

Delineation of eco–geographic regional system of China

WU Shaohong, YANG Qinye, ZHENG Du

(Inst. of Geographic Sciences and Natural Resources Research, CAS, Beijing 100101, China)

Abstract: Eco-geographic regionalization has been one of the most important topics in China's regionalization researches since the end of the 20th century. It is a major ecosystem in geographic zonality. A hierarchical system, which is formed by division or combination of natural features based on geographic relativity and comparison of major ecosystem factors (including biological and non-biological) and geographic zonality, is called eco-geographic regional system. This paper introduces process of China's regionalization development. The first level unit, temperature zone, is delineated with main criteria of temperature. The second level unit, humidity region, is based on criteria of water/moisture states. The third level unit, natural region, is divided according to medium geomorphologic units. Vegetation types and soils are applied as supplementary criteria to indicate temperature and water/moisture states. Mapping process from qualitative to quantitative and China's eco-geographic regional system are also explained in this paper.

Key words: China; eco-geographic region; regionalization

CLC number: P902; P942; Q948

1 Introduction

Eco-geographic region is a major ecosystem in geographic zonality. A hierarchical system, which is formed by division or combination of natural features based on geographic relativity and comparison of major ecosystem factors (including biological and non-biological) and geographic zonality, is called eco-geographic regional system. The system indicates patterns of temperature, water/moisture, biomass, soil and their corresponding resources and environment. Eco-geographic regional system is a way to recognize environment and ecosystem. It is important for environmental conservation, vegetation restoration, ecosystem construction and sustainable regional development.

As early as 500 B.C., China, based on soil types and fertility, was delineated into nine areas limited by mountains, rivers, lakes and seas. The other work was delineating land of the whole country into three main groups with 25 types (Zhao *et al.*, 1988). The modern regionalization work of China began in 1931 as the publication of *Study on Climatic Regions of China* by Zhu Kezhen. Later in the early 1940s, Huang Bingwei started the first vegetation division work in China (Huang, 1993).

In 1956, the Chinese Academy of Sciences (CAS) organized "Natural Regionalization Work Commission", which began the systematic modern regionalization in China. Under the leadership of Huang Bingwei, the integrated natural regionalization has been widely applied in different industries. The regionalization, consisting of nine "species" of regionalizations: physico-geographical, climatic, geomorphologic, hydrologic, hydrogeological, pedological, vegetational, zoogeographical, and entomological, aimed at serving agriculture, forestry, livestock farming, and water conservancy. The integrated regionalization (Huang, 1959; 1960) gave prominence to rule of natural geographic zonality, delineating China into three natural realms with 6 heat zones, 18 natural divisions/sub-divisions, 28 natural zones/sub-zones, and 90

Received date: 2003-03-27 **Accepted date:** 2003-06-09

Foundation item: National Natural Science Foundation of China, No.40171040; Director Foundation of IGSNRR, CAS, No. SJ10G-A00-06

Author: Wu Shaohong (1961-), Ph.D. and Professor, specialized in physical geography. E-mail: wush@igsnr.ac.cn

natural provinces. In the 1960s, Huang modified the project of the regionalization. The heat zones were identified as temperature zones. In the 1980s, he systematically modified the project again, delineating the whole country into 12 temperature zones, 21 divisions and 45 regions (Huang, 1989). In the 1960s-1980s, there were some studies of regionalization, which differed from Huang's scheme (Ren *et al.*, 1961; 1982; 1992).

At the beginning of the 1980s, Chinese geographers started to introduce ecosystem and to apply principles and methodology of ecology to regionalization. Hou Xueyu (1963; 1988) delineated eco-regions of China based on vegetation distribution and discussed the regions with agricultural development strategy, in which he divided the whole country into 20 natural eco-regions. Some eco-regions were further divided into sub-regions. Zheng Du's study group carried out a systematic and detailed study on eco-geographic regional system by the end of the 20th century (Zheng, 1999). The study brought regionalization into a new stage of eco-geographic regions, which is the main content of this paper. Other scholars, such as Fu Bojie, also had delineation of eco-regions of China (2001).

2 Hierarchical units

Eco-geographic regional system divides or combines natural features of such a region as China, based on geographic relativity, comparison of major ecosystem factors (including biological and non-biological) and geographic zonality. Internal complexity in ecosystems is not always the same. An ecosystem at lower level has high homogeneous eco-factors. Eco-geographic regional system serving different objectives should indicate different complexity degrees of ecosystems. Therefore, eco-geographic regional system is a hierarchical system.

The most important way to recognize regional differentiation is thought delineation at different levels of regional system. China's eco-geographic regions are delineated based on principles of hierarchical, relative regional coherence, regional genesis and regional conjugation. Regional dominant ecosystem type, stability, succession orientation, and regional environmental problems, degree of eco-risk, geographic distribution, and "eco-construction" are taken into consideration. Units of different levels indicate various homogeneousness of ecosystem. Marking the definite difference (boundary) forms this hierarchical system. Ecological climate relation between ecological features and the environment is the best factor to indicate the differences of ecosystem. Within climatic scope, temperature and water/moisture have definite geographical differences. For further subclassification beyond climate, the macrofeatures of the vegetation appear to be the appropriate criteria for defining secondary divisions (Bailey, 1983). Soils reflect regional natural states of a former period (Wu *et al.*, 2000). So they are always applied as a supplementary indicator to climate and regions. Medium geomorphologic units have a profound influence on climate, vegetation and soils. The boundary of the units is always coincident to that of eco-geographic regions. Therefore, in delineation of eco-geographic regions of China, temperature is the main criteria for zone, water/moisture for region and medium geomorphologic unit for natural region. An example is given as Figure 1.

3 Index system and mapping

In climatic factors, in terms of biology, daily temperature $\geq 10^{\circ}\text{C}$ ensures that most plants and crops grow in the course of nature. Period of daily temperature $\geq 10^{\circ}\text{C}$ is the season that most crops and plant grow well. Hence the number of days and accumulating temperature $\geq 10^{\circ}\text{C}$ are used as the main criteria of temperature zones. Average temperatures of the coldest and warmest months indicate regional temperature states impersonally, which is used as supplementary criteria of temperature zones (Table 1). Annual aridity shows the relationship between regional precipitation and potential evaporation. It indirectly indicates moisture used by plant except evaporation. Annual precipitation is an important source of regional water

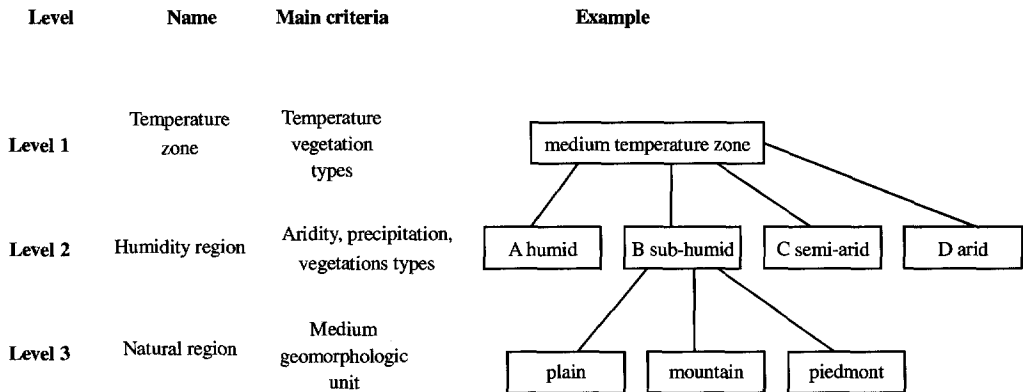


Figure 1 Example of hierarchical system of eco-geographic region

Table 1 Criteria for temperature zones

T zone	Main criteria		Supplementary criteria		Vegetation type
	Days of $\geq 10^{\circ}\text{C}/\text{d}$	Annual acc. T $\geq 10^{\circ}\text{C}/^{\circ}\text{C}$	Ave. T of the coldest month/ $^{\circ}\text{C}$	Ave. T of the warmest month/ $^{\circ}\text{C}$	
Cold temperate	< 100	< 1600	< - 30	< 16	Dark F
Medium temperate	100-170	1600-3200(3400)	< - 30- - 12(6)	16—24	Coniferous and deciduous broad-leaved mixed F
Warm temperate	171-220	3200(3400)-4500(4800)	- 12(6)-0	>24	Deciduous broad-leaved F
N subtropical	220-239	4500(4800)-5100(5300)	0-4	>24	Mixed evergreen
M subtropical	240-285	5100(5300)-6400(6500)	4-10	>24	broad-leaved F
S subtropical	286-365	6400(6500)-8000	10-15	>24	
Marginal tropical	365	8000-9000	15-18	>24	Seasonal rainforest
Medium tropical	365	> 8000(9000)	18-24	>24	Rainforest
The equator tropical	365	> 8000(9000)	>24	>24	
P sub cold temperate	< 50		- 18-10(12)	< 10(12)	
P temperate	50-180		- 10(12)-0	12-18	

T—temperature, Ave—average, F—forest, N—north, M—mid, S—south, P—plateau

recharge. It also indicates regional water/moisture state. Aridity has been calculated with Селяниноѡ model and modified with ecological types (Yang *et al.*, 2002). Annual aridity and precipitation is employed as criteria of regions (Table 2). Natural vegetation types and soils are taken to indicate temperature and water/moisture.

Prior to the 1960s, China's lacked records on climate and other natural factors. The boundary of regional system was determined with "typical" landscape type. At that time, there was an expert group that discussed how to draw the boundary. The boundary was decided by the expert group's opinion. For example, they "agreed" that hot climate without winter season,

Table 2 Criteria for humidity region

Region	Annual aridity	Annual precipitation/mm	Natural vegetation type	Other
Humid	<0.99	>800	Forest	
Sub-humid	1.00-1.49	800-400	Forest-steppe (meadow)	Possible secondary salinization
Semi-arid	1.50-4.00	400-200	Steppe/meadow-steppe	Possible dry-land cultivation
Arid	≥ 4.00	< 200	Desert	Irrigation required for agriculture

growth of tropical plants such as coconut (*Cocos nucifera*), pepper (*Piper nigrum*), and rubber trees (*Hevea brasiliensis*), and cocoa (*Theobroma cacao*), and laterize soil were the indicators for tropical and subtropical zones. The boundary between evergreen and deciduous broad-leaved forests served as delineation of warm temperate and subtropical zones. Limitation of steppe was taken as the boundary between semi-arid and sub-humid regions. Of course such delineation was somewhat subjective. Since the 1960s, China has established network for eco-geographic factor observation and records gradually. Using the international relative researches as reference, China's regionalization researches have been orientated to a quantitative way. Ecological factors of the former typical landscapes have been quantified forming an index system for eco-geographic regional delineation. The boundary of the regions is determined according to such an index system. Since the 1980s, development of remote sensing and geographical information system (GIS) has provided technical support for eco-geographic regional mapping. In recent years, supported with GIS techniques data of ecological factors from observation stations are generated into isolines of the index items. With modification of vegetation and soil maps the boundary of eco-geographic regions has been mapped.

Database of China's eco-geographic factors has been set up according to the mapping methodology described above. Climatic data (1951-1995) used are from the basic weather observation stations of the National Meteorological Administration. Isolines of climatic items for temperature zones and humidity regions are generated with ArcView GIS software on map of 1:4,000,000. The isolines are integrated with *Vegetation Map of China* (1:1,000,000) (Hou *et al.*, 2001) and *Soil Map of China* (1:20,000,000) (Editorial Committee of Physical Geography of China *et al.*, 1982) to generate the boundary for temperature zones and humidity regions. The boundary of natural regions is delineated according to medium units of *Geomorphologic Map of China* (1:4,000,000) (Li *et al.*, 1994).

4 Eco-geographic regions of China

Eco-geographic regions of China are showed in Figure 2 and Table 3. Roman numerals I to IX stand for cold temperate zone to the equator tropical zone. HI and HII stand for plateau sub-cold temperate and plateau temperate zones. Letter A means humid region, B sub-humid, C semi-arid, and D arid. Arabic numbers stand for natural regions.

5 Comparison

International regionalization has been a long-term research work. In Germany, many scholars link ecosystem with geography together. Schultz studies ecozone or geozonal ecosystem. Others, such as Passarge, Maull, Mueller-Hohenstein, Bramer,



Figure 2 Eco-geographic regional system of China

Table 3 Scheme for a three-order eco-geographic regionalization of China

Temperature zone	Humidity region	Natural region
I Cold temperate zone	A Humid region	IA1 North Da Hinggan mountain deciduous coniferous forest region
II Medium temperate zone	A Humid region	IIA1 Sanjiang plain swamp region
		IIA2 East of Northeast China mountain broad-leaved and coniferous forest region
		IIA3 East of Northeast China piedmont platform broad-leaved and coniferous mixed forest region
	B Sub-humid region	IIIB1 Middle Songhuajiang and Liaohe plain forest-steppe region
		IIIB2 Middle Da Hinggan mountain steppe-forest region
		IIIB3 Hilly land of north part of west Da Hinggan mountain piedmont forest-steppe region
	C Semi-arid region	IIIC1 West Liaohe plain steppe region
		IIIC2 South Da Hinggan steppe region
		IIIC3 East Inner Mongolia mid-altitude plain steppe region
		IIIC4 Hulun Buir plain steppe region
	D Arid region	IID1 Hetao and west Inner Mongolia mid-altitude plain desert steppe region
		IID2 Alax and Hexi Corridor shrub and semi-shrub desert region
		IID3 Junggar Basin small arbor, semi-shrub desert region
IID4 Altay and Ertix plain steppe, coniferous forest region		
IID5 Tianshan Ili high mountain basin semi-shrub desert and broad-leaved and coniferous mixed forest region		
III Warm temperate zone	A Humid region	IIIA1 East Liaoning and Jiaodong hilly land deciduous broad-leaved forest, and cultivated vegetation region
		B Sub-humid region
	IIIB2 North China Plain cultivated vegetation region	
	IIIB3 North China mountain deciduous broad-leaved forest region	
	IIIB4 Fenhe and Weihe river basins and loess tableland deciduous broad-leaved forest, and cultivated vegetation region	
	C Semi-arid region	IIIC1 Loess hill/ridge and mountain steppe region
	D Arid region	IIID1 Tarim Basin and east Xinjiang shrub and semi-shrub desert region
IV North subtropical zone	A Humid region	IIVA1 Mid-lower reaches of Changjiang and Huaihe plains and Dabieshan Mountain cultivated vegetation, evergreen and deciduous broad-leaved forest region
		IIVA2 Qinling and Bashan mountains evergreen and deciduous broad-leaved forest region
V Middle subtropical zone	A Humid region	VA1 Hilly land and basins of the South of Changjiang River evergreen forest and cultivated vegetation region
		VA2 Nanling, Zhejiang and Fujian mountains evergreen broad-leaved forest region
		VA3 Hunan and Guizhou Plateau mountain evergreen broad-leaved forest region
		VA4 Sichuan Basin cultivated vegetation region
		VA5 Yunnan Plateau evergreen broad-leaved forest and pine forest region
		VA6 South of east Himalaya mountain seasonal rainforest evergreen broad-leaved forest region
VI South subtropical zone	A Humid region	VIA1 Middle and north Taiwan plain cultivated vegetation and evergreen broad-leaved forest region
		VIA2 Fujian, Guangdong and Guangxi (South China) low mountain and plain evergreen broad-leaved forest and cultivated vegetation region
		VIA3 Middle Yunnan sub-high mountain and valley evergreen broad-leaved forest and pine trees region
VII Marginal tropical zone	A Humid region	VIIA1 South Taiwan mountain and plain seasonal rainforest and rainforest region
		VIIA2 Hainan and Leizhou mountain and hilly land semi-evergreen seasonal rainforest region
		VIIA3 South Yunnan medium mountain and valley seasonal rainforest and rainforest region
VIII Middle tropical zone	A Humid region	VIIIA1 South Hainan lowland and East, Middle and West Archipelagos seasonal rainforest and rainforest region
IX The Equator tropical zone	A Humid region	IXA1 Nansha Archipelagos coral islands vegetation region
HI Plateau sub-cold zone	B Sub-humid region	HIB1 Sichuan, Qinghai and Xizang high mountain and valley alpine shrub-meadow region
		C Semi-arid region
	D Arid region	
HID1 Kunlun high mountain and plateau alpine desert region		
HII Plateau temperate zone	A/B Humid/sub-humid region	IIIA/B1 West Sichuan and east Xizang high mountain and deep valley coniferous forest region
		C Semi-arid region

Haggett, study landscape belts, geographic zones, or geozones (Schultz, 1995). Their system describes spatial distribution of ecosystems, but not a hierarchical system. Robert G. Bailey systematically studies ecoregions, which is a hierarchical system. He edited maps of ecoregions of the United States, North America, the Continents and the Oceans (Bailey, 1985; 1995; 1998). The main criteria for the first level domain of his system are climatic zone or group, the second level division Köppen's climatic type, the third level province climax plant formations, and the fourth level section Köchler's climax plant associations. The system of Bailey's ecoregions is a type regionalization, which means that the same type of ecoregion would possibly repeat in different locations. The China's system is a spatial regionalization, in which regions do not repeat anywhere. Of the above-discussed systems of regionalization, Bailey's system is most similar to China's system (Table 4).

Because of differences in the study areas, detailedness and study background, the eco-geographic regional system of China and Bailey's ecoregional system take similar criteria but obtain both similar and dissimilar results in regional delineation. Overlapping the China's part on his Map of Ecoregion of the Continents with China's eco-geographic regional map will find that for temperate states, boundaries of cold temperate (about 50°N) and warm temperate-subtropical (about 32°-34°N) zones are almost unanimous (Bailey, 1983; Wu *et al.*, 2001). However, the difference in location of boundary of tropical-subtropical is as much as 4 degrees of latitude (Wu *et al.*, 2001; Bailey, 1989). His northern boundary of tropical is as northbound as to Fuzhou City of Fujian Province lying about 26°N. In China, climax vegetation northward to the Tropic of Cancer could hardly find species of tropical plants and so is the case of tropical rainforest. For water/moisture states, delineation of eastern China between Bailey's system and China's system is almost the same. But for the western China system, it has much larger arid area. Arid region in China's system was delineated according to that dryness is 4 or more, annual precipitation less than 200 mm with desert landscape. Bailey applies Köppen's climatic types that have no criteria of dryness.

Table 4 Comparison of eco-geographic regions between Köppen's, Bailey's and China's systems

Köppen groups and types	Bailey's system	China's system vs. Köppen's types
A-Tropical humid climate	Humid tropical domain (4000)	Marginal, middle and equatorial tropical
Tropical rainforest (Tf)	Rainforest division (4200)	Humid region (A)
Tropical savanna (Aw)	Savanna division (4100)	
B-Dry climates	Dry domain (3000)	Arid and semi-arid region
Steppe (BSk)	Steppe division (3100)	Semi-arid region (C)
Desert (BWh, BWk)	Desert division (3200)	Arid region (D)
C-Sub-tropical climate	Humid temperate domain (2000)	Subtropical zones
Mediterranean (Csa)	Mediterranean division (2600)	
Humid subtropical (Cfa)	Subtropical division (2300)	Humid region (A)
Prairie division (2500)		
Marine west coast (Cfb)	Marine division (2400)	Humid region (A)
D-Temperate climate		Cold, middle and warm temperate zone
Humid continental, warm summer (Dfa)	Hot continental division (2200)	Warm temperate zones (I,II)
Prairie division (2500)		Semi-arid region (IID1-IID4)
Humid continental, cool summer (Dfb)	Warm continental division (2400)	Middle temperate zones (III)
Prairie division (2500)		Semi-arid region (IIIC1, IIIC1-IIIC2)
Polar domain (1000)		Plateau sub-cold zone
Sub-arctic (Dfc, Dfd)	Sub-arctic division (1300)	Sub-humid region (HIIB1)
E-Polar climate		
Tundra (ET)	Tundra division (1200)	
Ice cap (EF)		

* Columns 1 and 2 see reference 14

6 Summary

Eco-geographic region delineation becomes one of the dominant works of regionalization in China. Delineation of eco-geographic regions is based on ecological principles and factors. Methodology and mapping procedure are determination of criteria for delineation, generating isolines of items of the criteria and then dividing eco-geographic regions by integrated cartographic methods. For China's system temperature zone based on temperature is similar to domain of Bailey's system, humidity region based on water/moister state is similar to division and natural region based on medium geomorphologic units is similar to province.

References

- Editorial Committee of *Physical Geography of China* of the Chinese Academy of Sciences, 1982. *Physical Geography of China: Pedological Geography*. Beijing: Science Press. (in Chinese)
- Fu Bojie, 2001. Scheme of ecological regionalization in China. *Acta Ecologica Sinica*, 21(1): 1-6. (in Chinese)
- Hou Xueyu, 1963. Opinions on development orientation of agriculture, forestry, livestock farming, sideline and fishery of each natural region of China. *Scientia*, (9): 8-26. (in Chinese)
- Hou Xueyu, 1988. *Natural Ecological Regionalization and Agricultural Development of China*. Beijing: Science Press. (in Chinese)
- Hou Xueyu, 2001. *Vegetation Map of China (1:1,000,000)*. Beijing: Science Press. (in Chinese)
- Huang Bingwei, 1959. Draft of the complex physical geographical division of China. *Scientia*, (18): 594-602. (in Chinese)
- Huang Bingwei, 1962. Some points of view on comprehensive natural regionalization. In: *Collections of China's Academic Conference of Geography 1960*. Beijing: Science Press, 5-14. (in Chinese)
- Huang Bingwei, 1989. Map of China's comprehensive natural regionalization. In: *Atlas of Natural Conservation of China*. Beijing: Science Press, 20-21; 155-157. (in Chinese)
- Huang Bingwei, 1989. Outline of China's Comprehensive Natural Regionalization, Geographic Collection. Beijing: Science Press, 10-20. (in Chinese)
- Huang Bingwei, 1993. Climatic division and physical-geography division of China: retrospect and prospects. In: *Sixty Years of Study on Integrated Physical Geography*. Beijing: Science Press, 130-142. (in Chinese)
- Schultz J, 1995. *The Ecozones of the World*. Springer
- Li Bingyuan, 1994. *Geomorphologic Map of China (1:4,000,000)*. Beijing: Science Press. (in Chinese)
- Ren Mei'e, Yang Renzhang, 1961. Some issues on China's natural regionalization. *Acta Geographica Sinica*, 27: 66-74. (in Chinese)
- Ren Mei'e, 1982. *Outline of China's Physical Geography*. Beijing: The Commercial Press. (in Chinese)
- Ren Mei'e, Bao Haosheng, 1992. *China's Natural Regionalization and Management*. Beijing: Science Press. (in Chinese)
- Robert G Bailey, 1983. Delineation of ecosystem regions. *Environmental Management*, 7(4): 365-373.
- Robert G Bailey, 1985. Ecological regionalization in Canada and the United States. *Geoforum*, 16(3): 265-175.
- Robert G Bailey, 1989. Explanatory supplement to ecoregions maps of the continents. *Environmental Conservation*, 16(4): 307-309.
- Robert G Bailey, 1989. *Map of Ecoregion of the Continents*, USDA Forest Service, Washington, 1995. *Map of Ecoregion of the Continents, Supplement to Environmental Conservation*, 16(4).
- Robert G Bailey, 1995. *Description of the Ecoregions of the United States*, USDA Miscellaneous Publication 1391.
- Robert G Bailey, 1995. *Ecosystem Geography*. Springer.
- Robert G Bailey, 1998. *Ecoregions: The Ecosystem Geography of the Oceans and Continents*. Springer.
- Wu Shaohong, Zheng Du, 2000. New recognition on boundary between tropical/subtropical in the middle section for eco-geographic system. *Acta Geographica Sinica*, 55(6): 689-697. (in Chinese)
- Wu Shaohong, Zheng Du, 2001. Delineation of boundary between tropical/subtropical in the middle section for eco-geographic system of South China. *Journal of Geographical Sciences*, 11(1): 80-86.
- Yang Qinye, Zheng Du, Wu Shaohong, 2002. Eco-geographic region study in China. *Natural Science Progress*, 12(3): 287-291. (in Chinese)
- Zhao Songqiao, Huang Rongjin, Sun Huinan *et al.*, 1988. *Modern Physical Geography*. Beijing: Science Press. (in Chinese)
- Zheng Du, 1999. A Study on the Eco-geographic Regional System of China, *FAO FRA2000 Global Ecological Zoning Workshop*, Cambridge, UK, July, 28-30, 12.