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Urban Gray Water Footprint Analysis Based on Input-Output Approach

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Abstract

The Gray Water Footprint (GWF), defined as the volume of fresh water required to assimilate the load of pollutants discharged into water based on natural background concentration, starts to be used as a water research management indicator which reflects the impact of pollution into water requirements in recent researches. GWF is used to measure the direct and indirect dilution water requirements in different socio-economic sectors, which is internalized the degree of water pollution. In this study, we calculate the GWF of Beijing Municipality in 2007 based on input-output approach. The results show that the total domestic GWF is 563.99×10^7 m^3, which much bigger than the Blue Water Footprint (BWF). The quantity of GWF is also larger than gross river flow, it implies that assimilation capacity of the river is insufficient to take up the discharge and will result water quality degradation. The sector with the largest GWF is other services. Although the COD concentration of other services is not the largest ($281 g/m^3$), the huge output cause a large GWF. This study shows that the GWF methodology could be used on how to better estimate the values of the regional water resource supply.

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Keywords: Gray Water Footprint; Input-Output Approach; Assimilation Capacity

1. Introduction

Freshwater pollution (not saline), is one of the main issues to be settled by water resources management [1]. Even though, there is a wide range of measurements and pollutants considered for the water pollution evaluation, there are lack of homogenous indicators which are used for the comparison of

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the pollution impacts across different geographical areas [2]. The concept of GWF, defined as the volume of fresh water required to assimilate the load of pollutants discharged into water based on natural background concentration [3], is an indicator reflects the impact of pollution into water requirements.

The advantage of GWF is that it can measure the degree of water pollution caused by socio-economic sectors within a uniform unit: fresh water consumption. However, the existing methods for calculating the GWF of each economic sector only account for the fresh water consumption caused by the direct wastewater discharge, seldom consider the waste water discharge indirectly induced by other sectors [4]. For example, if sector B requires intermediate products from sector A, the effluent discharged by sector A to produce these intermediate products should represent sector B's indirect required fresh water consumption [5]. In this study, we propose a framework that can quantity both direct and indirect fresh water consumption of each economic sector based on input-output approach.

2. Methodology

Taking Beijing Municipality as a case study. The I/O based GWF calculation equation can be presented as follows [6]:

$$G = R \times B \times M = \left[r_{ij} \right] \times \left[l_{ij} \right] \times \lambda \times diag\left(M \right) \tag{1}$$

$$\lambda = \frac{x_j}{x_j + IM_j} \tag{2}$$

$$B = \left[b_{ij} \right] = \left[1 - \lambda \times A \right] \tag{3}$$

$$\left[r_{ij} \right] = \frac{g_i}{t_i} \tag{4}$$

where G (m^3) is the gray water matrix ($n \times n$), n is the number of socio-economic sectors included in the analysis. R is a diagonal matrix that contains the dilution water requirement coefficients in the analysis. B is the Leontief inverse matrix which eliminate the influence of import products. M is a diagonal matrix that represents the final consumption. λ is the proportion of locally produced, x_j represents the locally produced by sector j, IM_j means the import products of sector j from other regions. A means the amount of input from sector i needed to increase one monetary unit output in sector j. g_i (m^3) is the dilution water requirement which means the volume of fresh water consumed to dilute the wastewater discharged into a water body by sector i, and t_i is the gross output (RMB) of sector i.

In this study, Chemical Oxygen Demand (COD) was used as critical indicator to reflect the GWF. To identify water dilution requirements g_i, the standard formulation of the GWF was adapted:

$$g_i = \frac{L}{C_{\max} - C_{nat}} = \frac{qc_s}{C_{\max} - C_{nat}} \tag{5}$$

where L is the pollutant load (mass), q is the wastewater discharge (mass), c_s is the concentration of COD discharged by each sector, c_{max} is the maximum acceptable concentration of the substance (mg/L), c_{nat} is the natural concentration that would occur if there were no human influence (mg/L).

In addition, conventional studies often only consider blue water consumption but ignore the GWF. In order to compare the difference between the two methods, the paper also calculated the conventional water footprint (Blue Water Footprint) matrix of Beijing in 2007.

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