Average Propagation Length Analysis for Water-land Resource in Urban Socio-economic System: A Nexus Perspective

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Abstract

In order to realize the efficiency and stability of economic development and agricultural production, great efforts are needed to coordinate the water conservation and intensive use of land resources. This study investigates the coupling effects between water-land resources among different sectors in urban socio-economic network. In the production chain, the connection length of trade linkages between regions and sectors could be evaluated by average propagation length (APL) index in an input-output framework. The combination of the size of the linkages and the distance between sectors can visualize the production structure and water-land correlation between each sector and region along the production chains. It illustrates that the fragmentation production structure shows a remarkable influence on both water and land resources, leading to heavy environmental stress on water or land scarcity region. The inequality between regions is not only reflected from economic benefit (added-value gains) aspect, but also shown by the utilization of natural resource. Furthermore, the food production chain, including agricultural sector, food processing sector, dairy sector and catering sector, shows remarkable integral water-land nexus strength.

1. Introduction (heading 1: size 12)

The rapid development of urbanization makes the contradiction between the demand and supply of water and land resources increased gradually. Due to the intertwined relationship of water and land resources, great efforts are needed to coordinate the water conservation and intensive use of land resources, in order to realize the efficiency and stability of economic development and agricultural production \cite{1}. To probe into the resource consumption characteristics of each economic sectors in the socio-economic system, input-output analysis (IOA) provides a powerful tool to exhibit the emission flow pathway within the system. IOA is developed by Wassily Leontief in the late 1930s \cite{2} and has been further applied in studies for economic activities' impacts on environment, like influences on carbon emission \cite{3}, air pollution \cite{4}, energy resource \cite{5} and water resource \cite{6}.

In the production chain, the connection length of trade linkages between regions and sectors could be evaluated by average propagation length (APL) index in an input-output framework. The APL index is proposed by Dietzenbacher, Luna \cite{7} to evaluate the economic distance between sectors, which is defined as the average number of steps it takes an exogenous change in one sector to affect the value of production in another sector. For the determination of production chains, all the industries could be placed in an early stage, middle stage and late stage. The APL approach can measure the distance from industries toward final consumers incorporating the strength of trade activities, therefore, judging the economic position (upstream industry chain or downstream industry chain) of each region in the national or global economy.

The APL method has been widely used for the economy trade analysis between various regions. Dietzenbacher and Romero \cite{8} analyze intercountry linkages between industries of Europe and identify the

Nomenclature (Font: Arial, Size: 12)

\textbf{Abbreviation}

\begin{itemize}
  \item APL average propagation length
\end{itemize}

\textbf{Subscript}

\begin{itemize}
  \item i i-th sector
\end{itemize}
important production chain within the trade network by means of APL. De Backer and Miroudot [9] utilized APL to assess the integrations and positions of countries within international production networks. The APL approach has been widely used in the economy system to incorporate both intensity and length of the relations between final consumers and intermediate industries [10, 11]. Incorporating with carbon emission along the whole production chain, the APL approach can provide a clear picture of the resource consumption of each region during the process of production fragmentation and vertical specialization in regional or global trade system.

In this study, Zhangye City in China under severe stress of water scarcity is chosen as typical case. In the production chain, the connection length of trade linkages between regions and sectors could be evaluated by average propagation length (APL) index in an input-output framework. It quantifies the water-land nexus relations between sectors and identifies the key sectors and critical pathways of water-land nexus system.

2. Methodology and data

2.1 Input-output model

Input-output model enables us to calculate water and land resource consumption along supply chains [12]. The mathematical equation of an input-output model is shown in Eq. 1:

\[ x_i = \sum_{j=1}^{n} z_{ij} + y_i \]

Eq. 1

where \( x_i \) is the total output of sector \( i \); \( z_{ij} \) represents the monetary flow from sector \( i \) to sector \( j \); \( y_i \) is the final demand of sector \( i \); \( n \) is the number of economic sectors of the target economy.

The technical coefficient \( a_{ij} \) is defined as the ratio of the inter-sectoral flows \( z_{ij} \) over total input of sector \( j \):

\[ a_{ij} = \frac{z_{ij}}{x_j} \]

Eq. 2

Eq. 1 could be transformed into the matrix format:

\[ x = (I - A)^{-1} y \]

Eq. 3

A matrix is set as the technical coefficient; \( x \) is a sectoral output vector; \( y \) is a final demand vector. where \((I-A)^{-1}\) is the Leontief inverse matrix which illustrates the total production needed to fulfill one unit of final demand in the economy.

Let \( k_{\text{Water}} \) and \( k_{\text{Land}} \) refer to coefficient vector of water and land resource consumption intensity for all economic sectors.

Let \( \hat{k}_{\text{Water}} (I-A)^{-1} \) and \( \hat{k}_{\text{Land}} (I-A)^{-1} \) be the initial effect caused by the final goods production from sector \( i \) to sector \( j \) directly and indirectly, and \( \hat{d} \) stands for direct value added coefficient vector.

2.2 Average propagation length

The average propagation length (APL) evaluation is used to evaluate the economic distance and sized of linkages between sectors.

The APLs can be calculated as:

\[ W = \hat{k}_{\text{Water}} (I-A)^{-1} \hat{y} \]

Eq. 4

\[ L = \hat{k}_{\text{Land}} (I-A)^{-1} \hat{y} \]

Eq. 5

in which the notation \(^{\wedge}\) indicates the diagonalization of corresponding column vectors. \( W \) and \( L \) are \( n \times n \) matrix, showing the inter-sectoral flows of water and land resource.

\[ V = \hat{d} (I-A)^{-1} \hat{y} \]

Eq. 2

where \( V_i \) refers to the value added associated with final goods production from sector \( i \) to sector \( j \) directly and indirectly, and \( d \) stands for direct value added coefficient vector.

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3. Results

\[
APL_{ij} = \begin{cases} 
    h_{ij} / p_{ij} & i \neq j \\
    h_{jj} / (p_{jj} - 1) & i = j
\end{cases}
\]

Eq. 3

Figure 1 Water consumption of each sector for the final demand of food processing sector

Figure 2 Land consumption of each sector for the final demand of food processing sector

4. Conclusions

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Reference