Water-carbon-ecological Footprint Change Characteristics and Its Balance Analysis in the Nine Provinces of the Yellow River in China

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Introduction

The Yellow River Basin (YRB) holds a crucial position in China's economic and social development as well as ecological security (Figure 1). The Chinese government has carried out long-term and large-scale comprehensive control of ecological problems such as soil erosion, environmental pollution and natural disasters in the YRB. However, with the rapid development of industrialization and urbanization, the levels of production, living, and consumption have significantly increased, revealing the gradual rise of ecological resource overload issues, seriously hindering the green and sustainable development of the YRB economic belt.

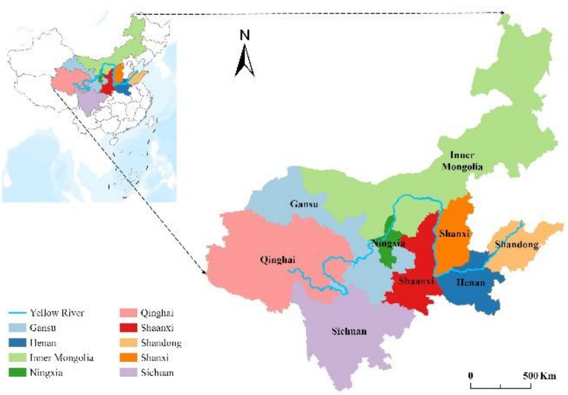

Fig.1 Schematic diagram of the nine provinces of the Yellow River.

Recognizing the balance of ecological footprints is of great significance for ecological compensation between urban agglomerations and the sustainable development of the YRB. The Ecological Footprint method, as a globally accepted priority tool for assessing sustainable development, can effectively evaluate the coordination between resource consumption intensity and ecological carrying capacity. The water-carbon-ecological footprint can trace greenhouse gas emissions and the consumption and pollution of freshwater resources generated by human activities from the three key ecosystems of the hydrosphere, atmosphere, and biosphere.

Methodology

Ecological footprint (EF_e) represents the biologically productive land area needed to meet the resource consumption of a given population or a specific activity, including six categories: cultivated land, grassland, forest land, water area, construction land and unused land. The biological productive area that this area can provide is called ecological carrying capacity (EC_e).

$$EF_e = N \times ef_e = N \times \sum_{i=1}^{n} (r_j \times a_i) = N \times \sum_{i=1}^{n} r_j \left(\frac{c_i}{p_i}\right)$$

$$EC_e = N \times ec_e = N \times \sum_{i=1}^{6} A_j \times r_j \times y_j (j = 1,\ 2,\ \dots 6)$$

Carbon footprint refers to the area of biologically productive land required to absorb the carbon dioxide emitted by the area. EF_g is the per capita carbon footprint (hm^2 / *person*) generated by total net carbon emissions (*NCE*). EC_g is the per capita carbon carrying capacity (hm^2/*person*).

$$EF_g = \frac{NCE}{N}\left(\frac{P_f}{NEP_f} + \frac{P_g}{NEP_g} + \frac{P_a}{NEP_a}\right)$$

$$EC_g = \frac{CA}{N}\left(\frac{P_f}{NEP_f} + \frac{P_g}{NEP_g} + \frac{P_a}{NEP_a}\right)$$

Water resources ecological footprint (EF_w) refers to the area of water resources required by human life, production, and the natural environment. It consists of direct water footprint (embodied water) and indirect water footprint (virtual water), where the indirect water footprint is equal to the product of the consumption quantity of a certain commodity and its virtual water content per unit product. EC_w is the total carrying capacity of water resources.

$$EF_w = N \times ef_w = N \times R_w \times \frac{W}{P_w}$$

$$EC_w = N \times ec_w = (1-\alpha) \times \beta \times R_w \times \frac{Q}{P_w}$$

Zhao et al. (2016) based on the footprint family theory, constructed the concept of the Water Pressure Index (*WPI*), Greenhouse Gas Emission Index (*GEI*) and Ecological Pressure Index (*EPI*). These take into account, respectively, human pressure on water supply and demand, greenhouse gas emission pressure, and supply and demand for ecosystem biological products. These three indicators are combined to form the Resource and Environmental Stress Index (*REPI*).

$$EPI = EF/EC$$

$$GEI = CF/CC$$

$$WPI = WF/WC$$

$$REPI = W_w \times EPI + W_w \times GEI + W_w \times WPI$$

Tab. 1. Grade of resource environment pressure index.

Grade	State	Sub-grade	REPI	Stade
I	Low pressure	I_a	< 0.20	Very low
		I_b	0.20 - 0.35	Low
II	Middle pressure	II_a	0.36 – 0.50	Below average
		II_b	0.51 – 0.65	Above average
III	High pressure	III_a	0.65 – 0.80	High
		III_b	0.80	Very high

In this study, the water-carbon-ecological footprint of provinces and municipalities in the YRB was studied by using the footprint family model. Using the improved 3D ecological footprint model, the size and depth of the footprint were constructed, and the spatio-temporal variation trend was analyzed. At the same time, the resource and environmental pressure evaluation system is also constructed to evaluate the spatiotemporal changes.

Figure 2 shows the average water-carbon-ecological footprint of provinces and municipalities. Other results and discussions will be detailed at the annual meeting of DPRI.

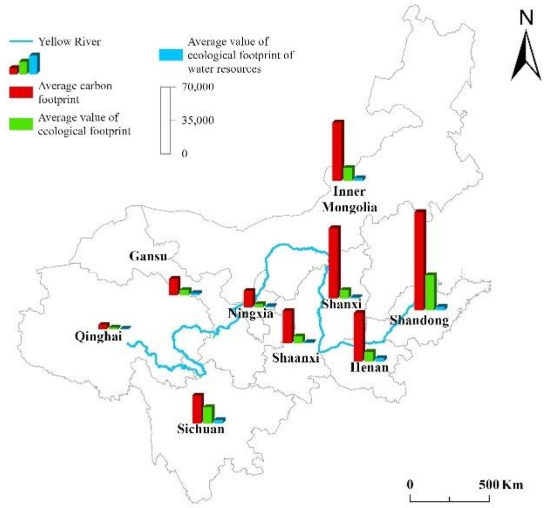

Fig. 2 Average water-carbon-ecological footprint of provinces and municipalities.

Reference

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(Note: The specific explanation of the formula will be given at the time of presentation.)