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Decoupling agricultural water consumption and environmental impact from crop production based on the water footprint method: A case study for the Heilongjiang land reclamation area, China

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ABSTRACT

Crop production consumes and pollutes large volumes of water. Previous literature predominantly discusses a single indicator of agricultural water consumption or environmental impact from crop production. This study integrates a water footprint method into a decoupling analysis. The water footprint method uses multidimensional indicators to illustrate agricultural water consumed or polluted in crop production according to its elements and sources. Using the largest commodity grain in China during the years 2000–2009 as a case study, this research focuses on the analysis of decoupling agricultural water consumption and environmental impact from crop production based on two indexes, D_{Y-WC} and D_{Y-WEI}. The results show the following: (1) a strong decoupling trend occurred more in the analysis of decoupling agricultural water consumption from crop production; (2) weak decoupling occurred more often in the analysis of decoupling agricultural water environmental impact from crop production.

1. Introduction

The term "decoupling" (or de-linking) originates from the field of physics with the idea of "uncoupling", meaning that the mutual relationship between two or more physical quantities no longer exists. Decoupling refers to breaking the link between "environmental bads" and "economic goods", and decoupling environmental pressure from economic growth is one of the primary objectives of the OECD Environmental Strategy for the First Decade of the 21st Century (OECD, 2002). The decoupling state has been adopted as a policy goal in the European Union, and decoupling human well-being from resource consumption is at the heart of the Green Economy Initiative of UNEP (UNEP, 2011).

Decoupling analysis is becoming increasingly popular for measuring the relationship between resource use (environmental impact) and economic activity (OECD, 2003; Tapio, 2005; Jarmo et al., 2007; Enevoldsen et al., 2007; Lu et al., 2007; Massimiliano and Roberto, 2008; Mazzanti, 2008). A stylized representation of resource decoupling and impact decoupling is shown in Fig. 1 (UNEP, 2011). In studies of agricultural production, the available literature focuses on decoupling cultivated land occupancy from GDP growth, but the topic of crop production is addressed less frequently. For example, He et al. (2005) carried out an agricultural eco-environment assessment according to a decoupling index system on soil erosion, Yu (2008) generated a set of criteria for decoupling crop production from irrigation water, and Xu et al. (2010) analyzed the relationship between fertilizer application and crop production using panel data (1999–2007) of 31 provincial areas in China.

Water is an element of production and the base of the ecosystem; the properties of water resources and the water environment are inseparable. In the field of agricultural production, the dual properties of agricultural water include both water consumption and water environmental impact due to the application of fertilizers and pesticides. Therefore, the analysis of decoupling agricultural water from crop production inevitably involves two factors: agricultural water consumption and water environmental impact. The water footprint (WF) method integrates the dual properties of water and tracks the footprints of agricultural water in terms of the blue water footprint, the green water footprint and the gray water footprint of crop production. However, a decoupling analysis of agricultural water from crop production based on the water footprint has not been reported to date.

2. Study area

The Heilongjiang land reclamation area (HLRA) is located in the world-famous Blacklands of China; it has an area of approximately 57,600 km^2, including 113 farms located on 9 branches (Fig. 2). The

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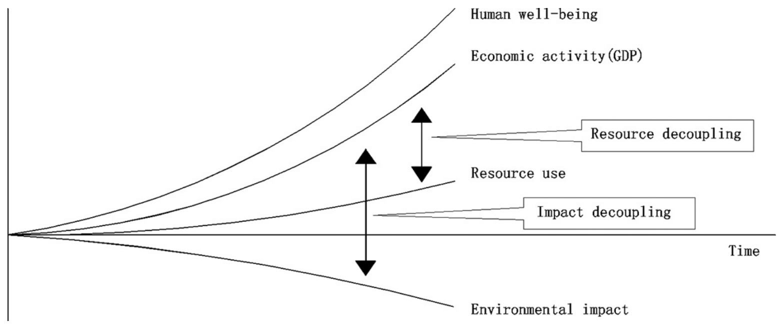

Fig. 1. Stylized representation of two aspects of decoupling (source: UNEP, 2011).

climate ranges from humid to semi-humid, with an average precipitation of approximately 540 mm/year, and the growing season precipitation (May–September) accounts for 80–90% of the yearly rainfall. The study area is divided into two parts: the humid eastern four branches and the semi-humid western five branches. Crops appropriate for the HLRA include rice, corn, soybean and wheat; the yields of these crops accounted for 94% of the sum total in 2011. In the HLRA, the cultivated land area per capita is 15 times greater than the national average, and the crop yield per unit area exceeds that of the USA; thus, this area represents highest production capacity in China.

Economic growth in the HLRA has been very costly, especially in terms of water resources and the water environment. Since 2000, the rice planting areas in the eastern Sanjiang plain have increased in size quickly because of economic factors, while local irrigation systems lag behind and well-irrigated areas for rice makeup 80–90% of the entire rice planting area. As a result, land subsidence occurs widely, and the average groundwater recession in the eastern Sanjiang plain is 2.5 m (Liu et al., 2006). Moreover, the non-point source pollution caused by chemical fertilizers in crop production constitutes over 80% of the total pollution in the HLRA, which has become the largest hidden threat to food and ecological security. Using this largest green grain production base in China as an example, do the high yields come with high energy costs, high material consumption, and high pollutant emission in the HLRA? By focusing on these questions, decoupling analysis of agricultural water from crop production contributes to constructing an "ecological, intelligent and low carbon" agricultural production system.

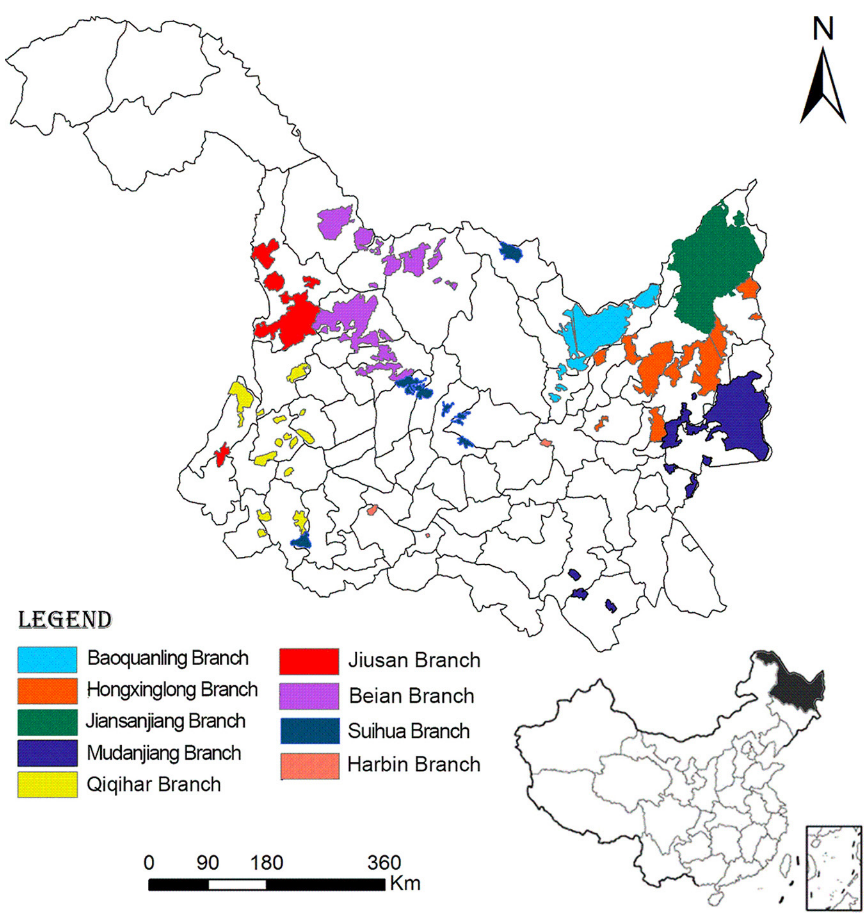

Fig. 2. Location of the Heilongjiang land reclamation area (HLRA) in China.