We deeply appreciate the detailed and constructive comments provided by the three anonymous reviewers. Following their suggestions and comments, we have extensively revised the manuscript and provided a point-to-point response to each comment. The original comments are in **bold** font, our response is in regular font, and the changes in the text are in blue.

Comment 3

The present manuscript provides an emblematic example of integrating green water flows at a sub-national level in water management strategies. It expands on recent studies that highlighted the socio-economic value of green water teleconnections. The topic is suitable for publication and of interest to the readership of EGUsphere.

Response: Thank you for taking your time to review our study and provide feedback and comments.

I would recommend the publication of this paper after major revisions. In the following, there are some comments that the authors may want to consider when revising their manuscript. These revisions should enhance the manuscript's clarity and depth.

Specific comments:

Abstract:

Lines 15-16: Pay attention to verb consistency for better clarity and flow.

Response: Thank you for the comments.

We modified this part to be more specific, and the revised texts are shown below:

Green water (terrestrial evapotranspiration), flows from source regions and precipitates downwind via moisture recycling, recharges water resources and sustains socio-economy in sink regions.

Lines 19-21: The dataset used for the analysis is not well introduced or explained. Provide a more detailed and concise explanation of the data used.

Response: Thank you for the comments.

In the revision, we revised the sentence to include more information. The revised texts are shown below:

This study used the moisture tracking dataset which contains monthly moisture flows at the global scale with a spatial resolution of 0.5° for 2008-2017 to quantify interprovincial green water flows in China and their socio-economic contributions.

And in Section 2.1, we added a more detailed introduction about the UTrack moisture tracking dataset. The revised texts are shown below:

This study used the moisture trajectory dataset generated by the Lagrangian moisture tracking model "UTrack-atmospheric-moisture" driven by ERA5 reanalysis data. The model is the state-of-the-art moisture tracking model, producing more detailed evaporation footprints due to the highest spatial resolution and reducing unnecessary complexity (Tuinenburg and Staal, 2020). The dataset provides monthly moisture flows at the global scale with a spatial resolution of 0.5° for 2008-2017, expressed as the fractions of evaporation from a source grid allocated to precipitation at a sink grid (Tuinenburg et al., 2020). It has been widely used in moisture recycling research with various spatial scales, such as precipitation source of grid (Staal et al., 2023; Wei et al., 2024; Zhang et al., 2023) and basin scale (Wang et al., 2023), and moisture transport between nations (Dirmeyer et al., 2009).

Line 22: Include the specific value of the average self-recycling ratio.

Response: Thank you for the comments.

In the revision, we added the range of self-recycling ratio, and revised texts are shown below:

The precipitation recycling rate (PRR) range of 31 provinces is from 0.6% to 35%.

Lines 32-35: This passage is unclear. Consider rephrasing and supporting it with specific results.

Response: Thank you for the comments.

In the revision, we rephrased this passage, and the revised texts are shown below:

Green water primarily flows from underdeveloped regions to developed provinces, such as Xizang and Xinjiang whose exported green water having the most added socio-economic value. This suggests that less developed provinces effectively support the higher socio-economic status of developed provinces through green water supply.

Introduction:

Line 45: Consider adding additional references for the average global terrestrial moisture recycling ratio. Rockström (2023) cites Tuinenburg (2020), they are essentially the same reference.

Response: Thank you for the comments.

In the revision, we changed the references, and the revised texts are shown below:

Terrestrial evapotranspiration (i.e., green water) (Falkenmark and Rockström, 2006), which includes evaporation and transpiration from land and vegetation, contributes to over half of the global precipitation on land (van der Ent et al., 2010; Theeuwen et al., 2023; Tuinenburg et al., 2020).

Lines 60-61: Clarify the period of reference for the change mentioned. Specify when the change occurred and add recent references for support.

Response: Thank you for the comments.

In the revision, the period of reference was clarified, and the revised texts are shown below:

Global total blue water flow into oceans and internal sinks has decreased by 3.5% in 2002 compared to 1961–1990 due to upstream water withdrawal and dams (Döll et al., 2009)

Lines 99-103: This section is unclear. Rephrase for better clarity.

Response: Thank you for the comments.

In the revision, we rephrased this passage and revised texts are shown below:

Recent studies analyzed green water flows at the national or regional scale to identify the source and sink areas of specific regions, like the Tibetan Plateau (Zhang et al., 2024) and Europe (Pranindita et al., 2022). However, green water flows from different regions are interlinked and become sources and sinks of each other. Such green water transfer at a sub-national scale effectively forms a complex green water flow network, and highlights the mutual dependency of green water and its socio-economic contributions, especially for large countries like China.

General Comments:

The Introduction could benefit from clearer explanations of certain passages. Include a characterization of China's moisture recycling patterns, atmospheric

circulation, and climatic seasonality to frame the phenomenon of moisture flows. For instance, compare the importance of moisture recycling in China to other regions globally.

Response: Thank you for the comments.

In the revision, we added the introduction about China's moisture recycling patterns, atmospheric circulation, and climatic seasonality. The revised texts are shown below:

The moisture flows in China are mainly influenced by prevailing westerly winds (from the west toward the east) in most regions of China between 30° and 60° (Bridges et al., 2023), the East Asian monsoon in eastern China, and India monsoons in southwestern China. In summer, the East Asian summer monsoon and India summer monsoon bring moisture for precipitation in eastern and southwestern China, (Tian and Fan, 2013). In winter, the East Asian winter monsoon drives northwesterly moisture transport across much of China and generate precipitation (Wu and Wang, 2002). These regional atmospheric circulation systems determine the basic spatial and seasonal patterns of green water flow across China.

Discuss the socio-economic background of the Chinese provinces involved. Highlight key socio-economic sectors and societal issues/characteristics of these regions.

Response: Thank you for the comments.

In the revision, we added the socio-economic background of the Chinese provinces. The revised texts are shown below:

Furthermore, the substantial disparities in socio-economic development among Chinese provinces add complexity to the socio-economic contributions of green water. The western provinces have a weak economic base and sparse populations, but are abundant in water resources (Ya-Feng et al., 2020). The eastern provinces are economically developed and densely populated, whereas they suffer from water scarcity (Varis and Vakkilainen, 2001). There is an urgent need to quantify moisture flows at provincial scale and to evaluate the socio-economic value embedded in interprovincial green water. This offer new perspectives for optimizing water resource utilization and mitigating the imbalance in regional socio-economic development.

Explain why analyzing green water flows at an inter-regional scale is significant, both generally and specifically for China.

Response: Thank you for the comments.

Although many research analyzed the spatial pattern of moisture recycling in China from amphoteric and hydrological sciences, they identified moisture source and sinks at the grid (Zhang et al., 2023), river basins (Wang et al., 2023), and ecological regions scale (Xie et al., 2024). There is a clear understanding of the large-scale spatial pattern of moisture circulation, few researches focus on quantify moisture recycling at the administrative district scales, which is important for the water management. Therefore, this study applies moisture recycling techniques to inform green water transfer at among provinces, which is previously less known but important for regional water resources management.

In the revision, we will add the explanation.

Data and Methods:

General Comment: This section requires substantial improvements.

Structure: Separate the Data and Methods into two subsections. Move Figure 1 to the Methods subsection and provide detailed explanations in the caption.

Response: Thank you for the comments.

In the revision, we separated the Data and Methods into two subsections. And added detailed explanations in the caption of Figure 1.

Figure 1: The caption should be more detailed to enhance understanding.

Response: Thank you for the comments.

In the revision, we added detailed explanations in the caption of Figure 1.

The revised figure and its caption are shown below:

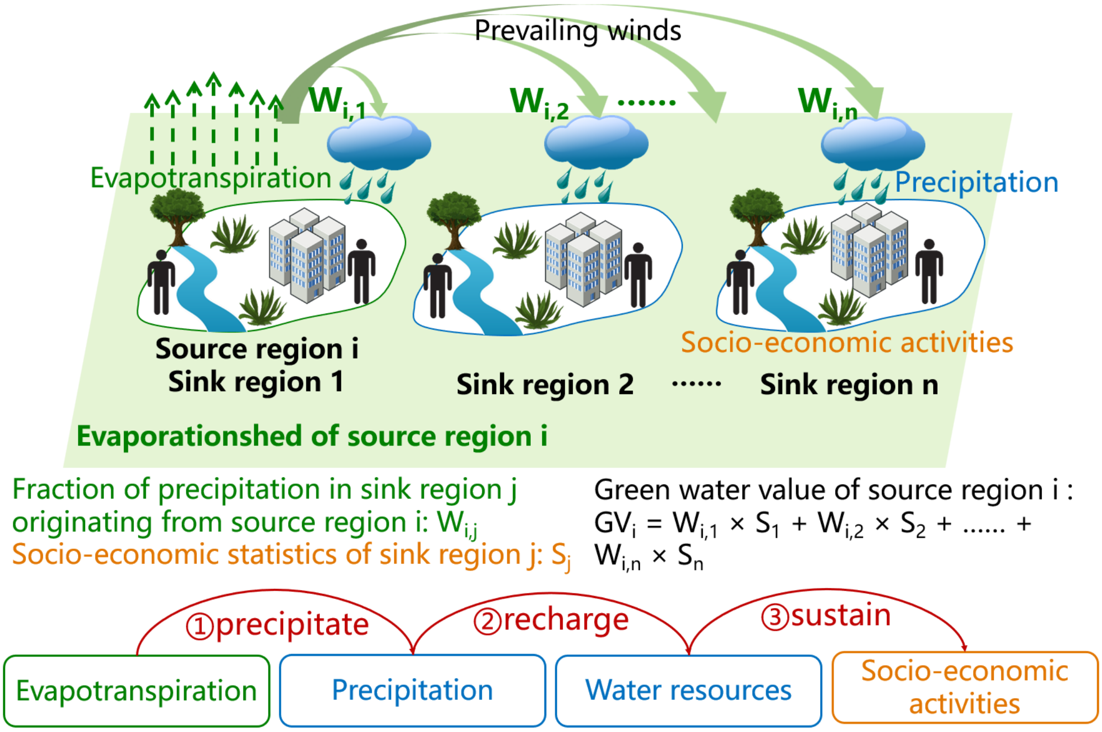


Figure 1. A conceptual diagram depicts the teleconnection of green water flows and their socioeconomic contributions in a cascade manner. Evapotranspiration (green dotted arrows) from source region i flows downwind with prevailing winds (green thick arrows) and precipitates in sink region n, which recharges water sources and sustains socioeconomic activities in sink regions.

Lines 127-138: Provide a more detailed explanation of the reconstruction of flows from the UTrack dataset. Clarify the processing with zonal statistics, possibly using equations or schemes for better comprehension.

Response: Thank you for the comments.

In the revision, we added detailed explanations of the reconstruction of flows from the UTrack dataset in Section 2.2 and Figure A1. The revised texts and figure are shown below:

Firstly, we quantified interprovincial moisture flows and their precipitation contribution (Fig. A1). At each sink grid, the ET to precipitation fractions from the moisture trajectory were multiplied by ERA5 evapotranspiration (ET) to obtain monthly precipitation contribution by moisture from all source grids. Repeating the calculation for all grids within a sink province and summing them up yielded the precipitation in sink province contributed by each of source grid (Fig. A1 Step 1). We next employed zonal statistics to sum up source grids by province to obtain precipitation in sink province contributed by each of source province, and the precipitation contribution was converted to relative values (i.e., the fraction of precipitation in sink province *j* originating from green water of a source province *i*, denoted as W_{ij}) rather than absolute contribution to reduce the uncertainty in the latter (Fig. A1 Step 2). The fractions W_{ij} multiplied by precipitation of sink province restore the absolute precipitation contribution. Finally, the interprovincial green water flows in China was derived after estimating each province individually.

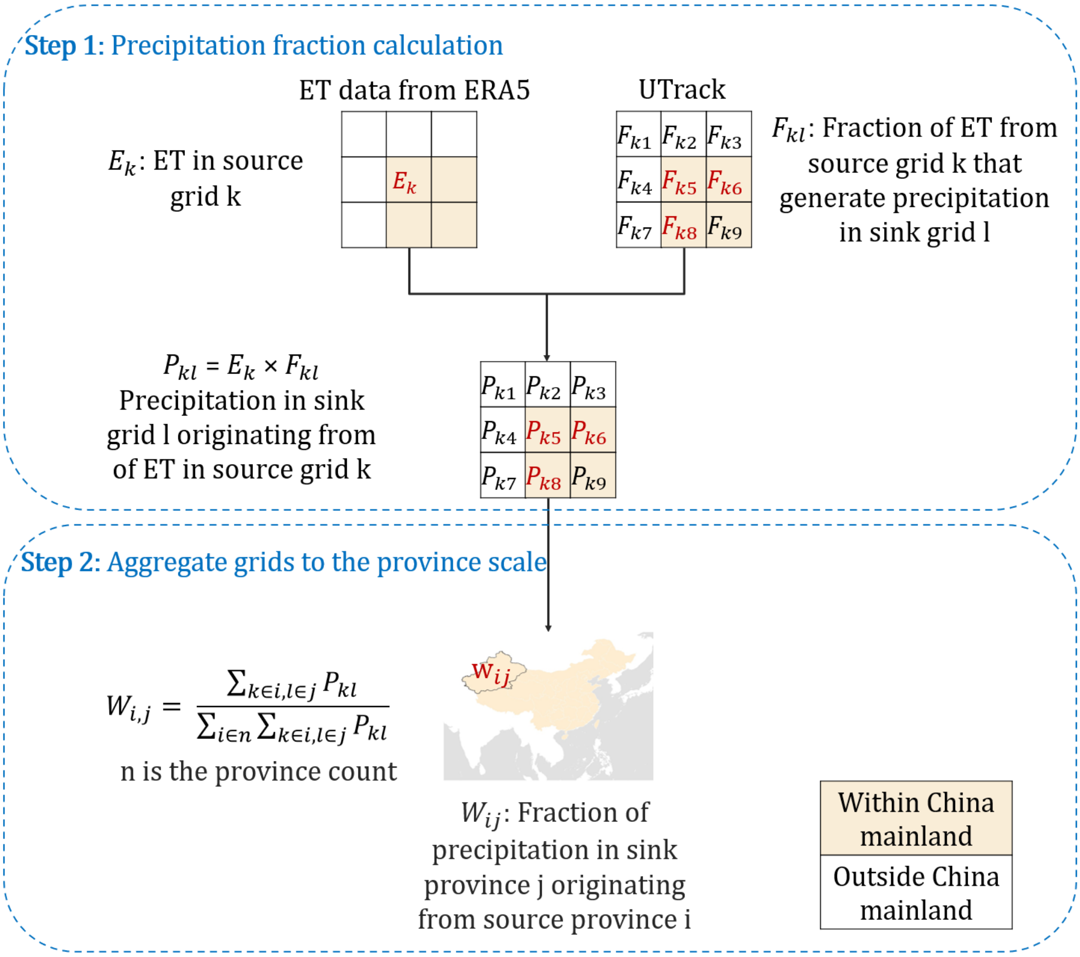


Figure A1. Interprovincial green water flowing network calculation. Step 1: calculate the precipitation in sink grids originating from ET in source grids. Step 2: calculate the fraction of precipitation in sink provinces originating from source provinces.

Socio-economic Analysis: Since this is the core of the study, it needs a more in-depth analysis. Explain the significance of green water flows for the variables considered. How do they contribute to the services these variables represent?

Response: Thank you for the comments.

In the revision, we added the explanation of green water flows' significance. The revised texts are shown below:

Consequently, precipitation, surface water resources, and socio-economic factors such as economy activities, human livelihood, and crop growth in sink provinces rely on green water exported from source provinces. Green water affects the surface water resource volume and crop growth by precipitating, and then impacts the water supply for economy activities, livelihood and irrigation of crop growth. We choose water resources volume, economy output (GDP), population and food production, the four socio-economic indictors to evaluate green water socio-economic contributions of the source province because they are tightly related to water resources (Li et al., 2018) and can capture the social dynamics of moisture recycling (Keys and Wang-Erlandsson, 2018).

Equation 1:

Consider incorporating the areal extension of the provinces. Using population density instead of population, and expressing surface water resources per unit area, would be more appropriate. Similarly, express food production per area rather than gross food production. Use GDP per capita (GDP/P) instead of gross GDP.

Response: Thank you for the comments.

The land area and population of source and sink provinces differ, when using per-unit measures, the socio-economic value of green water is affected by the denominators of the indicators for both the source and sink provinces, making the results difficult to interpret. Alternatively, per-unit measures reflect the different characteristics between the source and sink regions, such as the green water flowing from economically less developed to developed provinces indicated by per capita GDP. These results have already been discussed and analyzed in the manuscript in Section Discussion. Therefore, we choose to use total amounts of socio-economic indicators to calculate the green water value.

Address the role of irrigation and irrigation infrastructure in food production to avoid overestimating the contribution of green water flows. Differentiating between irrigated and rainfed productivity could be insightful.

Response: Thank you for the comments.

The irrigation increases ET in source region, then provides more moisture for downwind regions. Simultaneously, most of the water for local irrigation comes from upwind regions. Therefore, it is necessary to distinguish water sources more carefully. In the revision, we will add this point in Section Discussion.

However, the food production data from China Statistical Yearbook is the total food production including both irrigated and rainfed production. It's hard to differentiate the irrigated and rainfed productivity due to the data limitation.

Include units of measure.

Response: Thank you for the comments.

In the revision, we added units and the revised texts are shown below:

Where S_j is the average socio-economic value of 2008-2017 (i.e., surface water resources volume (km^3), GDP (CNY, 1 CNY = 0.14 USD), population (persons), and food production (ton)) at sink province j, n is the number of sink provinces.

Equations 2 and 3:

The focus shifts to the consumption patterns of each province. However, Equation 1 deals with food production, which does not equate to food consumption. Food production in one province might be exported elsewhere. Clarify whether the study focuses on production, consumption, or both, and how these dynamics are analyzed.

Response: Thank you for the comments.

We apologize for the confusion regarding the research's focus.

Our research focus on the food production. We used water productivity in source province to calculate socio-economic values of its exported green water in the counterfactual scenario when it was all consumed in source province without interprovincial transfer. The results were compared with the actual green water's socio-economic values (namely socio-economic values of exported green water when it is consumed in sink provinces). What we focused is the difference of food production between the scenario that green water is all consumed in source provinces and actual scenario.

In the revision, we will clarify this point more clearly.

General comment: Consider revising Equations 1,2 and 3 to enhance the rigor of the analysis.

Results:

Section 3.1:

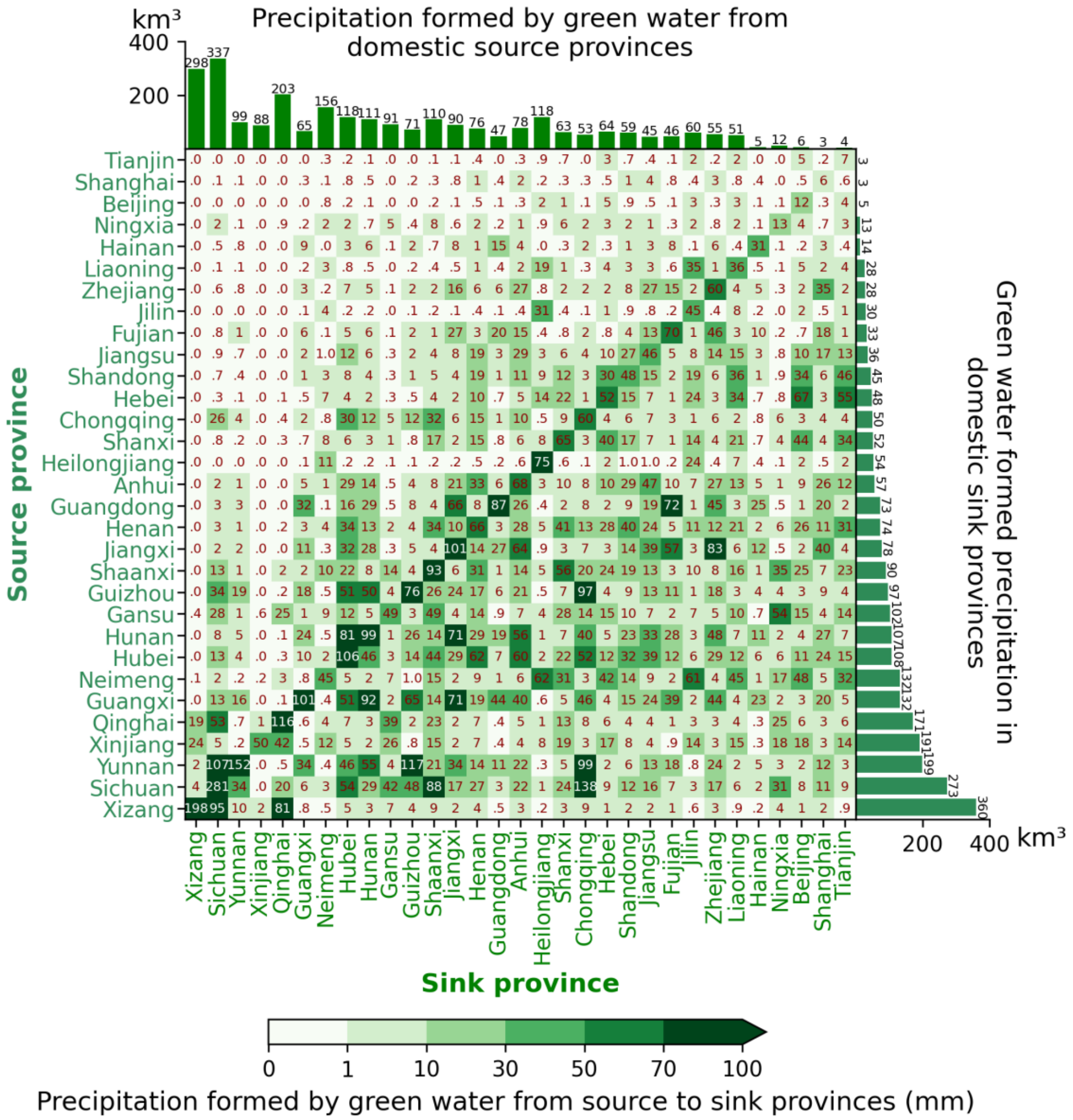
Figure 2: The figure has great potential but needs improvements.

Increase its size for better readability of numbers and histograms.

Clarify the label of the right bar in the figure, caption, and text. Consider rephrasing for better understanding.

Response: Thank you for the comments.

In the revision, we improved Figure 2 to increase its readability. The revised figure is shown below:



Lines 195-237: The discussion on PRR, DPR, and DSR contains a lot of information that is difficult to visualize. Consider creating a figure to represent these results to help the discussion of socio-economic implications.

Response: Thank you for the comments.

The information of PRR, DPR, and DSR in each province has shown in Figure A3 (Appendix Figure 3).

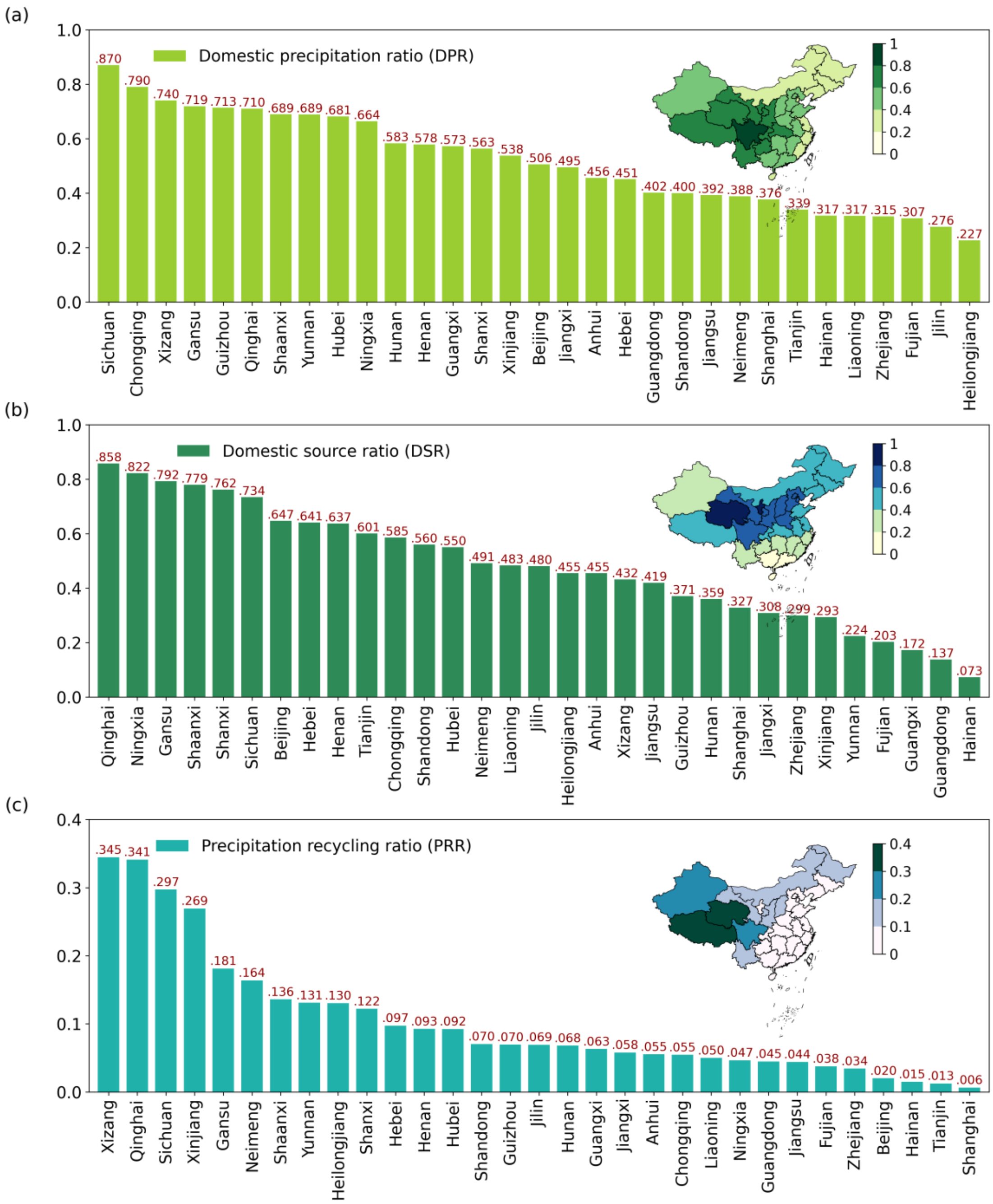


Figure A2. Domestic precipitation ratio (a), domestic source ratio (b) and precipitation recycling ratio (c) in each province.

Line 214: Provide a definition of westerly winds for a general audience. Also, it is the first time in the manuscript that atmospheric circulation is considered explicitly (see comment about the Introduction)

Response: Thank you for the comments.

In the revision, we provided the definition of westerly in Section Introduction. The revised texts are shown below:

The moisture flows in China are mainly influenced by prevailing westerly winds (from the west toward the east) in most regions of China between 30° and 60° (Bridges et al., 2023), the East Asian monsoon in eastern China, and India monsoons in southwestern China.

Section 3.2:

Suggest swapping the order with Section 3.1. The geographic visualization of flows in Section 3.2 aids in understanding the results presented in Section 3.1.

Response: Thank you for the comments.

Section 3.1 shows the network of interprovincial green water flows. Section 3.2 shows the spatial pattern of each province's composited green water flows direction based on the green water flowing network. We think it's more appropriate to clarify the interprovincial green water flowing network firstly.

Section 3.3:

This section is well-written and interesting. However, given its significance to the analysis, consider expanding and providing more in-depth discussion.

Response: Thank you for the comments.

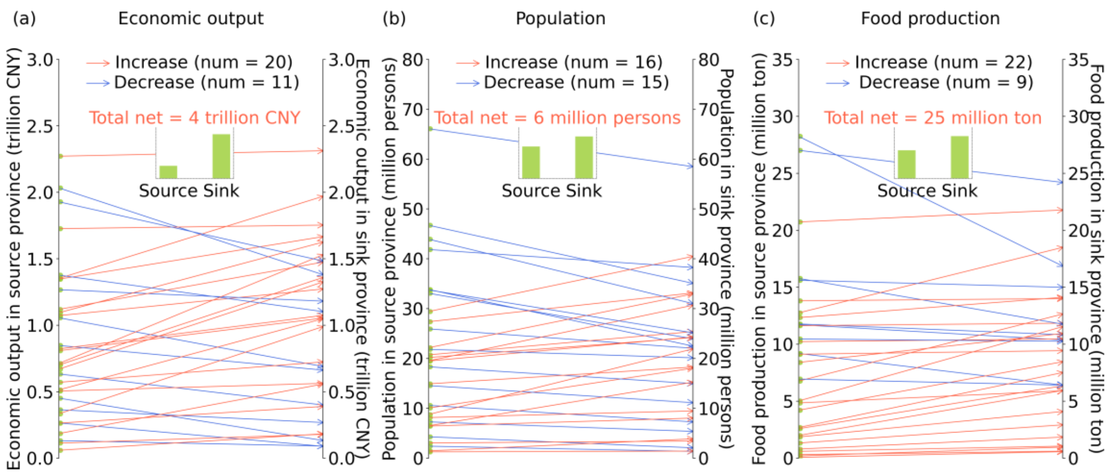
The in-depth discussion of Section 3.3 is in the Section Discussion. To make this part clearer, we will move the in-depth discussion to Section Results in the revision.

Discussion:

Overall, this section is well-structured and written, but improvements are needed: Enlarge Figure 5 for greater clarity.

Response: Thank you for the comments.

In the revision, we enlarged Figure 5, and the revised figure is shown below:



Provide a deeper discussion on the uncertainty of tracked precipitation at the provincial level.

Response: The uncertainty of tracked precipitation includes three aspects: (1) different ET and precipitation datasets lead to different precipitation contribution and PRR due to the ET amount and spatial distribution; (2)the non-closure of the moisture balance between ET and precipitation from ERA5 results in inaccurately capturing actual ET and precipitation volumes; (3) the moisture tracking model has some assumption and simplification. The purpose of our work is not to precisely quantify the moisture recycling quantification but to reveal the relationship between the moisture and socio-economy.

The revised texts in section Discussion are shown below:

Due to complex dynamics of the green water flow and limitations of the moisture tracking model, there are still major uncertainties in data and methods of this study. First, ET and precipitation datasets driving the UTrack model affect the tracked trajectories and magnitude of moisture flow. The resulting moisture trajectory is expressed as the fraction of ET to precipitation, and the amount of moisture is restored by the ET and precipitation dataset chosen by users. Different ET and precipitation datasets lead to different precipitation contribution and PRR (Li et al., 2023). We used the ERA5 dataset to keep consistent with the original UTrack model. It is noted that the non-closure of the moisture balance from ERA5 (Tuinenburg et al., 2020) results in more uncertainties in moisture tracking results (De Petrillo et al., 2024). Simplifications and assumptions introduced in the moisture tracking model also add uncertainty (Tuinenburg and Staal, 2020). Moreover, the resulting moisture trajectory data only represent the climatologically average moisture trajectories and ET (Li et al., 2023), neglecting the interannual variability in moisture flow trajectory, e.g., those induced by the influence of extreme weather events or ENSO (Zhao and Zhou, 2021). The interannual variations in green water flow may affect DPR and DSR in some provinces. Human adaptation tends to buffer impacts of interannual variations on socio-economy through water resource management such as reservoirs, dams and other infrastructure. Accounting for interannual variations in green water flows and their socio-economic contribution is worthy future investigation.

Lines 429-431: The sentence "Our attempt... [..]" is redundant here and would be more appropriate at the end of the discussion.

Response: Thank you for the comments.

In the revision, we moved this sentence to the end of the discussion.

General Comments for Discussion and Conclusions:

Include a more in-depth description of the limitations of the socio-economic analysis to add value to these sections and the overall study.

Response: Thank you for the comments.

The limitation of the socio-economic analysis includes:

(1) The green water's socio-economic contribution excludes green water flowing abroad, and did not separate water sources in assessing socio-economic contribution and consider the accessibility of precipitation formed by green water to human activities.

(2) The research selected three socio-economic indices which are tightly linked to the water resources. Other indices linked to water resources like livestock production and irrigated agriculture are not considered.

In the revision, we added these limitations in the section Discussion, and the revised texts are shown below:

Secondly, the socio-economic value assessment of green water in this study only considers green water flows within China, excluding flows moving abroad and to the ocean that may embody socio-economic value beyond territory of mainland China. We mainly attribute socio-economic values to green water and generated precipitation, because precipitation is the ultimate water source to recharge surface and groundwater of a region. Strictly speaking, such attribution is not precise because socio-economy also utilizes streamflow from upstream areas which deserve separate attention. In addition, not all water resources replenished by green water-generated precipitation are accessible for human activities, part of them serve the nature ecosystem, such as sustaining forest function (Keys et al., 2019). Despite three socio-economic indices closely linked to water resources, the socio-economic contribution of green water flows can be manifested in other aspects such as livestock production, irrigated agriculture.

Discuss potential improvements for this type of socio-economic analysis.

Response: Thank you for the comments.

Potential improvements for this type of socio-economic analysis include (1) the moisture recycling dataset improving; (2) the interannual variations analysis of green water's socio-economic contribution; (3) the distinguish of blue and green water source; (4) more comprehensive assessment of the green water's contribution.

In the revision, we added these potential improvements in the section Discussion, and the revised texts are shown below:

In future study, green water's socio-economic contribution can be assessed annually by using moisture tracking dataset containing interannual variations and with or separation of water resources consumed by socio-economy (surface and ground water), which is more conducive to understand long-term changes and variations in the linkage between green water, water resources and economic development. And the source of water resources sustaining the socio-economy in each province should be distinguished into green and blue water flow to exclude blue water's socio-economic contribution. Moreover, green water's contribution can be evaluated comprehensively through more socio-economic indicators.

Since this study is presented as a starting example of integrating green water teleconnections into water management strategies for socio-economic applications, it would be beneficial to elaborate on additional steps needed to achieve this goal.

Response: Thank you for the comments.

Additional steps should solve existing deficiencies to improve green water's socio-economic contribution.

In the revision, we added these potential improvements in the section Discussion, and the revised texts are shown below:

In future study, green water's socio-economic contribution can be assessed annually by using moisture tracking dataset containing interannual variations and with or separation of water resources consumed by socio-economy (surface and ground water), which is more conducive to understand long-term changes and variations in the linkage between green water, water resources and economic development. And the source of water resources sustaining the socio-economy in each province should be distinguished into

green and blue water flow to exclude blue water's socio-economic contribution. Moreover, green water's contribution can be evaluated comprehensively through more socio-economic indicators.

Consider discussing other variables that could enhance the analysis of socio-economic implications.

Response: Thank you for the comments.

Some other socio-economic variables like livestock and irrigated agriculture may enhance the analysis. In the revision, we added them and the revised texts are shown below:

Despite three socio-economic indices closely linked to water resources, the socio-economic contribution of green water flows can be manifested in other aspects such as livestock production, irrigated agriculture.

Supplementary Figures and Tables are not cited, and thus integrated in the text. Please integrate them in the main text.

Response: Thank you for the comments.

We apologize for the confusion regarding the figures citing and Supplementary Figures and Tables citing. In the main text, supplementary figures were cited as Fig. A1, Fig. A2; supplementary tables were cited as Table A1 and Table A2. All supplementary figures and tables were cited in section Result and Discussion.

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