

1. Background

- Agricultural production is accompanied by a large amount of water consumption, nonpoint source pollution, and greenhouse gas emissions.
- Researchers have conducted many studies on quantification and assessment method of virtual water flow, case studies of the virtual water trade, and impact evaluations of the virtual water trade on water resources.
- However, there is still a lack of the comprehensive and quantitative evaluation of the impact of grain virtual water flow on regional water resources, the economy, and the environment.

2. Research Objectives

- Assesses the temporal evolution of the grain production distribution and annual interregional virtual water flow related to grain transfer among regions (from 1997 to 2014).
- Evaluates the impacts of virtual water flow on the environment by estimating the net carbon emissions and gray water footprint.
- Establishes a framework for evaluating the economic impact of virtual water flow based on scenario analysis regarding industrial structure and water redistribution in different sectors.

3. Materials and Methods

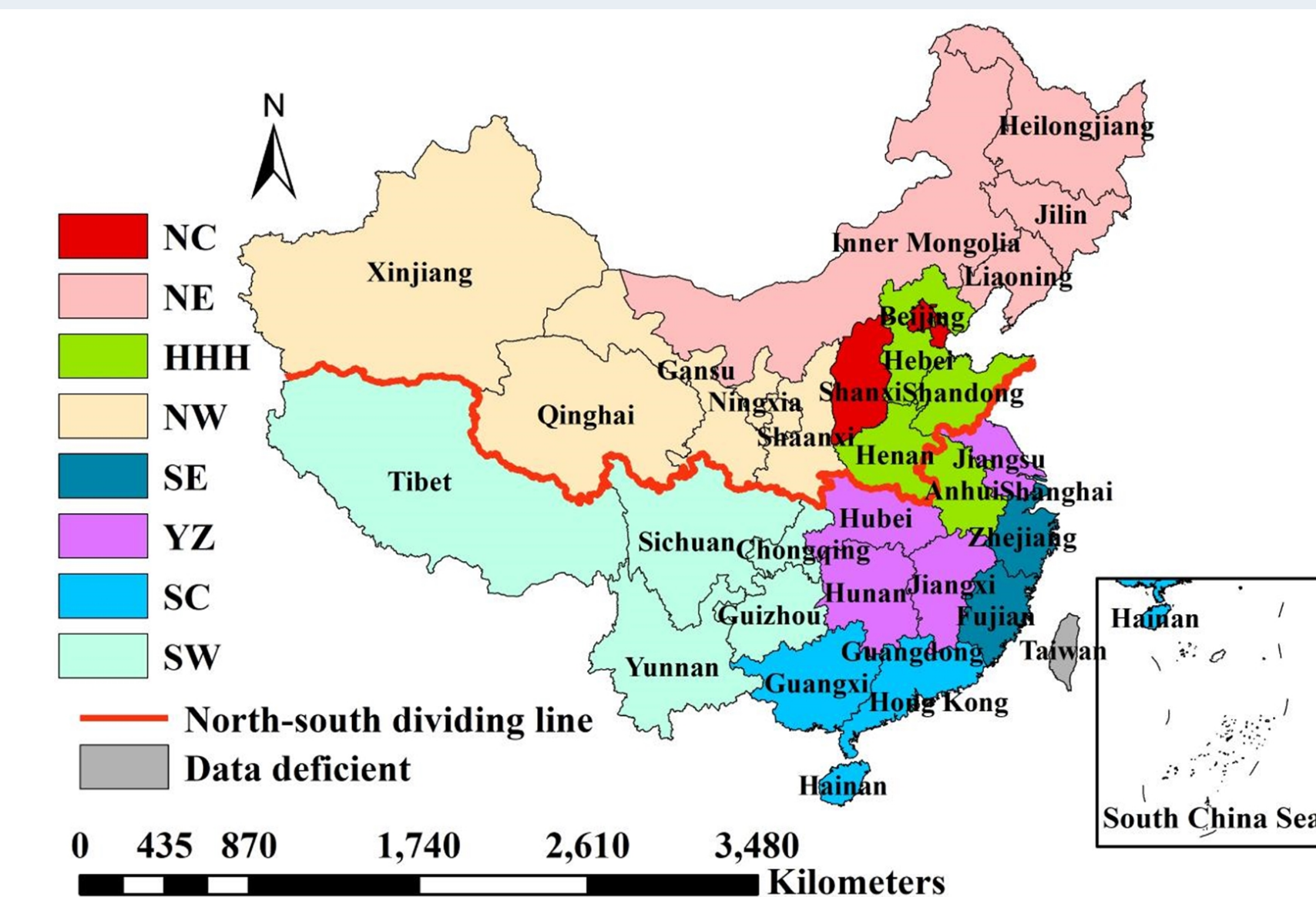


Fig.1 Location of the study area

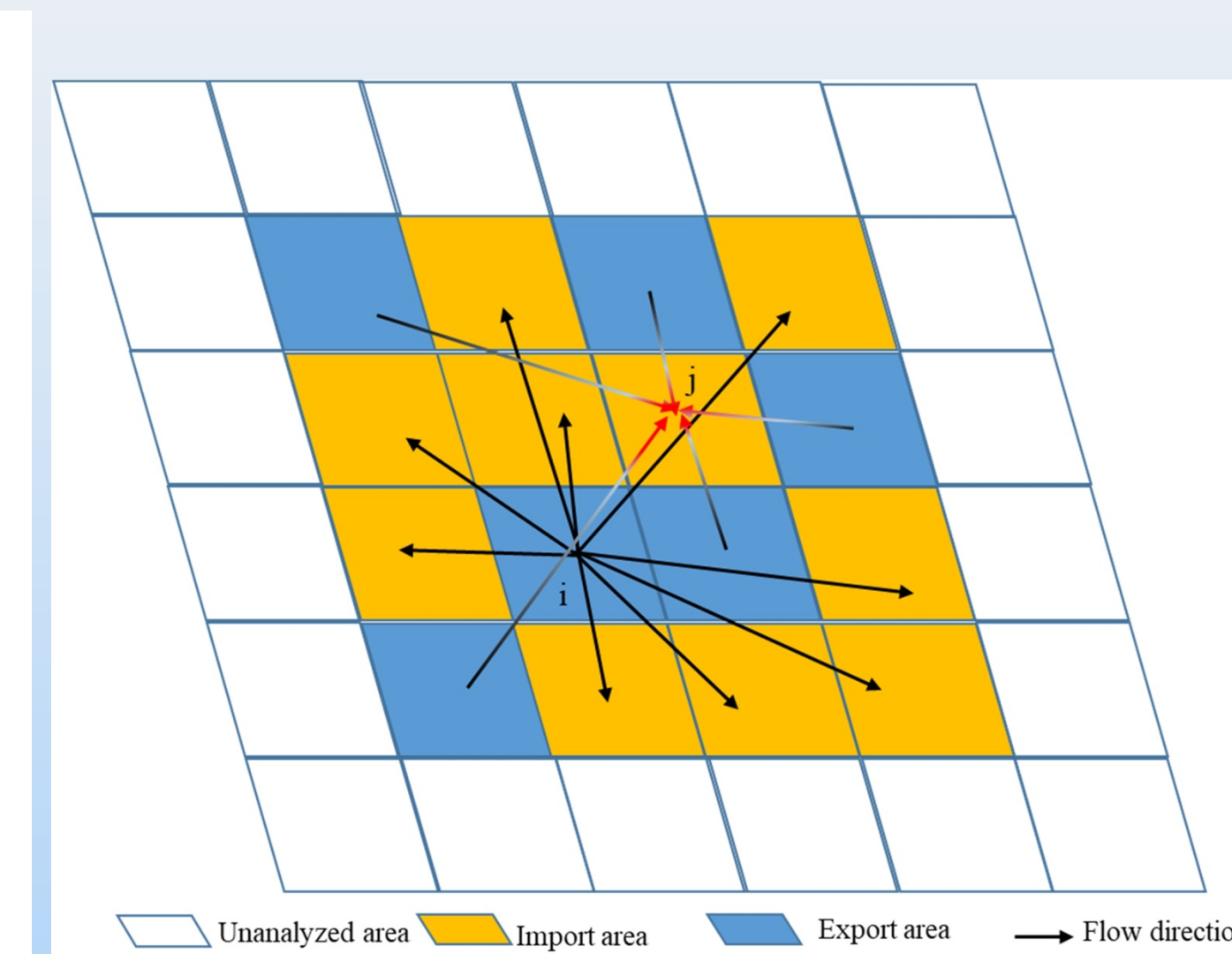


Fig.2 The diagram of the virtual water flow

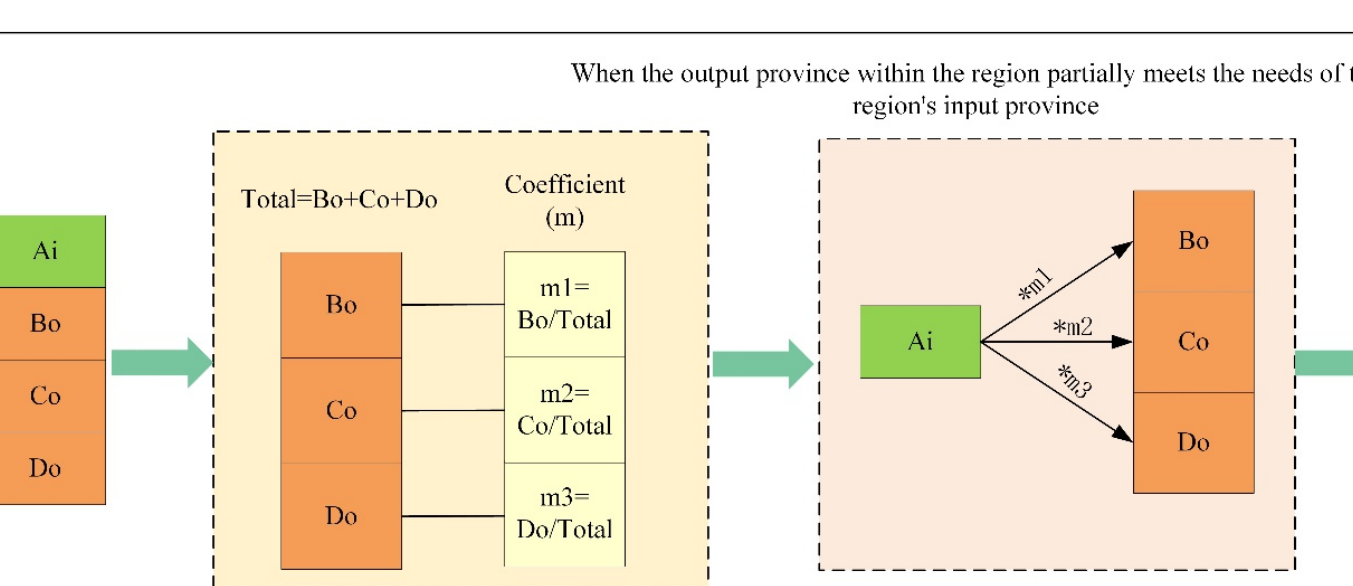
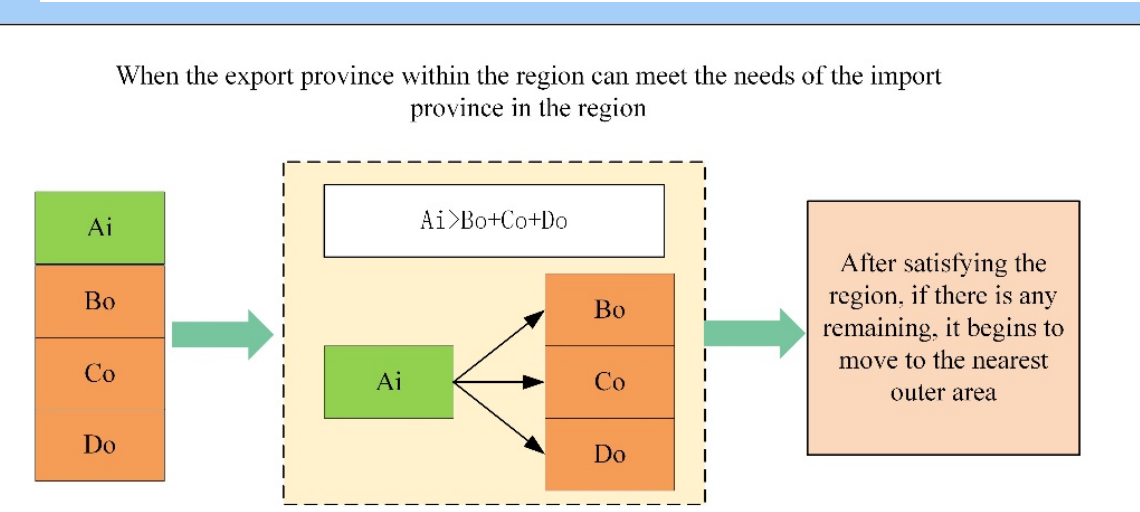


Fig.3 Calculation of virtual water flow

The data used in this study include meteorological data, agricultural data, irrigation data, population data, and gross domestic product (GDP) data in each province from 1997 to 2014..

4. Results

➤ Impact of the Geographical Evolution of Grain Production on Regional Water Resources

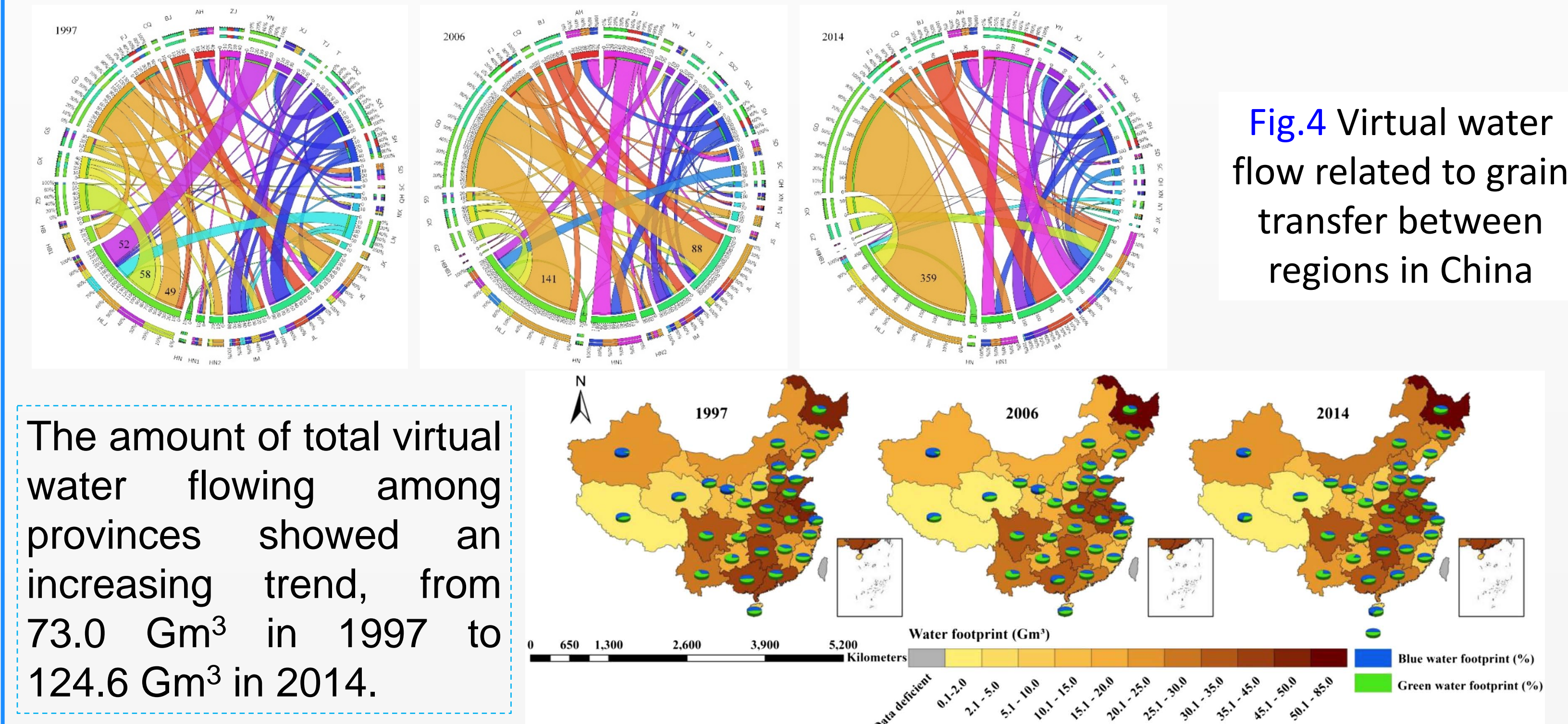


Fig.4 Virtual water flow related to grain transfer between regions in China

The amount of total virtual water flowing among provinces showed an increasing trend, from 73.0 Gm³ in 1997 to 124.6 Gm³ in 2014.

Fig.5 Water footprint of grain in China

➤ Influence of Geographical Evolution of Grain Production on Regional Economic Development

The results indicate that the grain production pattern and the virtual water flow accompanying the grain transfer have a potential impact on regional economies

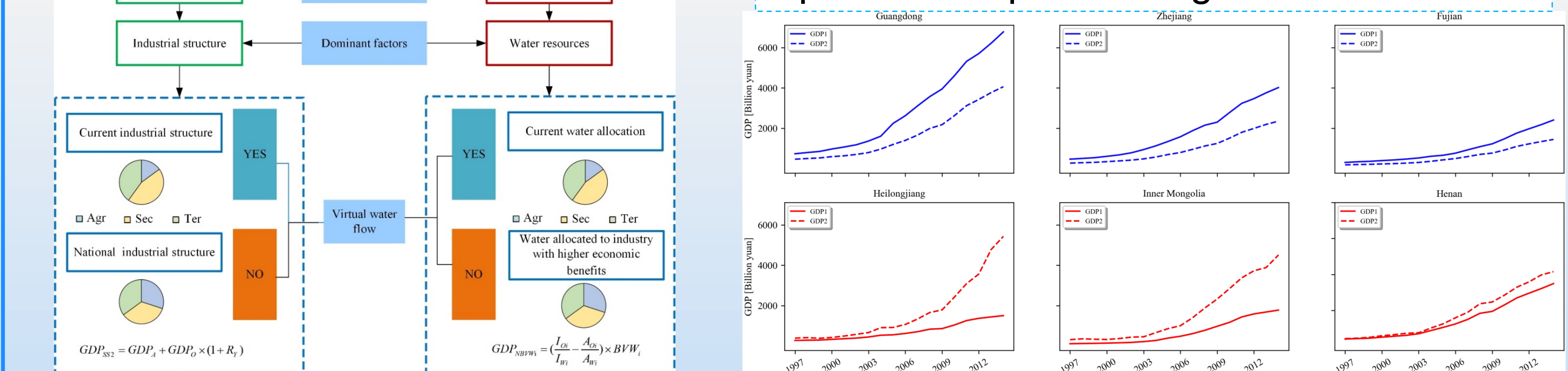
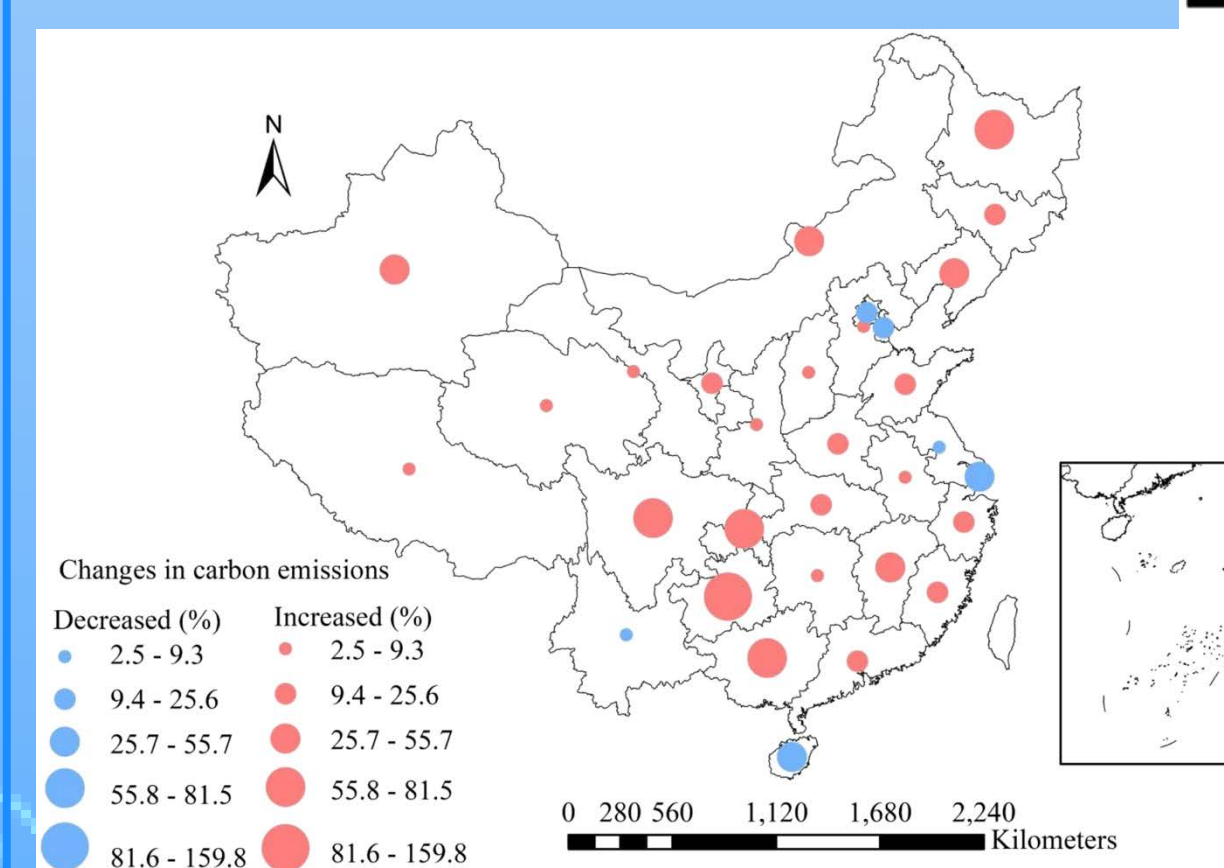


Fig.7 Difference of GDP between two scenarios in typical provinces

➤ Influence of Geographical Evolution of Grain Production on the Regional Environment

Fig.8 Gray water footprint of grain production

Fig.9 Changes in agricultural carbon emissions in different regions (2003 & 2013)



The results show that most of the grain export regions have an increasing trend for their gray water footprint. Overall, the larger the grain production scale is, the larger the gray water footprint is and the higher the carbon emissions are.

5. Discussion

- The effects of virtual water flow are multifaceted and complex. Virtual water flow will bring water - saving benefits if it flows from a region with high water productivity to a region with low water productivity.
- Virtual water has an important impact on the economic development of the grain import and export regions and the economic gap between the grain import and export regions is further expanded with the increase of the amount of virtual water flow.
- The larger the grain production and cultivated land are, the greater the carbon emissions and gray water footprint are. Agricultural production is a complex comprehensive system. On the one hand, grain production should ensure normal grain demand; on the other hand, environmental effects of different crops should be taken into account.

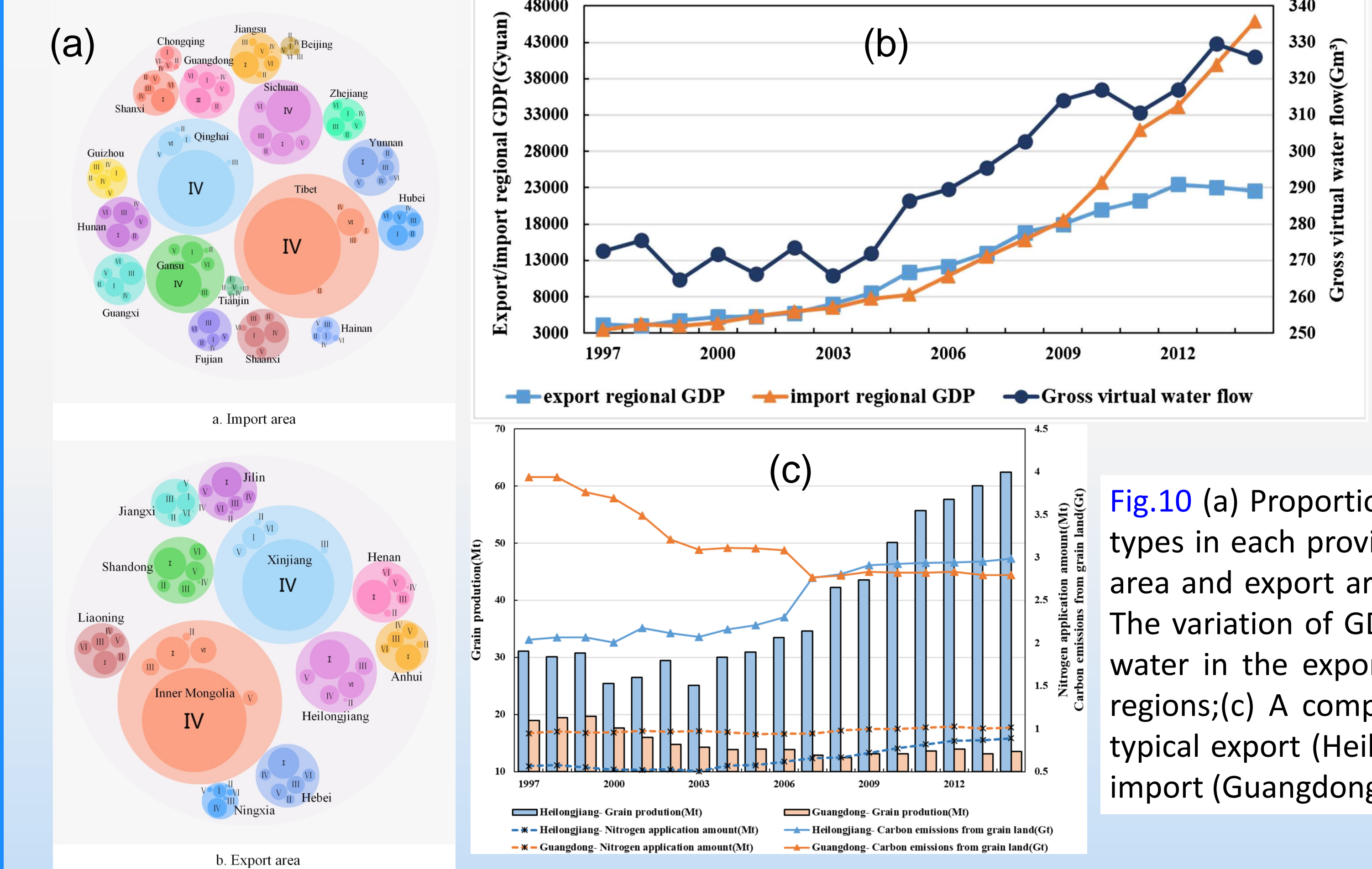


Fig.10 (a) Proportion of land use types in each province in import area and export area (2013); (b) The variation of GDP and virtual water in the export and import regions; (c) A comparison of the typical export (Heilongjiang) and import (Guangdong) regions

6. Conclusions

- Virtual water flow has formed a pattern of movement from the water - scarce northern region to the water - rich southern region.
- Grain virtual water transfer will redistribute water resources among different water use sectors, and it will have an influence on the economic development of the grain export and import areas.
- Although the results of this study provide a comprehensive assessment of the impacts of virtual water transfer on water resources, the environment, and the economy, further work is needed to develop socioeconomic modeling to evaluate the effects of virtual water flow on regional economy.

7. References

S. K. S , Y. L. Y , P. T. W , et al. Geographical Evolution of Agricultural Production in China and Its Effects on Water Stress, Economy, and the Environment: The Virtual Water Perspective[J]. Water resources research, 2019, 55(5):4014-4029.