Draft prepared for GTAP conference 2021, please do not circulate or cite this version.

Impact of China's South-North Water Transfer Project on Agriculture: A Multi-scale Analysis of the Food-Land-Water System

Zhan Wang[1], Jing Liu[1]

Abstract

Many countries have planned or implemented long-distance inter-basin water transfer projects to resolve water scarcity due to spatially imbalanced water application. The South-North water transfer project (SNWTP) in China is among the largest inter-basin water transfer projects built so far, which would transfer water from Changjiang (Yangtze) river to northern regions, in order to fulfill the gap between limited water supply and increasing water demand from civil, industrial, agricultural and ecosystem purposes. In order to research how will SNWTP influence future crop production, cropland expansion and irrigation water use, we use a model with global to spatial scale to project agricultural production from 2017 to 2050 with different SNWTP implementation and operation scenarios. Under current scenario of water transfer capacity, crop production would increase by 60.05% and cropland would expand by 4.01%. Increasing amount of water transfer from current level to full capacity of the whole SNWTP would decrease irrigation water use in water donating basins by 0.20% - 0.35%, while it would increase irrigation water use in water receiving basins by 0.4% - 4.67%. Along transfer routes, the mainstream Huai river basin is most responsive to SNWTP in irrigation water use, crop production and irrigated cropland expansion, where results indicate that impact of SNWTP would be spatial heterogeneous on local level as well. The multi-scale analysis of SNWTP's agricultural impact implies the importance of taken local impact and response of inter-basin water transfer into planning and associated policy making.

[1] Department of Agricultural Economics, Purdue University, USA

Draft prepared for GTAP conference 2021, please do not circulate or cite this version.

1 Introduction

Shortage of water resource can be caused by not only insufficient volume in total, but also by the inefficient spatial allocation. For this reason, many countries have planned or implemented long-distance inter-basin water transfer projects. Long suffered from water shortage in its northern regions, China has made ambitious move to tackle the issue by constructing large-scale inter-basin water transfer projects, particularly the South-North water transfer project (SNWTP). SNWTP consists of three routes, eastern, central and western (under planning) routes (Figure 1[2]). Since its operation, SNWTP has transferred over 40 billion cubic meter of water. In 2020, SNWTP transferred 9.46 billion cubic meter of water (H. Wang, 2021), or about 13% of total annual water use in the five water receiving provinces (Beijing, Tianjin, Hebei, Shandong and Henan) (National Bureau of Statistics of China, 2020), making it the largest inter-basin water transfer project in the world. Given the unprecedented scale of the project and the potentials of improving the balance of irrigation demand and availability, SNWTP could play critical role in achieving UN's Sustainable Development Goals (SDGs) in China, especially in light of the pandemic that could make sustainable development even more uncertain and challenging. In face of the challenge to feed its world's top one population with the trend of rising consumption and continuing urbanization, understanding the impacts of SNWTP on crop production and cropland change and irrigation water use under possible futures shaped by population growth, economic development, agricultural technology and project operation would be valuable for these expensive infrastructures to deliver more bang out of buck. To this end, an integrated analysis on the food-land-water system is needed.

[2] Only show mainland and major islands, same for other figures.

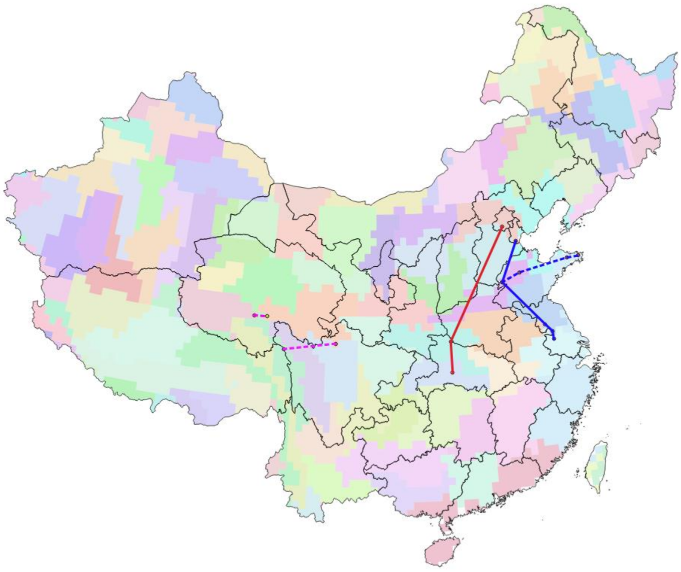

Figure 1 Eastern (blue), central (red) and western (purpose) routes of SNWTP (dashed line: under planning or construction; polygon with color: basins)

By far, existing studies have extensively examined the impacts of SNWTP from hydrological and environmental aspects, including how SNWTP influence surface water allocation (Chen et al., 2013), groundwater recharge (D. Zhang et al., 2019), water pollution (L. Zhang et al., 2019) , species (Zhu et al., 2019) and impacts climate-changes (Zou et al., 2016). Comparing with those studies, much less has been done to evaluate the larger-scale impacts of SNWTP on crop production, which can be decomposed into the intensive margin determined by irrigation induced yields improvement and the extensive margin associated with cropland expansion. Berkoff (2003) discussed the implication of SNWTP for agriculture in China. Since water used in irrigation usually have much less value added than civil or industrial demand, farmers usually have to take the residual of water after other purposes, driving them to be most vulnerable to water supply variance. However, with the task to feed the largest population and the already degraded environment in northern China, to reserve agricultural potential and protect ground water with SNWTP would have higher importance than economic return. This argument indicates the necessity of conducting further research on SNWTP's agricultural impact, which is still limited in literature by far. In addition, existing studies usually focus on national, provincial or spatial level impacts or responses, but few of them have researches the agricultural impact of SNWTP with an economic framework. Behavioral changes are often ignored such as improved irrigation efficiency and the substitution between water and other agricultural inputs. Analysis missing the linkages provided by domestic and global markets cannot comprehensively assess the impact of SNWTP. Finally, the demand, endowment and technology of agriculture are all spatially heterogeneous. This requires the impact analysis to be conducted not only at the national or provincial level, but also at the basin and local level, which is relatively sparse in the literature.

This paper aims at fulfilling the gap in current literature. In this paper, we will research how does the existence of SNWTP and its possible operation status influence crop production, cropland expansion and irrigated water use in China. Especially, in this study the impact of SNWTP would be researched with a multi-scale model, where the drivers from global level (crop demand and supply from international market), national level (population growth, economic development and production technology improvement), basin-level (water supply and demand by multiple purpose) and local level (crop production and cropland expansion on spatial grids) would be all integrated. By applying this multi-scale approach, our study provide overall assessment of SNWTP on the crop-land-water system. The paper is organized as follows: section 2 introduces the methodology of this study, including the model, experimental design and data source. Section 3 presents results from model simulations under each scenarios, Finally, section 4 discuss those results on their implication to SNWTP and agriculture for China.

2 Methodology

2.1 Model

To analyze the integrated impact of SNWTP, in this study we adopted the Simplified International Model of agricultural Prices, Land use and the Environment: Gridded version for China (SIMPLE-G-China). The SIMPLE-G-China model is developed based on the SIMPLE model (Baldos & Hertel, 2012) and global gridded SIMPLE model (SIMPLE-G-Global) (Liu et al., 2017) . In SIMPLE-G-China model, the whole China is downscaled to 88,948 five arc-minute grid cells, while the rest of world is aggregated into 15 regions. The SIMPLE-G-China model follows the global-local-global (GLG) approach. First, we set external drivers on population growth, per capita GDP growth, technological improvement and biofuel demand from global level (for non-China regions) and national level (for China). Also, we set up the projected agricultural water supply on basin level. Second, the model solves for crop production, cropland use and irrigation water use on each grid, which represents the heterogeneous local response to shocks on upper levels. Finally, local response on irrigation water use on grids are further aggregated on basin level to satisfy supply-demand equilibrium for irrigation water, and crop output and other factor input are aggregated on national level to satisfy equilibrium on crop demand and production. For detailed model information, please refer to Wang et al., (2020).

2.2 Experiments

In this study, we consider four SNWTP scenarios representing different cases of SNWTP operation. These scenarios include:

(1) Business-as-usual (BAU) scenario, where we assume in 2050, SNWTP is still operated at same capacity of year 2017 (annual water transferred is about 5.38 billion cubic meter) (Hou, 2017), which is the baseline year of SIMPLE-G-China model.

(2) Full capacity of current infrastructure (CI) scenario. By 2017, the first stage of infrastructure construction eastern and central route of SNWTP has been finished. In CI scenario, we assume that the currently finished infrastructure is operated at the full designed capacity in 2050, but no more infrastructure would be built and operated.

(3) Full capacity of SNWTP's whole project (WP) scenario. Here we expect by 2050, all stages of construction for all three routes of SNWTP would be finished and operated at the full capacity (the maximum of water transfer capacity in existing SNWTP planning).

(4) A counter-factual scenario: if the SNWTP is not ever built (No SNWTP). In this scenario, we taken away the amount of water transferred by SNWTP in 2017 to the original basin. This scenario would be used to evaluate the impact of SNWTP's existence or not.

For all four scenarios, we further combine the SNWTP impact with two other group of shocks: socioeconomic shock and water supply shock. Socio-economic shocks on population, per capita GDP, TFP development and biofuel demand under the Shared Socioeconomic Pathway 2 (SSP2) scenarios, which is shown in Table 1. Water supply shock refers to the projected supply of irrigation water in each basin, which equals the water residual between the projected water runoff and water demand by civil, industrial and livestock purposes, simulated from the Water Balance Model (WBM) under RCP26 climate scenarios. Figure 2 shows the classification of basins in SIMPLE-G-China model and their projected percentage change in irrigated water supply under BAU scenario, and table 3 shows the difference of irrigation water supply in four scenarios due to SNWTP.

Table 1 Socio-economic shocks

	Population	Per capita income	TFP (Crop)	TFP (Livestock)	TFP (Processed food)	Biofuel (BAU)
Eastern Europe	-8.98	289.98	28.94	32.56	27.17	0.00
North Africa	31.82	168.16	12.78	-7.55		0.00
Sub Saharan Africa	97.25	193.91	27.87	11.87		0.00
South America	19.72	107.22	18.10	109.03		128.15
Australia/New Zealand	32.56	55.96	36.29	11.87		531.07
European Union	2.96	44.13	36.29	14.31		105.93
South Asia	25.09	316.50	29.65	59.99		504.68
Central America	25.43	94.98	18.10	109.03		128.15
Southern Africa	18.75	107.82	28.94	11.87		0.00
Southeast Asia	23.72	182.81	-15.70	93.86		261.54
Canada	19.40	31.46	36.29	11.87		87.69
USA	19.40	31.46	36.29	11.87		92.81
China	2.68	450.46	48.65	93.86		1500.62
Middle East	38.98	31.46	12.78	-6.34		0.00
Japan/Korea	-5.11	71.80	36.29	11.87		0.00
Central Asia	29.65	307.87	28.94	32.56		0.00

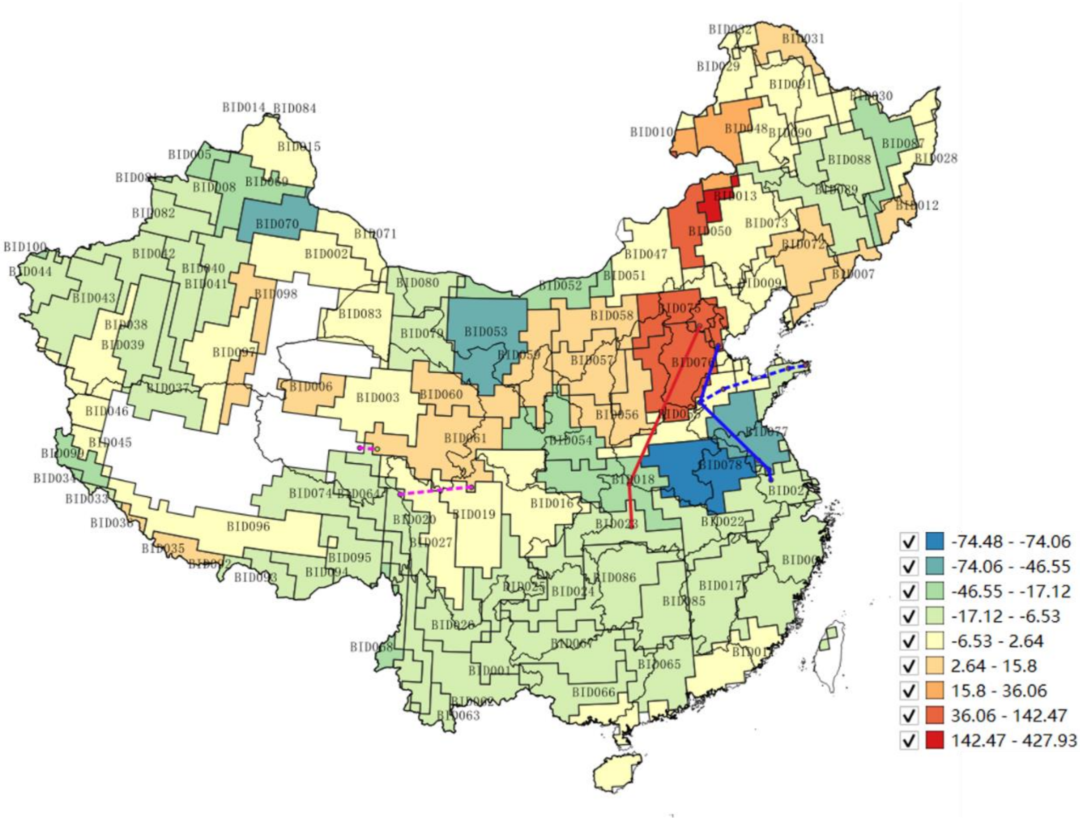

Figure 2 Water supply shock under BAU scenario

Table 2 SNWTP Shocks

BID	No SNWTP	BAU	CI	WP
BID018	-24.29	-23.49	-22.38	-21.73
BID019	-3.55	-3.55	-3.55	-1.83
BID020	-4.03	-4.03	-4.03	-1.82
BID021	-12.02	-12.53	-12.72	-13.19
BID023	-10.25	-10.70	-11.20	-11.52
BID027	-7.37	-7.37	-7.37	-10.52
BID055	-0.65	0.73	2.40	4.25
BID061	9.00	9.00	9.00	14.13
BID075	41.16	58.82	59.18	73.50
BID076	41.16	58.82	59.18	73.50
BID077	-68.48	-64.93	-63.16	-59.47

3 Results

To be updated.

4 Discussion

To be updated.

Funding Information

This study is supported by NSF under project "Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS: U.S.-China): A multi-scale integrated modeling approach to managing the transition to sustainability“.

Reference

Baldos, U. L. C., & Hertel, T. W. (2012). SIMPLE: a Simplified International Model of agricultural Prices, Land use and the Environment. *GTAP Working Paper*, 39.

Berkoff, J. (2003). China: The south–north water transfer project—Is it justified? *Water Policy, 5*(1), 1–28.

Chen, Z., Wang, H., & Qi, X. (2013). Pricing and water resource allocation scheme for the South-to-North Water Diversion Project in China. *Water Resources Management*, *27*(5), 1457–1472.

Hou, X. (2017). *SNWTP starts the 2017-2018 water transfer period (original text in Chinese, translated by authors)*. The State Council of People's Republic of China. http://www.gov.cn/xinwen/2017-11/02/content_5236668.htm

Liu, J., Hertel, T. W., Lammers, R. B., Prusevich, A., Baldos, U. L. C., Grogan, D. S., & Frolking, S. (2017). Achieving sustainable irrigation water withdrawals: Global impacts on food security and land use. *Environmental Research Letters*, *12*(10), 104009.

National Bureau of Statistics of China. (2020). Water supply and water use. In *China Statistical Yearbook 2020*.

Wang, H. (2021). *The accumulated waster transfer amount of SNWTP reaches over 40* *billion cubic meter (original text in Chinese, translated by authors)*. https://news.cctv.com/2021/02/08/ARTIQ3PaVq3sP87YfyS18aN4210208.shtml

Wang, Z., Liu, J., & Hertel, T. W. (2020). *The Uncertain Future of Biofuels in China and the Impacts on the Food-Land-Water Nexus: A Multi-scale Analysis*. the 23rd Annual Conference on Global Economic Analysis, Virtual Conference.

Zhang, D., Zhang, Y., Yang, Y., Li, B., & Li, Q. (2019). Numerical simulation of groundwater recharge from south-to-north water division project. *Journal Homepage: Http://Iieta. Org/Journals/IJHT*, *37*(1), 188–196.

Zhang, L., Wang, Z., Chai, J., Fu, Y., Wei, C., & Wang, Y. (2019). Temporal and Spatial Changes of Non-Point Source N and P and Its Decoupling from Agricultural Development in Water Source Area of Middle Route of the South-to-North Water Diversion Project. *Sustainability*, *11*(3), 895.

Zhu, J., Lei, X., Quan, J., & Yue, X. (2019). Algae growth distribution and key prevention and control positions for the Middle Route of the South-to-North water diversion project. *Water*, *11*(9), 1851.

Zou, J., Zhan, C., Xie, Z., Qin, P., & Jiang, S. (2016). Climatic impacts of the Middle Route of the South-to-North Water Transfer Project over the Haihe River basin in North China simulated by a regional climate model. *Journal of Geophysical Research: Atmospheres*, *121*(15), 8983–8999.