地理学报(英文版) 2003年第13卷第2期

Eco-environment range in the source regions of the Yangtze and Yellow rivers

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Based on geographical and hydrological extents delimited, four principles are identified, as the bases for delineating the ranges of the source regions of the Yangtze and Yellow rivers in the paper. According to the comprehensive analysis of topographical characteristics, climate conditions, vegetation distribution and hydrological features, the source region ranges for eco-environmental study are defined. The eastern boundary point is Dari hydrological station in the upper reach of the Yellow River. The watershed above Dari hydrological station is the source region of the Yellow River which drains an area of 4.49×104 km2. Natural environment is characterized by the major topographical types of plateau lakes and marshland, gentle landforms, alpine cold semi-arid climate, and steppe and meadow vegetation in the source region of the Yellow River. The eastern boundary point is the convergent site of the Nieqiaqu and the Tongtian River in the upstream of the Yangtze River. The watershed above the convergent site is the source region of the Yangtze River, with a watershed area of 12.24×104 km2. Hills and alpine plain topography, gentle terrain, alpine cold arid and semi-arid climate, and alpine cold grassland and meadow are natural conditions in the source region of the Yangtze River.

Eco-environment range in the source regions of the Yangtze and Yellow rivers DING Yongjian, YANG Jianping, LIU Shiyin, CHEN Rensheng, WANG Genxu, SHEN Yongping, WANG Jian, XIE Changwei, ZHANG Shiqing (Cold and Arid Regions Environmental and Engineering Research Institute, CAS, Lanzhou 730000, China) The Tibetan Plateau, as the origin of the Yangtze and Yellow rivers, is the region of climate variation and is very sensitive to climate change in China (Feng et al., 1998). The runoff in the upper reaches of the Yellow River has been decreasing at a rate of 9.8 m3/s per decade due to rapid climate warming in the Tibetan Plateau since the mid- and late 1980s (Zhang et al., 2000). Eco-environmental change is also extremely substantial in the source regions of the Yangtze and Yellow rivers. These variations are glacial retreat, permafrost degradation, wetland desiccation, and lake shrinkage. The change of the environmental elements results in expansive land desertification, soil and water loss, and noticeable grassland degeneration. Human activities have more and more effects on the waterhead regions of the Yangtze and Yellow rivers with construction of the Qinghai-Tibet Highway and starting of the west route water diversion from south to north in the future. So the problem of eco-environmental protection in the source regions of the Yangtze and Yellow rivers, located in the hinterland of the Tibetan Plateau, has attracted attention of the whole society. However, at present, when the eco-environmental elements in the source regions of the Yangtze and Yellow rivers were determined, there is a great deal of confusion in recognition because of lack of scientific and unified ranges of the source regions and there exist the problems of overstatement or understatement of the changing extent of the elements. The upper reaches and the source regions of the Yangtze and Yellow rivers are even mentioned in the same breath in some papers. In view of the above-mentioned confusion phenomenon, it is essential to define scientifically the boundary of the source regions of the Yangtze and Yellow rivers. But we have to emphasize that delimitation of the sources regions of the Yangtze and Yellow rivers means scientific and rational determination of the locations of the Yangtze and Yellow rivers running through the eastern boundaries of the source regions, not determination of all the boundaries of the source regions. Other boundaries are still watersheds around mountains. From the 1950s to the early 1980s, geographical and hydrological ranges of the source regions of the Yangtze and Yellow rivers are defined after several large scale comprehensive investigations (Institute of Geography, CAS, 1990). At that time the major means of the study are data and field investigations. F

urthermore, the majority of the study is on the source region of the Yellow River due to its inferior natural environment (Huang, 1955; Tian, 1981). From the late 1980s to the end of the 1990s, some progress was made in the research of the source regions of the Yangtze and Yellow rivers. Accumulation of data, especially, accumulation of meteorological data perfects analysis of climate change in the source regions of the Yangtze and Yellow rivers. But study at this stage concentrates mainly on geographic and hydrologic aspects due to short of materials and backward research means (Wang et al., 1998; Shao et al., 1998; Hou, 1998). Since the end of the 1990s, the application of the new research techniques, such as RS and GIS, provides technological support for comprehensive eco-environmental study in the source regions of the Yangtze and Yellow rivers. So all-round and thorough study is developed (Li et al., 1998; Li et al., 1998a; Sha et al., 2001; Wang et al., 2001). Under the situations of new researches, there again exists the phenomenon that the upstream and the source regions are confused and the ranges of the source regions of the Yangtze and Yellow rivers expand toward the downstreams. So the ranges of the source regions in eco-environmental study are delimited completely by synthesizing various factors on the basis of previous studies and our forty-day field investigations in 2001. 1 General situation of study Now understanding for the ranges of the source regions has mainly two kinds of typical opinions on eco-environmental study in the source regions of the Yangtze and Yellow rivers. One thinks that the source areas made up of hydrological networks of mainstreams in the upstreams of the Yangtze and Yellow rivers are the ranges of the source regions of the Yangtze and Yellow rivers based on geological tectonics and topographical features (Jing et al., 1982; Sun et al., 1995). The opinion still believes that whether it is eco-environmental study or geographical and hydrological study, geographical range of the source area must be strictly promised. In this opinion the valley up(above) Duoshixia situated on the upper reach of the Yellow River is known as the source area of the Yellow River, covering 2.2× 104 km2, and the valley up the convergent site of Chumaer and Tongtian rivers is known as the source area of the Yangtze River, covering 10.2×104 km2. The other opinion considers that the watershed up Tangneihe hydrological station is the source zone of the Yellow River and the watershed up Zhimenda hydrological station is the source zone of the Yangtze River based on macroscopic natural regionalization (Liu, 1995). However it is convenient to protect and manage the upstream watershed of the Yellow River. Usually, the drainage area up Longyangxia is regarded as the source zone of the Yellow River (Figure 1). In practice knowledge of the second opinion already goes beyond the concept of source region and belongs to entirely the category of upstream. The classification of the second opinion appears largely in these papers on eco-environment in the source regions of the Yangtze and Yellow rivers, especially in the papers on eco-environment in the source region of the Yellow River. The main cause is that the problems of grassland recession, land desertification, and soil and water loss are extremely severe in the ranges. 2 The ranges of the source regions of the Yangtze and Yellow rivers We think when the ranges of the source regions of the Yangtze and Yellow rivers are determined, the following basic principles have to be abided by. The first is the completion of administrative and topographical units. The principle stresses that delimitation of the range should be convenient to eco-environmental study and that topographical and administrative units are kept relatively complete as much as possible. The second is the similarity of the major eco-environmental elements in the source regions of the Yangtze and Yellow rivers. The third is the containment of the source region for eco-environmental system, including the environmental containment of mainstream for tributaries and the integration of environmental elements—vegetation, soil, climate and so on. The fourth is the identity of geographical and hydrological source regions. That means when we decide on the boundaries of the source regions of the Yangtze and Yellow rivers, geographical, hydrological, and other factors have to be taken into account comprehensively. So the boundaries determined are only scientific, rational, and integrated eco-environment boundaries of the source regions in the Yangtze and Yellow rivers. The main bases for delineating the ranges of the source regions of the Yangtze and Yellow rivers in eco-environmental study are, first of all, temperature and moisture conditions related closely with growth and distribution of plants, then vegetation variety and hydrological regime of rivers reflecting water and heat combination, and terrain structure associated inseparably with the elements. 3 Delimitation of the source regions of the Yangtze and Yellow rivers 3.1 Completion of topographical unit Firstly topographical characteristics in the source region of the Yellow River are analyzed. Topography is alpine plain controlled by geological tectonics in the watershed of the Yellow River up Dari County of Qinghai Province, with high terrain, relatively integrated plateau surface, mean 1.38-2.3‰ gradient of river bed (Wang et al., 1998). There distribute low mountains, wide valleys and marshland in the alpine plain. The valley up Duoshixia is the source region of the Yellow River in geographical concept, belonging to plateau lake and marshland topography. Whereas down (below) Duoshixia, the region with similar topographical features with the valley up Duoshixia can extend to Tehetu of Dari County, with gentle terrain along the mainstream (Figure 2). The area between Tehetu and Dari is the transitional belt from plateau lakes and marshland topography up Tehetu to high mountains and canyo

n topography down Dari. Down Dari, when the watershed lies between Bayankala and Animaqing Mountains, river valley narrows and the Yellow River begins to wind in the canyons of the Tibetan Plateau. Figure 3a shows mean gradient variations of watersheds up each control spots in the mainstream of the upper reach of the Yellow River. Mean gradient of watershed is lower than 2.2o in the source region of the Yellow River up Duoshixia. While, down Duoshixia, mean gradient of watershed controlled by Dari hydrological station increases abruptly, which indicates that Dari zone is the turning point of the topographical change in the upstream watershed of the Yellow River. Terrain above Dari is gentle and is controlled by the main body of the Plateau surface. Topography below Dari is gorges in the Tibetan Plateau. Elevation descends gradually and terrain changes toward the edge of the Tibetan Plateau. So we think the region up Dari hydrological station has unified topographic unit. The source region of the Yangtze River is a huge plateau basin and valley made up of Kunlun Mountains, Tanggula Mountains, Bayankala Mountains, and Wulanduola Mountains (Shen et al., 1998). Topography of watershed up the convergent site of Chumaer and Tongtianhe rivers is alpine plain and hills, with mean riverbed gradient being 5.7-1.03‰ (Wang et al., 1998). Terrain along both sides of the mainstream is gentle and expansive. Topography down the convergent site of Nieqia and Tongtianhe rivers is high mountains and canyons. The area from the convergent site of Chumaer and Tongtian rivers to the convergent site of Nieqia and Tongtian rivers is the transitional belt of two types of topography (Figure 2). Mean gradient sketch of watersheds up each control spot in the mainstream of the upper reaches of the Yangtze River shows that mean slope of watershed up the convergent site of Nieqia and Tongtian rivers is lower than 2.6o, with a gentle terrain. While, down the convergent site of Nieqia and Tongtian rivers, the mean watershed slope increases gradually and the valley enters into high mountains and gorges region (Figure 3b). 3.2 Similarity of major eco-environmental elements Mean summer air temperature forms closed isotherms in the source region of the Yellow River. The center of the closed isotherms is approximately located on the main peak of Bayankala Mountains, with a central temperature of 5oC. Temperature increases outside the center (Figure 4a). Air temperature in summer affected by longitude and latitude zonation rises from northwest to southeast in the upper reach of the Yellow River. As a dividing line, the area on the northwest of 12oC isotherm is the cold alpine source region and the one on the southeast of 12oC isotherm is the cool temperate southeast region in the upper reach of the Yellow River. As far as variations of mean annual relative humidity are concerned, it is the highest nearby the main peak of Bayankala Mountains, with a relative humidity of 56-58%. It decreases outside. It rises again to the east of Dari hydrological station, with a relative humidity of 54-60%. A turning point of relative humidity change is formed between Tehetu and Dari. Influenced by latitude zonation, the mean summer air temperature increases from north toward south and the mean annual relative humidity decreases from north toward south in the source region of the Yangtze River. Annual precipitation varies between 450 mm and 200 mm. By combining the above-mentioned analysis with natural zonation and climatic regionalization in the Tibetan Plateau (Zheng et al., 1979; Lin et al., 1981), the watershed of the Yellow River is classified significantly into semi-humid and semi-arid areas. Annual precipitation changes between 500 mm and 250 mm in the semi-arid area on the west of Dari hydrological station and increases from 500 mm to about 800 mm in the semi-humid area in the east of Dari hydrological station (Figure 4b). So unified climatic conditions, namely, cold alpine semi-arid climate, are formed in the source region of the Yellow River. The source region of the Yangtze River belongs to Naqu-Guoluo semi-humid region and Qiangtang arid and semi-arid region because of wide range. Among them, south Qiangtang cold alpine semi-arid climate is the main climatic type in the source region of the Yangtze River. The boundary of south Qiangtang cold alpine semi-arid climatic region and semi-humid region in eastern Tibet lies in the vicinity of Zhiduo and Qumalai counties (Lin et al., 1981). Controlled by water and heat, vegetation distribution also presents noticeable horizontal difference phenomenon (Figure 5). Vegetation transforms from shrubs and alpine meadow into steppe in the source region of the Yellow River to the west of Dari County. Conversely, vegetation is shrubs and meadow to the east of Dari County. The main vegetation types are cold alpine steppe in the source region of the Yangtze River. There distribute cold alpine cushion vegetation in the waterhead area and cold alpine meadow to the south of Tongtian river- Dangqu-Buqu-Gaerqu line. Vegetation transits gradually into cold alpine shrubs in the upper reach of the Yangtze River to the south of Zhiduo County. 3.3 Identity of geographical and hydrological source regions In geographical concept the mainstream of the Yellow River starts to form from Huangheyan up Duoshixia, with an annual discharge of 6.02×10^8 m3. But the first tributary with annual discharge going beyond 6.0×10^8 m3 still has three tributaries between Duoshixia and Dari, namely, Dari river, with an annual runoff of 7.96×10^8 m3; Requ, 6.6×10^8 m3; and Kequ, 6.1×10^8 m3. The total runoff of the three tributaries is 20.66×10^8 m3, accounting for over 63% of the mean annual discharge at Dari hydrological station, with an annual discharge of 32.55×10^8 m3 after deducting 6.02×10^8 m3 of water coming from the waterhead (Table 1). In addition, the length of the mainstream of the Yellow River is only 140 km between Duoshixia and Dari hydrological station. While the length of the mainstrea

m up Huangheyan is 270 km. The density of the first tributary is 6 rivers per 100 km2 between Duoshixia and Dari, an d 2.2 rivers per 100 km2 in the area up Duoshixia. Obviously, the density of the first tributary between Duoshixia an d Dari is larger than that of the area up Duoshixia. So the three tributaries between Duoshixia and Dari have simila r hydrological regime with the valley up Huangheyan. The fact that the source region of the Yellow River is regarded as hydrological system made up of four first tributaries is even more reasonable. Because the valley up Huangheyan ha s no containment for the watershed between Duoshixia and Dari possessing the same topographical unit and hydrologica l environment as the valley up Huangheyan, the watershed up Dari hydrological station plays a notable controlling rol e for discharge in the source region of the Yellow River. After Chumaer river converges into Tongtian river, watershe d area up the convergent site is 10.27×104 km2, with an annual discharge of 68.03×108 m3 and a mean multi-annual di scharge of 215.73 m3/s (Planning Committee of Qinghai Province, 1991). The watershed has environmental containment fo r any tributary in the source region of the Yangtze River. Moreover, analysis of water system features in watershed a lso shows the boundary of water system is clear. Six control spots, i.e., Huangheyan hydrological station, outlet of Duoshixia, Dari hydrological station, inlet of Maiduotanggongmaxia, Jiuzhi, and Maqu, are chosen successively in the upper reach of the Yellow River. Densities of water system of watersheds controlled by each control spot are compute d, respectively (Figure 6a). Dari hydrological station is the turning point of changes of density of the water syste m in the upstream watershed of the Yellow River. To the west of Dari, density of water system of the watershed is low er than 0.28 km/km2, while to the east of Dari, the density controlled by the control spots increases gradually. Up t o Maqu, it ascends to 0.36 km/km2. Similarly, six control spots—the convergent site of Dangqu and Tongtian rivers, t he convergent site of Chumaer and Tongtian rivers, the convergent site of Nieqiaqu and Tongtian rivers, the convergen t site of Dengequ and Tongtian rivers, Yushu, and Zhimenda, are selected in proper order in the upper reach of the Ya ngtze River. Densities of water system of watersheds controlled by each control spot are calculated, respectively (Fi gure 6b). Densities of water system of valleys controlled by the control spots increase gradually down from the conve rgent site of Dangqu and Tongtian rivers. To the convergent site of Nieqiaqu and Tongtian rivers, it is 0.24 km/km2, while below the convergent site of Nieqiaqu and Tongtian rivers, the density of the water system of the valley contro lled by the convergent site of Dengequ and Tongtian rivers reduces to 0.23 km/km2. Densities of water system of valle ys controlled by control spots enhance once again between the convergent site of Dengequ and Tongtian rivers and Zhim enda hydrological station. The variation of density of water system in the upstream of the Yangtze River indicates th at the convergent site of Nieqiaqu and Tongtian rivers is the turning point of density of water system change in the valley up Zhimenda. The communality of the density of water system change of watershed and the mean slope change of w atershed shows that the effect of topography on hydrological situations of watershed is extremely remarkable. Convers ely, the variation of density of water system and mean slope of watershed also reflects topographical change. 4 Discu ssion Tangneihe hydrological station is the eastern boundary of the source region of the Yellow River in hydrologica l concept. The classification is advantageous for both study on water system and hydrological regime and eco-environm ental study, such as, soil and water loss, in the upper reach of the Yellow River. But topography and terrain, climat ic conditions, and vegetation distribution vary greatly in the watershed up Tangneihe hydrological station, which is discordant with the four principles identified in the paper. So Tangneihe hydrological station cannot be regarded as the eastern boundary of the source region of the Yellow River in eco-environmental study. There are unified topograph ical unit, the same cold alpine semi-arid climate conditions, and unified grassland vegetation in the valley up Dari hydrological station. Furthermore, Dari hydrological station is taken again the turning point of variations of densit y of water system and mean slope in the upstream watershed of the Yellow River, controlling hydrological regime of th e valley up the station. By synthetic analysis we think that Dari hydrological station, designated as the division si te in eastern boundary of the source region of the Yellow River, is more appropriate and more scientific. The water c atchment up Zhimendai hydrological station is the source region of the Yangtze River in hydrological concept. Zhimend ai hydrological station is the boundary of the Yangtze River flowing out of Qinghai Province and controls discharge i n the watershed up the station, hence it is of great significance to the hydrological research in Qinghai Province. T here distribute alpine plain, high mountains, and gorge topography, Qiangtang cold alpine arid and semi-arid climate and Naquguoluo cold alpine semi-humid climate, and cold alpine steppe, cold alpine meadow, and cold alpine shrub vege tation from northwest toward southeast in the watershed of the Yangtze River up Zhimendai hydrological station. Accor ding to the above-mentioned four principles, no identical eco-environment can be formed in the source region. On the contrary there are basically unified topography, climate and vegetation in the watershed up the convergent site of Ni eqiaqu and Tongtian rivers. Furthermore, it is also the turning point of changes in water system density at the angl e of water system features of the watershed, and has also containment capacity for tributaries in the source region o

f the Yangtze River with water discharge variations. So it is rational that the convergent site of Nieqiaqu and Tongt ian rivers is regarded as the site in the eastern boundary of the source region of the Yangtze River. Table 2 is the general situation of the natural environment in the source regions of the Yangtze and Yellow rivers. Based on the bas ic principles of eco-environmental study range made above, the area up Dari hydrological station is the source regio n of eco-environmental study in the watershed of the Yellow River. The region is situated approximately between 33o00 ´-35o35´N and 96o00´-99o40´E, including Maduo, Dari, and Maqin counties and the part of Gande County in Guoluo Prefec ture of Qinghai Province, with a watershed area of 4.49×104 km2. The area up the convergent site of Nieqiaqu and Ton gtian rivers is the source region in the watershed of the Yangtze River, located between 32o30´-35o44´N and 90o30´-96 o00´E, including Qumailai and Zhiduo counties as well as Tanggula village belonging to Glomud city, and with a waters hed area of 12.24×104 km2.

关键词： the source regions of the Yangtze and Yellow rivers; eco-environmental range