This new geographic space has transcended the ranking of traditional space governance. The "scale" and "network" of space are not opposite to each other, but become a part of each other. This kind of space classification can not only re-build the administration area of a country by networks but also generate a new network space, which is a new space organization form for environmental governance.

Research Progress in China and Representative Achievements

The early regional planning in China emphasized particularly on industry, town distribution, and economic benefit. After the reform and opening up, great importance has been attached to natural resources and ecological benefit in national territory planning and town system planning (Hu 2006). In recent years, the territory space planning, major function-oriented zoning, and urban agglomeration planning have become the hot issues in regional governance (or regional planning) in China.

Compared with international study focus, the total frequency of "policy" ranked 6th in all Chinese literature on sustainable development, and its annual frequency increased from 4 times in 2000 to 34 times in 2014, which is close to the international hot word rank. Although the frequency of the word "planning" ranks relatively low (27th) compared with its international rank, it has grown very quickly and its annual frequency increased from once in 2000 to 19 times in 2014. However, the literature on "governance" is very limited. The total frequency of the word ranked 227th in all Chinese literatures of sustainable development, and its annual frequency is only about two and even zero in some years.

At present, there exist some differences between the projects supported by NSFC and international hot issues. In published papers supported by NSFC, the total frequency of the hot word "policy" ranked 15th, while "planning" ranked 53rd increasing from once in 2008 to 9 times in 2014. The total frequency of "governance" was only two and ranked 210th. However, among the highly cited articles on regional governance (regional planning), almost half of them are funded by NSFC.

China's representative achievements in recent years are as follows:

First, the methodology of territory space planning. Territory space planning is a comprehensive and strategic planning at national or local level, which includes regional planning, space planning, and territory planning etc. (Lu et al. 2011). Although physical geographic background controls the macro frame of territory development, economic globalization is one of the important factors in shaping China's regional development pattern (Lu et al. 2011). Therefore, strengthening regional competitiveness by constructing "urban regions" should be the focus of space planning in many regions (Liu and Lu 2005). Besides, the distribution and the urban and rural population by region and their spatial-temporal changing trends must be considered in territory space planning due to the rapid progress of urbanization (Lu et al. 2011). Determining development axes, gateway cities, and regional space areas are the major steps of regional space planning, in which analysis of inter-city space relations and mathematic modeling analysis are the key methods for defining urban space (Liu and Lu 2005).

Second, methodology on major function-oriented zoning. Major function-oriented zoning is the guideline for optimizing the spatial pattern of regional development in China (Fan 2007: 339–350). To clearly define the basic category of territorial function and put forward the goal orientation of each major function zone are essential conditions for identifying territory function and expressing it scientifically. At present, the index system for major function-oriented zoning at national level and provincial level is composed of regional resources and environmental carrying capacity, current development intensity and future development potential. The dominant factor evaluation and comprehensive index evaluation methods are used for zoning. The space overlay analysis and clustering analysis by GIS are also used in zoning based on the classifications of ecological restriction and regional social economic development potential (Zhu et al. 2007). Fan (2007) holds that the difficulty of comprehensive geographic research still lies in the integrated methodology of major function-oriented zoning. The major function oriented zone cannot satisfy the basic requirement of rational spatial organization structure. The reason is that although it is the key presentation method for "area" geographical entities, it lacks presentation of the "line" set such as axis and corridor. Therefore, major function-oriented

zoning cannot solve all problems of rational organization of spatial structure, and cannot substitute for spatial planning at the same level.

Third, eco-city construction. The metropolitan area, which consists of central city and periphery towns in terms of its spatial area and impact area, becomes a new spatial unit for contemporary urban development (Cui 2001). Eco-city is a social-economic-natural harmonization development system according with the ecological principle (Wu et al. 2005). It is one of the main countermeasures to climate change. The eco-city theory is one of the important bases for urban planning. Actually, the main objective of eco-city construction is to achieve sustainable development. Therefore, the index system for evaluating the effect of eco-city development can be included in a sustainable development index system. The index system of eco-city consists of social, economic and natural subsystems, and the assessment of eco-city's integrated development ability is based on the status, dynamics, and strength of these three subsystems(Wu et al. 2005). Apart from the integrated weighting method, the entire-array-polygon method is also used for systematic and scientific multi-objective evaluation for eco-cities.

Future Research

The cross-administration regions (urban agglomerations, metropolis, and great regions) based on "hierarchy" and "network" will become the main spatial units for regional governance. Although major function-oriented zoning has been widely used by China's national government, the theory and methods need further study. Eco-city, being a new urban development mode, will be an important measure for regional governance in the future. New regional governance mode must be employed; the relationship between sustainable development and regional governance needs to be studied, and the consequence of the intervention of "governance" on regional sustainable development must be discussed. Although some practices on regional governance have been carried out in China, e.g., territory planning, major function-oriented zoning, urban agglomeration planning, etc., compared with foreign academia, there still remains a large gap in the construction of new governance ideas and theoretical system, especially in the research on relationship between regional governance and regional sustainable development.

13.3 Roadmap for Further Research

Regional sustainable development is not an area of enquiry that has a clear boundary and fixed objects of analysis, but an area that focuses on specific problems encountered by societies as they develop. Since sustainable development involves various factors, the study of regional sustainable development is an almost all-embracing topic. Its mission is not only to reveal scientific rules of the interactions between human being and nature, but also to promote actions and the practice of sustainable development. At present, the truth is that the outputs of many studies remain silent on library shelves and cannot be turned into policies and actions. As such, the Future Earth program jointly proposed by the International Council for Science and International Social Science Council calls for multi-disciplinary studies to support decision-making relating to environmental management of our earth. In addition to a more dynamic cognition of man-land relationships and developing theories, methods and technologies to achieve such cognition, this area of study needs to make further progress in the following three aspects to enhance its role as a field of science and as a contributor to society.

(1) Undertaking Multi-disciplinary Integrated Research Towards Guiding Sustainable Development Practice

Geography has a long history of advocacy of comprehensive research, but this type of research has figured less and less prominently in the last few decades as a result of the continuous sub-division of the disciplines and self-consciousness of scholars as belonging to different disciplines. Only if research is organized to address specific problems, and managed not to follow closely existing research traditions in which different disciplines have particular strengths, can the study of regional sustainable development provide useful knowledge for social practice. Such problems can be common problems faced by many regions like climate change, but can also be local problems like economic recession or local pollution.

(2) Understanding the Critical Role of Governance Structure in Regional Sustainable Development

Scholars have indicated that sustainable development is an area that raises many governance issues. Governance structures decide how resources are allocated in a country or region, and hence play a major role in solving sustainable development problems. After the 2008 global financial crisis, neoliberal governance has been widely queried. How to make the market, the state and society play appropriate roles in governance for sustainable development is not only affected by prevalent theories and ideology, but also based on historical, cultural and natural conditions. Therefore, comparative national and regional research on governance structures is a critical topic in the field of regional sustainable development research.

(3) **Enhancing Recognition of Interactions Among Different Scales**

Most sustainable development problems involve issues that arise at different spatial scales, from the global to the national, the regional and the local. Sustainable development at a regional level is affected by global environmental and economic change, such as global warming and world-wide economic crisis. It is also affected by local resources, and by environmental, social and economic problems like pollution and poverty, which are in part related to development stages. Thus, regions need to strive for local sustainable development and must at the same time assume responsibilities for global sustainable development. No regional "fix" is possible without a deep understanding of the interactions among different things happening at different geographical scales.

13.4 Summary

Sustainable development embraces a wide range of research themes, and involves many disciplines in both the natural and social sciences. In this area, geographers have particular skills in research at regional and local levels and have made important contributions to studies at these spatial scales, although they are also involved in studies of global environmental change. This review reveals that scholars in western countries are particularly concerned with the dynamic drivers of regional sustainable development, and in particular with governance mechanisms. As for the objects of research, in the early days, western scholars undertook a lot of research dealing with natural resources and their management, especially resource conservation and bio-diversity. More recently, they have focused more on global issues, perhaps because western countries had started to resolve some local environmental problems soon after the notion of sustainable development was coined. Besides, many western scholars have asked whether neoliberal reform or environmental policy was the most important driver of policy outcomes. As well as the global level western scholars also pay attention to the local level in part due to changes in governance which have seen responsibilities (but not necessarily resources) moved downwards releasing central government from responsibility for handling some intractable issues. On the contrary, Chinese scholars tend to examine the meaning of sustainable development and to study practical issues that are closely related to policy making. They also focus studies at national and regional levels since the goverments at these two levels play a more important role in governance related to sustainable development. Chinese scholars should undertake more studies of theories and dynamics of regional sustainable development while maintain their advantages in serving the demands of the state. In addition, they need to pay more attention to the role of social, cultural and economic factors, and to undertake more integrated studies.

In general, the study of regional sustainable development in China has made a great progress in the last three decades. Since 2010, China has ranked first in the world in terms of both the number of articles published in SCI/SSCI indexed journals and the number of citations, while a gap exists in the number of top 50 most highly cited articles at present. This situation indicates that, in the field of regional sustainable development, China is still far from being a leading country. To further increase the degree of international influence of Chinese research in this study area, NSFC should give more support to integrated studies that address major regional sustainable development problems while maintaining the strengths of sponsoring free-application projects. In addition, NSFC should encourage collaboration with top research universities and top scholars in the world.

References

Adger WN (2000) Social and ecological resilience: are they related? Prog Hum Geogr 24(3):347–364

Adger WN, Brown K, Fairbrass J, Jordan A, Paavola J, Rosendo S, Seyfang G (2003) Governance for sustainability: towards a thick analysis of environmental decision making. Environ Plan A 35 (6):1095–1110

Arrow KJ (1995) Viewpoint: the future. Science 267(17):1617–1618

Barredo JI, Kasanko MN, McCormick Lavalle C (2003) Modelling dynamic spatial processes: simulation of urban future scenarios through cellular automata. Landsc Urban Plan 64(3):145–160

Bilgen S, Keleş S, Kaygusuz A, Sarı A, Kaygusuz K (2008) Global warming and renewable energy sources for sustainable development: a case study in Turkey. Renew Sustain Energy Rev 12(2):372–396

Bulkeley H (2005) Reconfiguring environmental governance: towards a politics of scales and networks. Polit Geogr 24(8):875–902

Cai YL (1995) Role of technology in human-land relationship. Stud Nat Dialect 11(2):19–22 (in Chinese)

Cai YL, Chen YG, Que WM, Liu WD, Qi QW (2012) Geography: the scientific status and social function. Science Press, Beijing (in Chinese)

Cai BF, Zhang LX, Song YQ (2002) Analysis of the vulnerability of human-land system in the interlock area of farming-pastoral region in northern China. Environ Prot 11:22–23 (in Chinese)

Cao LJ, Jin SL (2010) Model of cleaner production based on life cycle assessment. Chin J Environ Manag 3:27–30 (in Chinese)

Cheng YQ (2006) Optimized regulation model of human-earth system based on system dynamics. J Grad Sch Chin Acad Sci 23(1):83–90 (in Chinese)

Cheng YQ, Li TS, Zhang PY (2004) Application of system dynamic model in regional sustainable development. Plan Syst Eng Theory Pract 12(2):13–18 (in Chinese)

Cheng GD, Xiao HL, Li CZ, Ren J, Wang S (2008) Water-saving eco-agriculture and integrated water resources management in Heihe River Basin, northwest China. Adv Earth Sci 23(7):661–665 (in Chinese)

CSD (The Centre for Sustainable Development) (2006) Sustainable development: a review of international literature. University of Westminster and the Law School, University of Strathclyde

Cui GH (2001) Metropolitan planning—new trend of geographical spatial planning. Urban Plan Int 5:1 (in Chinese)
Daly H, Cobb J (1989) For the common good: redirecting the economy towards community, the environment, and a sustainable future. Beacon Press, Boston
Deas I, Ward KG (2000) From the 'new localism' to the 'new regionalism'? The implications of regional development agencies for city–regional relations. Polit Geogr 19(3):273–292
European Commission and Eurostat (1999) Towards environmental pressure indicators for the EU: statistics and indicators. The Stationary Office, Brussels
Fan J (2007) The scientific foundation of major function oriented zoning in China. Acta Geogr Sinica 62(4):339–350 (in Chinese)
Fan J (2009) The national post-earthquake reconstruction planning of Wenchuan: evaluation on carrying capacity of resources and environment. Science Press, Beijing (in Chinese)
Fan J (2010) The post-earthquake restoration and reconstruction planning of Yushu: evaluation on carrying capacity of resources and environment. Science Press, Beijing (in Chinese)
Fan J (2011) Scientific foundation for optimizing the pattern of China's economic geography. Econ Geogr 30(1):1–6 (in Chinese)
Fan J (2014a) Frontier approach of the sustainable process and pattern of human-environment system. Acta Geogr Sinica 69(8):1060–1068 (in Chinese)
Fan J (2014b) The post-earthquake restoration and reconstruction planning of Lushan: evaluation on carrying capacity of resources and environment. Science Press, Beijing (in Chinese)
Fang CL (2002) Industrial emphases of economic sustainable development and man-land system optimization in Hexi Region in new century. J Desert Res 22(1):75–81 (in Chinese)
Fang CL (2003) The optimal control of regional human-earth system and its sustainable development. Earth Sci Front 10(4):629–635 (in Chinese)
Fang CL, Yang YM (2006) Basic laws of the interactive coupling system of urbanization and ecological environment. Arid Land Geogr 29(1):1–8 (in Chinese)
Feng ZM, Yang YZ, Zhang J, Wang XF (2007) A GIS based study on the grain productivity and potential yield increase at multi-levels in China. J Nat Resour 22(5):747–755 (in Chinese)
Feng ZM, Yang YZ, Zhang J (2008) The land carrying capacity of China based on man-grain relationship. J Nat Resour 23(5):865–875 (in Chinese)
Gao JX (2001) An explore of the sustainable development theory—theory, methods and application of ecological carrying capacity. China Environmental Science Press, Beijing (in Chinese)
Geng Y, Sarkis J, Ulgiati S, Zhang P (2013) Measuring China's circular economy. Science 339(6127):1526–1527
Grossman GM, Krueger AB (1991) Environmental impacts of a north American free trade agreement. MIT Press, Massachusetts
Hepbasli A (2008) A key review on exergetic analysis and assessment of renewable energy resources for a sustainable future. Renew Sustain Energy Rev 12(3):593–661
Hu XW (2006) Evolution and prospect of China's regional planning. Acta Geogr Sinica 61(6):585–592 (in Chinese)
Huang BW (1999) Integrative projects in geography and cross discipline researches. In: Editorial board of collected works of Huang Bingwei. Territorial system sciences and geographical integrative research-bulletin of academic thoughts workshop of Academician Huang Bingwei. Science Press, Beijing (in Chinese)
Huang CC (2001) The deterioration of land resource and the change in human-earth relationship in the Weihe River Basin at 3100 a B. P. Sci Geogr Sinica 21(1):30–35 (in Chinese)
Jordan A (2008) The governance of sustainable development: Taking stock and looking forwards. Environment and Planning C 26:17–33
Juhasz F (1991) An international comparison of sustainable coastal zone management policies. Mar Pollut Bull 23:595–602
Leontief W (1970) Environmental repercussions to the economic structure: an input-output approach. Rev Econ Stat 32:262–271
Li BC (2008) General discussion on relationship between residents and region in the region system. J Guizhou Norm Univ (Nat Sci) 26 (2):36–38 (in Chinese)
Li H, Zhang PY (2008) Economic system vulnerability of mining cities in northeast China. J China Coal Soc 33(1):116–120 (in Chinese)
Li L, Zhang PY, Hou W (2006) Study on the spatial pattern of land use and land cover change and driving forces in southern Liaoning since 1950's. J Arid Land Resour Environ 20(2):133–138 (in Chinese)
Liu Y, Jin FJ (2006) Strategy of human-environmental coordinated development in coastal area. The Commercial Press, Beijing (in Chinese)
Liu WD, Lu DD (2005) Methodological basis for making regional spatial planning in China in the new era: A preliminary study based on planning of key economic regions in developing western China. Acta Geogr Sinica 60(6):894–902 (in Chinese)
Liu J, Shi PJ, Ge Y, Wang JA, Lv HF (2006) The review of disaster resilience research. Adv Earth Sci 21(2):211–218 (in Chinese)
Liu WD, Chen J, Tang ZP, Liu HG, Han D, Li FY (2012) Theory and practice of China's regional input-output table establishment of 30 provinces and municipalities in 2007. China Statistics Press, Beijing (in Chinese)
Lockie S, Franettovich M, Petkova-Timmer V, Rolfe J, Ivanova G (2009) Coal mining and the resource community cycle: a longitudinal assessment of the social impacts of the Coppabella Coal Mine. Environ Impact Assess Rev 29(5):330–339
Lu DD (2002) Theoretical studies of man-land system as the core of Geographical Science. Geogr Res 21(2):135–145 (in Chinese)
Lu DD (2003) Theory and practice of regional development in China. Science Press, Beijing (in Chinese)
Lu DD, Fan J, Liu WD, Jin FJ, Wu SH, Li LJ (2011) China's territorial space, function and its development. China Land Press, Beijing (in Chinese)
Luo F (2007a) The environmental effect of China's trade of pollution-intensive industrial good. Int Trade Probl 10:96–100 (in Chinese)
Luo F (2007b) The relationship between population growth and land use under the restriction of present land-use system. Popul Econ 3:1–5 (in Chinese)
Luo J, Chen YG (2003) Toward man-land relationship and its policy adjustment on the era of economic globalization. Human Geography 18(5):8–10 (in Chinese)
Mao HY (1996) The research about an indicator system of sustainable development in Shandong province. Geogr Res 15(4):16–23 (in Chinese)
Mao HY, Yu DL (2001) A study on the quantitative research of regional carrying capacity. Adv Earth Sci 16(4):549–555 (in Chinese)
McCall MK (2003) Seeking good governance in participatory-GIS: A review of processes and governance dimensions in applying GIS to participatory spatial planning. Habitat Int 27(4):549–573
Mccool SF, Stankey GH (2004) Indicators of sustainability: challenges and opportunities at the interface of science and policy. Environ Manag 33(3):294–305
Miao R, Wang LF, Wu D, Hu XL, Zhou FQ (2012) Construction and preliminary assessment of evaluation index system of China's energy sustainable development. Energy China 34(3):22–27 (in Chinese)
Moldan B, Janoušková S, Hák T (2012) How to understand and measure environmental sustainability: Indicators and targets. Ecol Indic 17:4–13

Ness B, Urbel-Piirsalu E, Anderberg S, Olsson L (2007) Categorising tools for sustainability assessment. Ecol Econ 60(3):498–508
NRC (National Research Council) (2010) Understanding the changing planet: strategic directions for the geographical sciences. National Academies Press, Washington, DC
Opdam P, Steingröver E, van Rooij S (2006) Ecological networks: a spatial concept for multi-actor planning of sustainable landscapes. Landsc Urban Plan 75(3):322–332
Pan YJ (2000) A theoretical study on the regional system coordination and lasting development between man and land. J Qiqihar Univ (Philos Soc Sci) 1:16–20 (in Chinese)
Plummer R, Fitzgibbon J (2004) Co-management of natural resources: a proposed framework. Environ Manag 33(6):876–885
Prandle D (1991) A 5-year scientific research programme for managing coastal seas. Mar Pollut Bull 23:63–68
Pré Consultants (2001) The eco-indicator 99—a damage oriented method for life cycle impact assessment. Methodology Report, 2001. Available at: http://www.pre.nl/
Prescott-Allen R (2001) The wellbeing of nations: a country-by-country index of quality of life and the environment. Island Press, Washington, D.C.
Pretty J, Ward H (2001) Social capital and the environment. World Dev 29(2):209–227
Qiao B, Fang CL (2005) The dynamic coupling model of the harmonious development between urbanization and eco-environment and its application in arid area. Acta Ecol Sinica 25(11):3003–3009 (in Chinese)
Qin YC, Xu MJ (1998) Publication of sustainable development and land utilization. Acta Geogr Sinica 53(2):149–156 (in Chinese)
Qin DY, Lu CY, Liu JH, Wang H, Wang JH, Li HH, Chu JY, Chen GF (2014) Theoretical framework of dualistic nature-social water cycle. Chin Sci Bull 59(4):419–427 (in Chinese)
Ren QP, Ren JL (2006) Study on elements of man-land relationship areal system. J Shandong Norm Univ (Nat Sci) 21(3):95–98 (in Chinese)
Research Group on Sustainable Development of the Chinese Academy of Sciences (1999) Strategic report of China's sustainable development. Science Press, Beijing (in Chinese)
Robinson J (2004) Squaring the circle? Some thoughts on the idea of sustainable development. Ecol Econ 48(4):369–384
Rosenthal S, Strange W (2001) The determinants of agglomeration. J Urban Econ 50(2):191–229
Safavi HR, Darzi F, Mariño MA (2010) Simulation-optimization modeling of conjunctive use of surface water and groundwater. Water Resour Manag 24(10):1965–1988
Selden TM, Song D (1994) Environmental quality and development: is there a Kuznets curve for air pollution emissions? J Environ Econ Manag 27(2):147–162
Shafik N, Bandyopadhyay S (1992) Economic growth and environmental quality: time-series and cross-country evidence. World Bank Publications, Washington, D.C.
Shen L, Liu LT (2011) Functional zoning and zoning plan of sustainable development of energy in China. In: Proceedings of annual academic meeting of the Chinese society of natural resources in 2011—Taking advantages of resources and technology to ensure the innovational development of Western China, vol 1 (in Chinese)
Shi YF, Qu YG (1992) Water resources carrying capacity and its reasonable use in Urumqi river basin. Science Press, Beijing (in Chinese)
Sleeser M (1990) Enhancement of carrying capacity options ECCO. The Resource Use Institute, London
Solow RM (1974) Intergenerational equity and exhaustible resources. Rev Econ Stud 41:29–45
Song ZJ, Liu LM (2010) Study on the functions and research method of modern suburban agriculture regions in China. J China Agric Univ 15(6):120–126 (in Chinese)
Statistics Finland (2003) Index of environmental friendliness. Available at http://www.stat.fi/tk/yr/ye22en.html
Stiglitz J (1974) Growth with exhaustible natural resources: efficient and optimal growth paths. Rev Econ Stud 41:123–137
Sustainable Development Strategy Research Group (2014) China Sustainable Development Strategy Report. Chinese Academy of Sciences
Tang ZP, Zhang J, Liu WD (2010) A comparative study on the differences of physical process and human process modeling. Acta Geogr Sinica 65(12):1581–1890 (in Chinese)
Turner BL, Lambin EF, Reenberg A (2007) The emergence of land change science for global environmental change and sustainability. Proc Natl Acad Sci USA 104(52):20666–20671
UNCSD (The United Nations Commission on sustainable development) (2008) Report of the Joint UNECE/OECD/Eurostat Working Group on Statistics for Sustainable Development
UNDP (United Nations Development Programme) (1990) Human development report. Oxford University Press, New York
Verburg PH, Veldkamp W, Espaldon R, Mastura S (2002) Modeling the spatial dynamics of regional land use: the CLUE-S model. Environ Manag 30(3):391–405
Vogt W (1949) Road to survival. Victor Gollanez Ltd., London
Wackernagel M, Schulz NB, Deumling D, Linares AC, Jenkins M, Kapos V, Monfreda C, Loh J, Myers N, Norgaard R, Randers J (2002) Tracking the ecological overshoot of the human economy. Proc Natl Acad Sci USA 99(14):9266–9271
Wang CC (2010) An analysis of complex mechanism in human-environment system. J Hainan Norm Univ (Nat Sci) 23(2): 219–223 (in Chinese)
Wang H, Wang JH, Qin DY, Jia YW (2007) Theory and methodology of water resources assessment based on dualistic water cycle model. J Hydraul Eng 37(12):1496–1502 (in Chinese)
Wang H, Jia YW, Yang GY, Zhou ZH, Qiu YQ, Niu CW, Peng H (2013) Integrated simulation of the dualistic water cycle and its associated processes in the Haihe River Basin. Chin Sci Bull 58 (12):1064–1077 (in Chinese)
Wang WT, Liu YH, Yu HY (2014) The geopolitical pattern of global climate change and energy security issues. Acta Geogr Sinica 69 (9):1259–1267 (in Chinese)
World Economic Forum (2002) An initiative of the global leaders of tomorrow environment task force. In: 2002 annual meeting on pilot environmental performance index
Wu CJ (1991) Research core of geography: human-land territorial system. Econ Geogr 12(3):1–6 (in Chinese)
Wu Q, Wang RS, Li HQ, Xi XB (2005) The indices and the evaluation method of eco-city. Acta Ecol Sinica 25(8):2090–2095 (in Chinese)
Wu DW, Mao HY, Zhang XL, Huang JC (2011) Assessment of urban land use efficiency in China. Acta Geogr Sinica 66(8):1111–1121 (in Chinese)
Xu ZM, Zhang ZQ, Cheng GD (2000) The calculation and analysis of ecological footprints of Gansu Province. Acta Geogr Sinica 55 (5):607–616 (in Chinese)
Xu ZM, Song XY, Cheng GD (2013) A new explanation of virtual water strategy. J Glaciol Geocryol 35(2):490–495 (in Chinese)
Yang QS (2002) The conceptual recognition of the coordinated development of human-land relationship territorial system. Econ Geogr 22(3):289–292 (in Chinese)
Yang GS (2004) Land use and land cover change and regional economic development: the revelation of the change in cropland area in the Yangtze River Delta during the past 50 years. Acta Geogr Sinica 59(sup):41–46 (in Chinese)
Yin GY, Liu LM, Qi XX, Yuan CC, Zhuo D (2015) Environmental risk assessment in high intensive farming area based on material flow analysis. Trans Chin Soc Agric Eng 31(5):235–243 (in Chinese)

Yu YJ, Lu YL (2003) Studies on character of economic location and spatial structure of regional development in Jiangxi province. Econ Geogr 23:462–471 (in Chinese)

Yu DL, Mao HY (2003) Study on regional carrying capacity: theory, method and example—take the Bohai-Rim area as example. Geogr Res 22(2):201–210 (in Chinese)

Yue DX, Ma JH, Gong J, Xiong YC, Song YJ (2009) Quantitative estimation and spatial pattern analysis of ecological carrying capacity in northwestern China based on GIS. J Lanzhou Univ (Nat Sci) 45(6):68–75 (in Chinese)

Yue DX, Du J, Liu JY, Guo JJ, Zhang JJ, Ma JH (2011) Spatial-temporal analysis of ecological carrying capacity in Jinghe Watershed based on remote sensing and transfer matrix. Acta Ecol Sinica 31(9):2550–2558 (in Chinese)

Zhang ZW, Zheng BH (2000) On the coordination of regional sustainable development and human-land system. J Xiangfan Univ 21(5):85–88 (in Chinese)

Zhang ZQ, Xu ZM, Cheng GD, Chen DJ (2001) The ecological footprints of the 12 provinces of west China in 1999. Acta Geogr Sinica 56(5):599–610

Zhang L, Shen XJ, Yang YK, Cheng XL, Wu YM (2004) Regional development and its resource and environmental harmony in China. Prog Geogr Sci 23(6):10–19 (in Chinese)

Zhao MH (2000) Analysis on man-land system mechanism of action and its modeling in sea (salt) water intrusion zone-A case on coast of Laizhou Bay in Shandong Province. Econ Geogr 20(2):27–30 (in Chinese)

Zheng D, Cheng SP (2001) Progress and disciplinary frontiers of Geographical Research. Adv Earth Sci 16(5):599–606 (in Chinese)

Zhu KZ (1964) Some characteristic features of Chinese climate and their effects on crop procution. Acta Geogr Sinica 1:1–13 (in Chinese)

Zhu CG, Qiu FD, Ma XD, Wang ZB, Li ZJ, Meng SY, Yan QW (2007) The theories and methods of major function regionalization. Sci Geogr Sinica 27(2):136–141 (in Chinese)

Zuo QT, Zhou KF, Xia J, Chen X, Wang YQ (2006) Quantitative research methods and their application in sustainable management of water resources in arid areas. Sci Sinica Terrae 36(A2):9–14 (in Chinese)