

## ***Interactive comment on “A novel data-driven analytical framework on hierarchical water allocation integrated with blue and virtual water transfers” by Liming Yao et al.***

**Liming Yao et al.**

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1. The conception of “blue water” and “virtual water” should be clearly described. Do they have an inclusion relationship?

Response: Thank you for your question. Blue water is the surface or groundwater that runs off to the ocean, which is used for industrial and domestic purposes and irrigation in agriculture; while virtual water is the water embedded in a product (Allan et al., 1993). Virtual water content is the amount of water per unit of product that is consumed during the production process.

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In addition, it's known that freshwater essentially stems from precipitation, which partitions into green and blue water (Falkenmark, 2013a). Virtual water content can be specifically divided into blue water content and green water content. In this paper, blue water transfer is regarded as a means of reallocating water among sectors, it can be directly transferred from one sector to another through conveyance infrastructure after each sector (e.g., domestic, industrial or agricultural) has been granted temporary water withdrawal rights. Virtual water transfer is characterized by crops trade. It helps import countries save the volume of water necessary to produce a certain commodity.

## Reference

[1] Allan J A. Fortunately there are substitutes for water otherwise our hydro-political futures would be impossible. Priorities for water resources allocation and management, 1993, 13(4): 26.

[2] Falkenmark M. Growing water scarcity in agriculture: future challenge to global water security. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 2013, 371(2002): 20120410.

2. The proposed model focused on the irrigation district problem. So the title of this research article should be more specific to highlight the water allocation in the irrigation sector.

Response: Thank you for your comment, we changed the title from the original one to "A novel data-driven analytical framework on hierarchical water allocation integrated with blue and virtual water transfers: A case study of China" after careful consideration.

3. There are many useful conclusions drawn from the results of the proposed optimization. Maybe you should give some advice to the decision-makers facing similar problems.

Response: Thank you for your suggestion. It's important to give managerial insights to decision makers who may encounter the same problem.

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In many places, including the north of China, there are two different hierarchical structures, the water affairs bureau and the water usage sectors, within an irrigation area. Against the backdrop of water scarcity, incommensurable conflicts exist among different water users and the water affairs bureau because of differing objectives. Additionally, faced with multiple followers, another main problem is that various water usage sectors, such as agricultural, industrial, domestic and ecological sectors, compete for limited water resources. Due to the unsuitability of this problem for modeling by conventional methods, a novel game model is presented considering the water allocation and blue/virtual transfers together, in view of the hierarchical structure of the problem.

In terms of management insight, some policy implications have been provided in the manuscript based on the results solved by the proposed model. In the response letter, we listed some of them.

1) blue water transfer is suggested in areas with uneven water distribution condition, which provides an opportunity for each sector to achieve an efficient utilization of water. To be specific, some initial water rights could be transferred from the agricultural sector to the industrial and domestic sector.

2) virtual water transfer is suggested in (semi)-arid areas, which provides a new opportunity for water conservation and land saving. To be specific, key crops, particularly water-intensive crops (e.g., wheat and sunflower), could be imported from other countries rather than being grown domestically.

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