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

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Presented by Zhan Wang

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Introduction

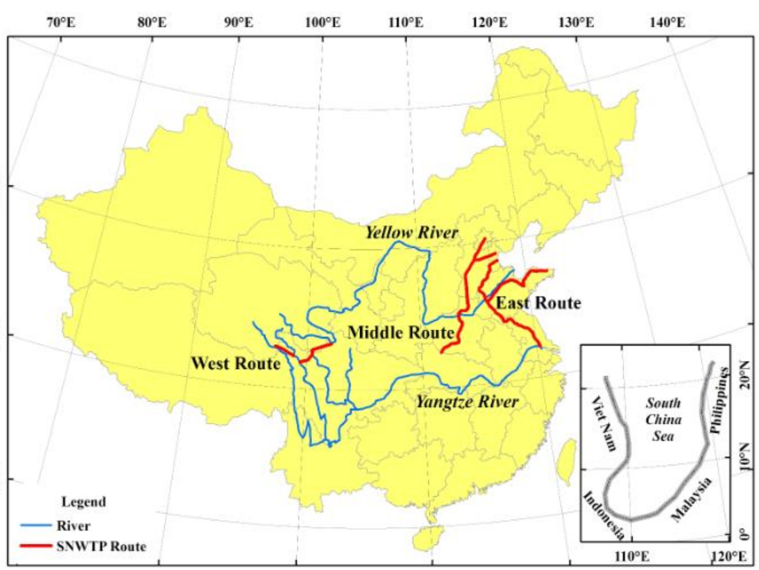
South-North water transfer project (SNWTP)

- Main purpose: relieve water deficit in North China
- Eastern, central and western routes, linking Yangtze river and Yellow river basins
- Multi-stage project

Stage 1 of eastern and central routes were completed 2013-14. Western route is still under planning.

2 Water donating provinces:
Jiangsu, Hubei

5 Water receiving provinces:
Beijing, Tianjin,
Hebei, Shandong, Henan



Source: Figure 1 from Wilson et al., (2017)

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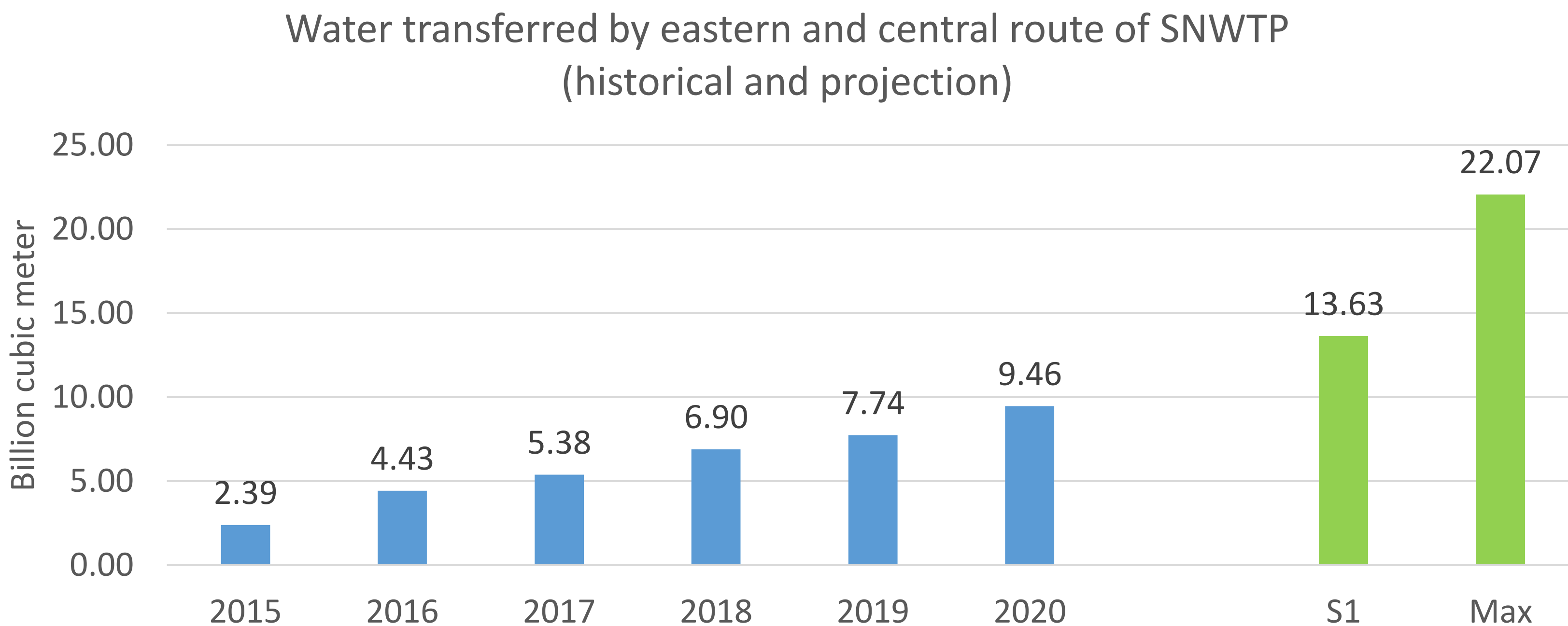
Introduction

South-to-North water transfer project (SNWTP)



Designed water capacity of stage 1 (**S1**): 19% of total water use in five water receiving provinces in 2019

Maximum capacity for all stages (**Max**): 31%

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Source: Ministry of Water Resources, (2003b, 2003a).
http://www.gov.cn/xinwen/2015-12/08/content_5021383.htm
http://www.chinanews.com/sh/2016/11-01/8049852.shtml
http://www.gov.cn/xinwen/2017-11/02/content_5236668.htm
http://news.sina.com.cn/o/2018-01-19/doc-ifyquixe4804350.shtml
https://news.cctv.com/2021/02/08/ARTIQ3PaVq3sP87YfyS18aN4210208.shtml

Introduction

Importance of SNWTP

- SNWTP has moderate impacts on water supply for donating basins, but has great impacts for receiving basins

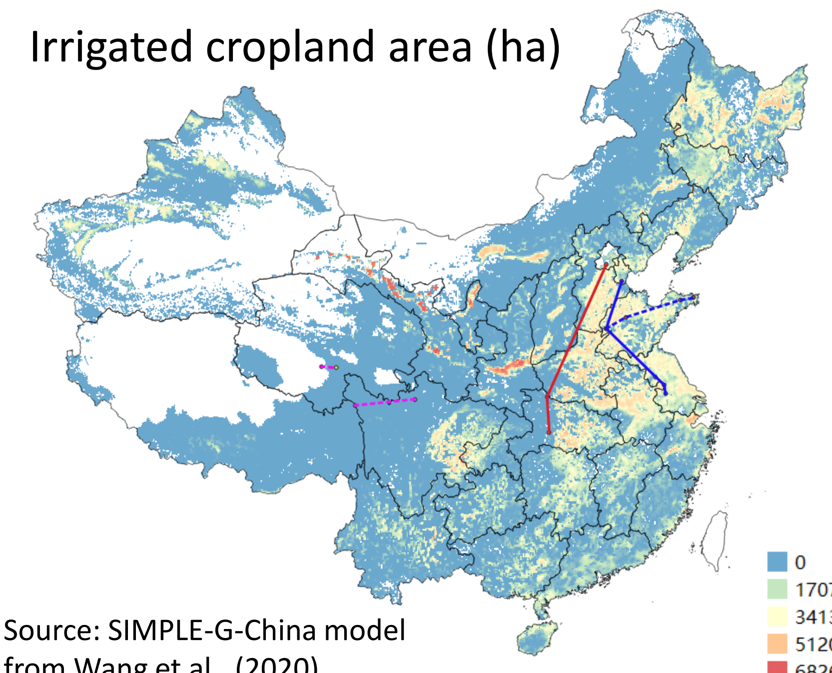
Water transferred
as % of agricultural water supply

Basins	2017	2050 S1	2050 Max
Water donators	0.60	1.19	1.78
Water receivers	3.03	7.33	11.77

Source: Ministry of Water Resources, (2003a, 2003b)
Water balance model (WBM) projection.

- SNWTP's water receiving basins cover major irrigated cropland in central China

Irrigated cropland area (ha)



Source: SIMPLE-G-China model
from Wang et al., (2020)

Introduction

- **Motivation**
  - Potential of SNWTP to alleviate water shortage in irrigation-dependent North China
  - ‘Foot race’ between water demand and supply driven by pop & income growth, tech change, and climate
  - Present vs. future impacts of SNWTP

- **Research question**: How will SNWTP affect the land-water-food system in China?

- **Contributions**
  - Impacts of SNWTP on agriculture based on integrated hydro-economic modeling
  - The global-local-global (GLG) approach: macro driver=> local response=> feedback to macro
  - Multi-factor, multi-market linkages

Literature review

Existing studies on impacts of SNWTP and research gaps

- Existing studies focus on **hydrological and environmental** impacts of SNWTP
  - surface water allocation (Chen et al., 2013) & groundwater recharge (D. Zhang et al., 2019)
  - water pollution (L. Zhang et al., 2019)
  - bio-diversity (Zhu et al., 2019)
  - local climate change (Zou et al., 2016)

- However, little is known about the impact of SNWTP on **agriculture**

- SNWTP has the potential to help China achieve the **dual goals** of food security and environmental sustainability (Berkoff, 2003)

- Devils in the detail! Endowment and ag production technology are all **spatially heterogeneous**, whereas existing analysis mostly done at the national or provincial level, lack of local details.

Methodology

We use the **S**implified **I**nternational **M**odel of agricultural **P**rices, **L**and use and the **E**nvironment: **G**ridded version for **China** (**SIMPLE-G-China**) model to evaluate

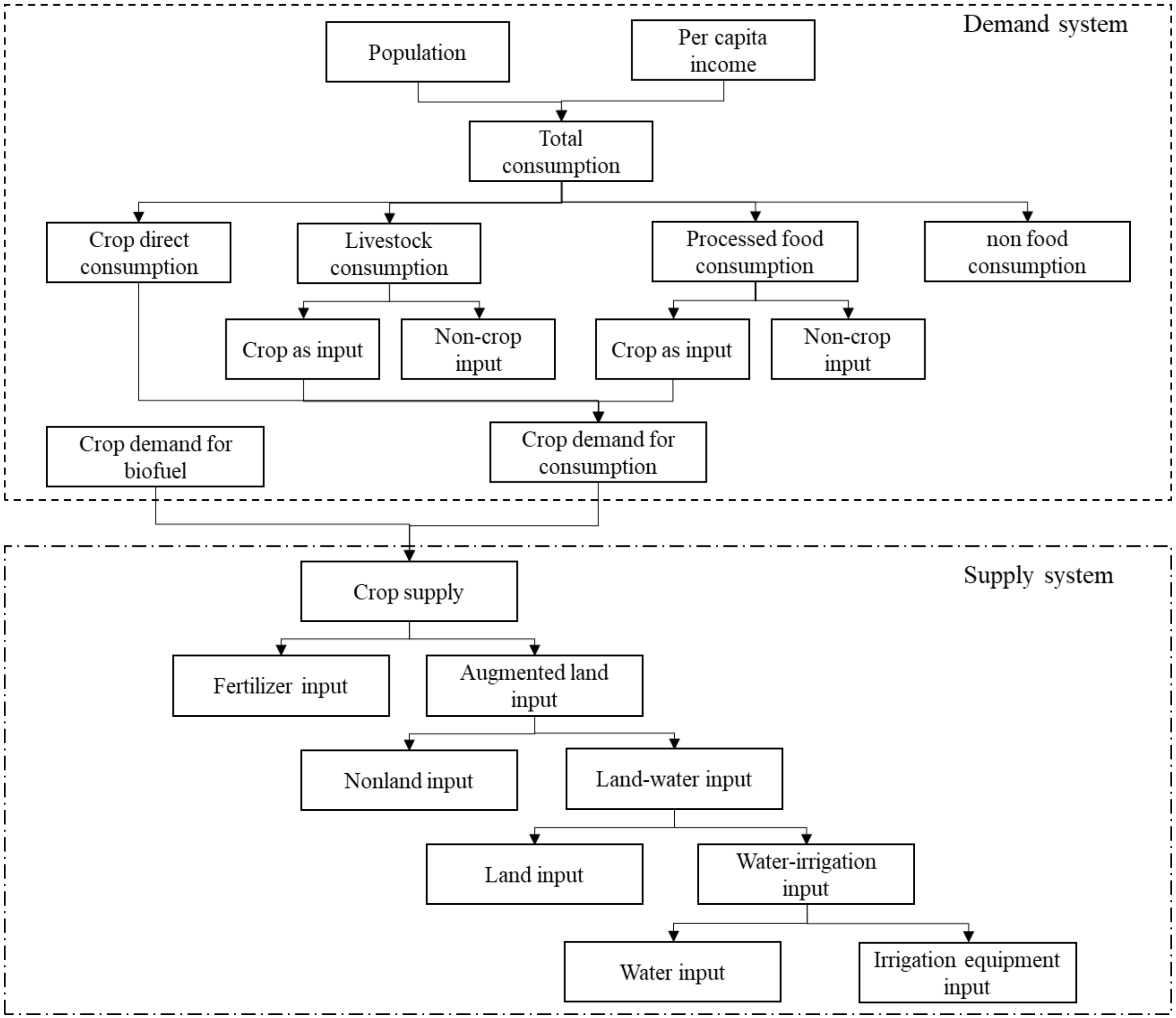
- Impact of water transfer from SNWTP in 2017 vs. 2050 under different transfer plans

SIMPLE-G-China

- Grid-specific crop production and input (e.g., land, water, fertilizer) use
- Have been applied to evaluate impacts of biofuel expansion (Wang et al., 2020), Grain-to-Green program (working paper)
- Global-local-global (GLG) approach

Methodology

Basic structure of SIMPLE-G-China

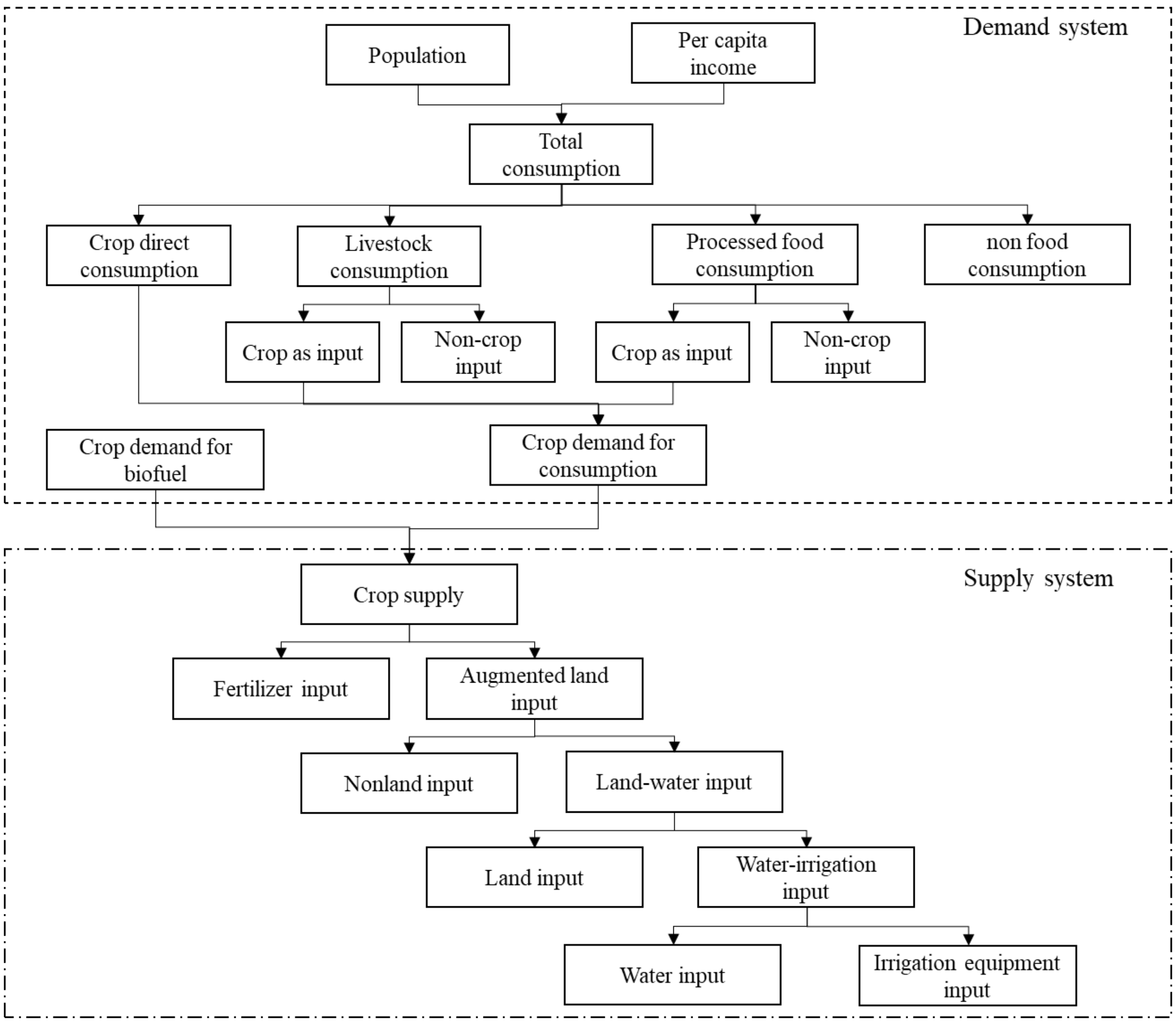


Socio-economic drivers → national crop demand

Response of crop production and input use → spatial crop supply

Methodology

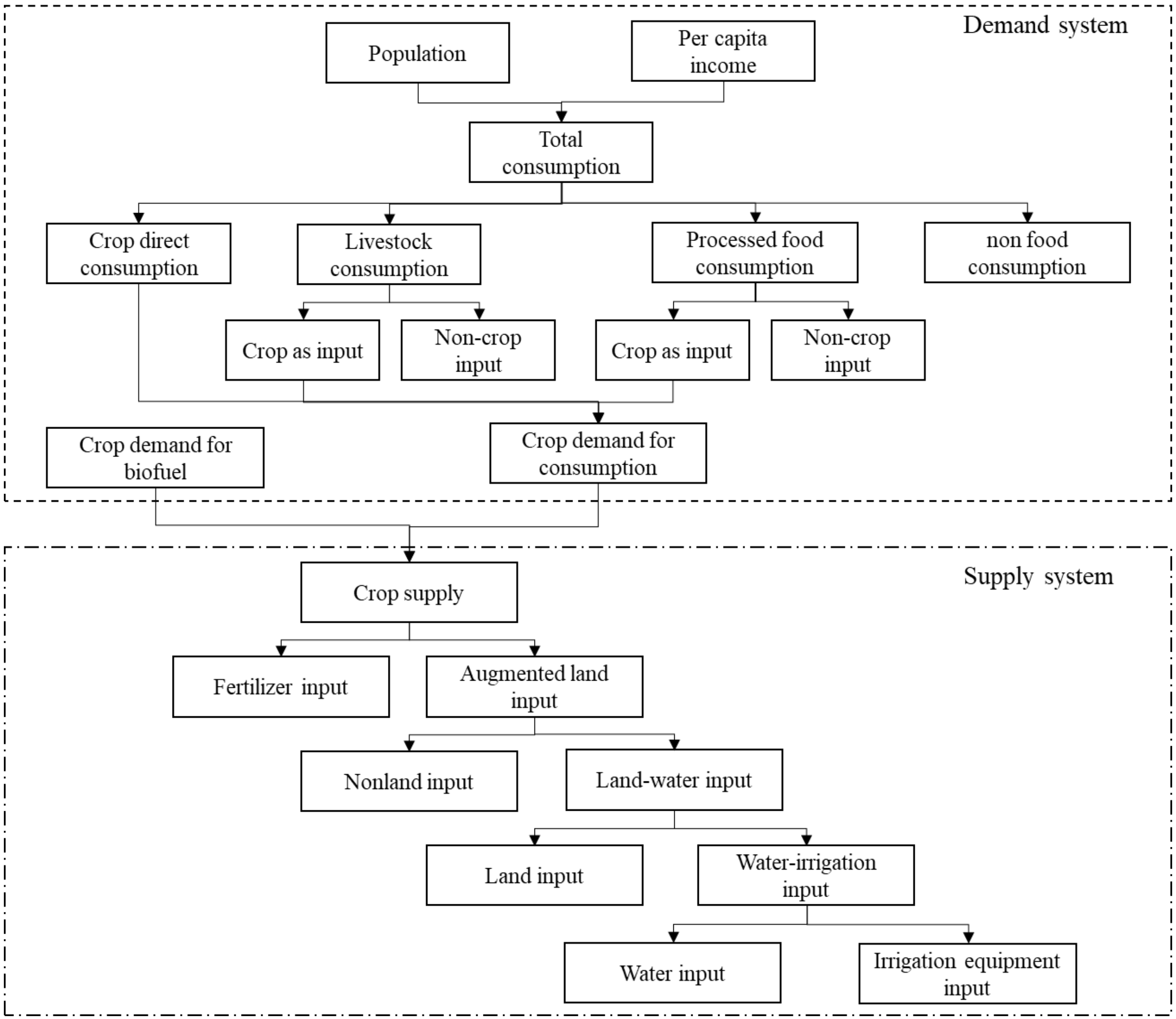
Basic structure of SIMPLE-G-China



For SNWTP basins: If exogenous ag water supply ↑
(1) Cost of irrigation ↓

Methodology

Basic structure of SIMPLE-G-China



(2) Crop production ↑
Other input use: uncertain
(Substitution of input: ↓
Expansion of production: ↑)

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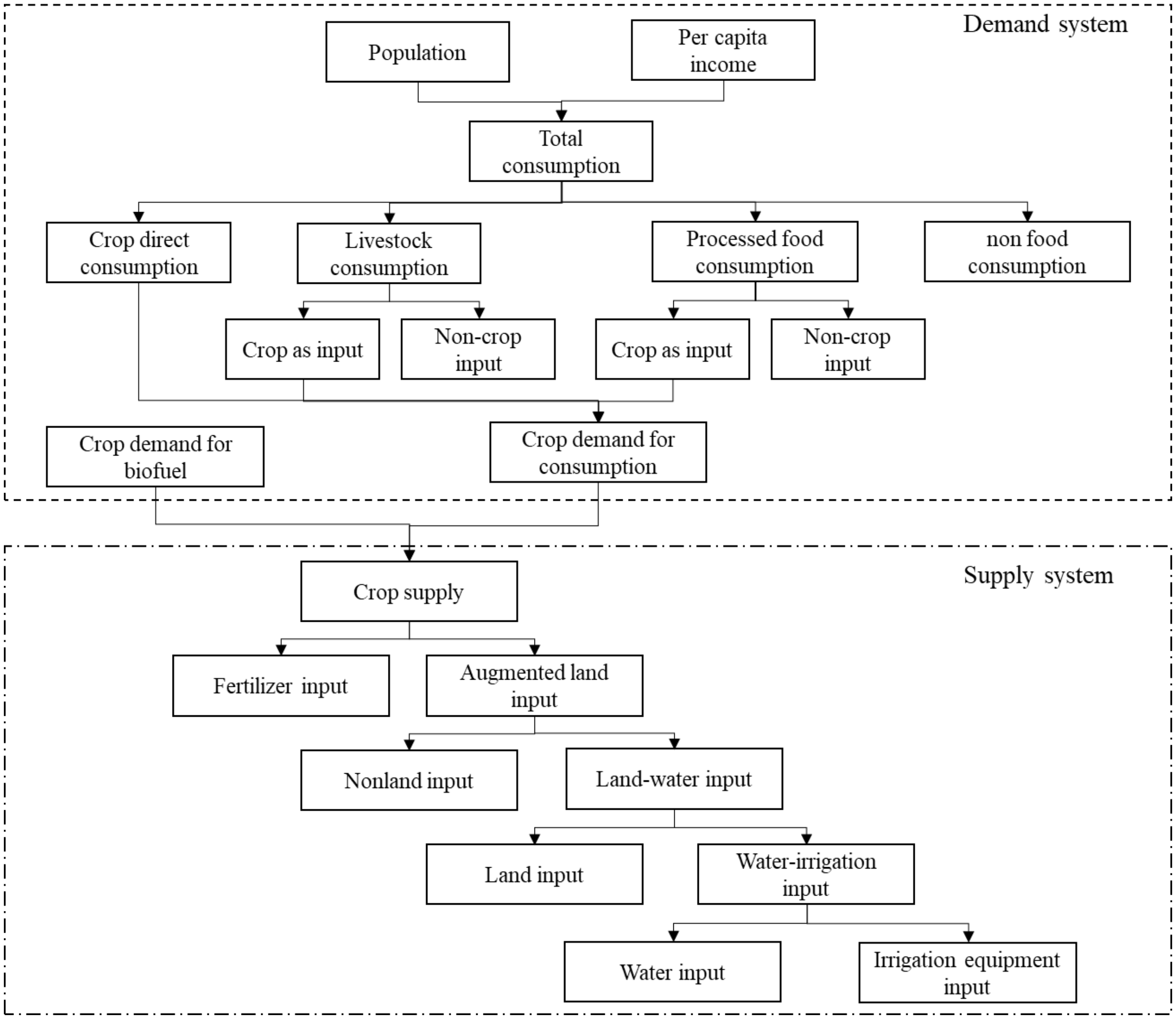
Methodology

Basic structure of SIMPLE-G-China



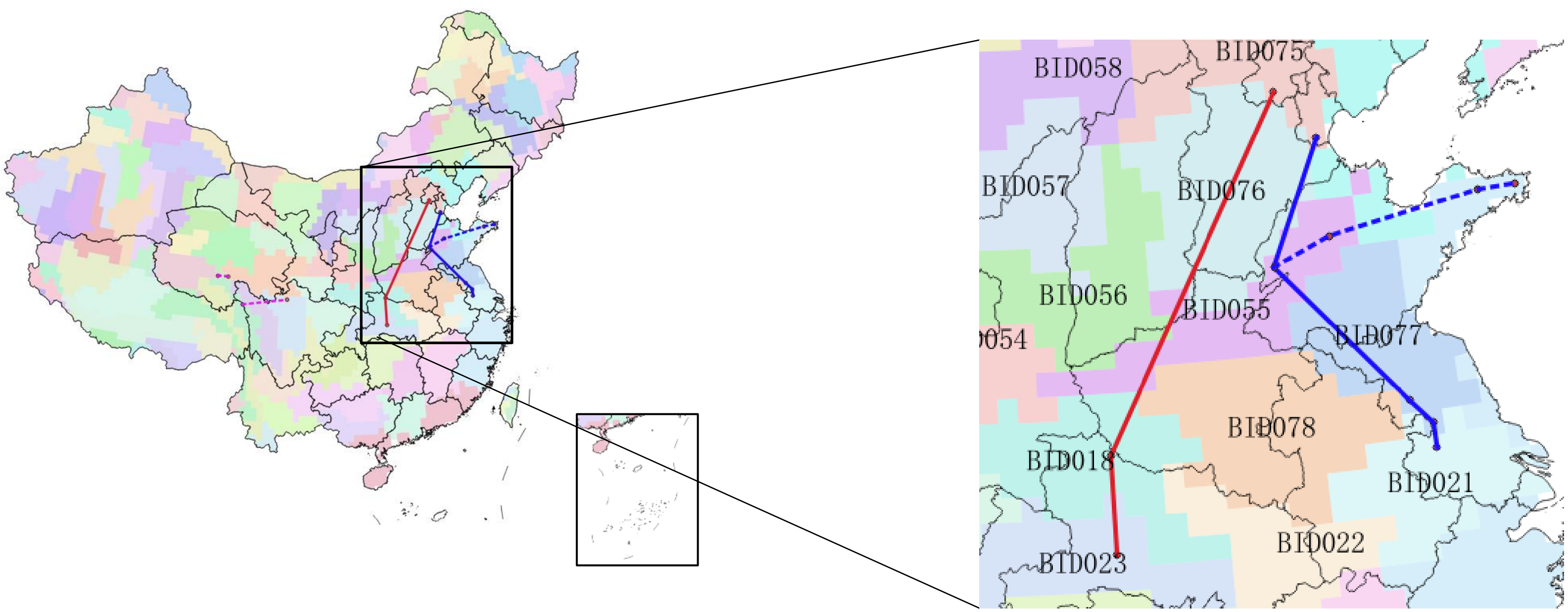
(3) Supply-demand equilibrium of crop
→ Affect crop production patterns

(2) Crop production ↑
Other input use: uncertain
(Substitution of input: ↓
Expansion of production: ↑)

For SNWTP basins: If exogenous ag water supply ↑
(1) Cost of irrigation ↓

Methodology

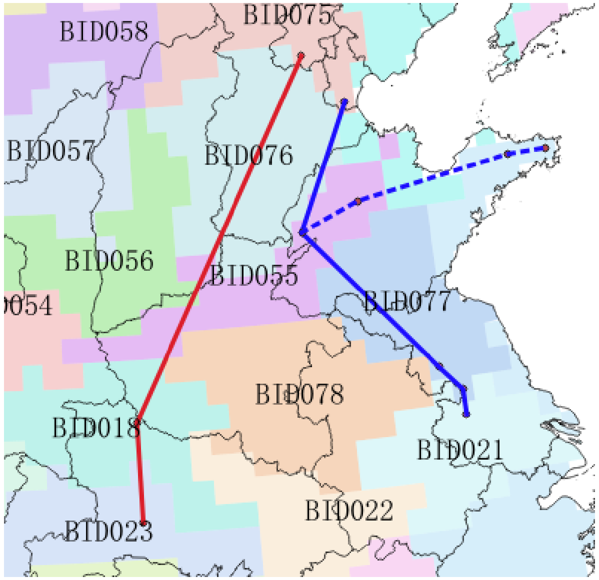
Focus: basins with water transfer from SNWTP



Methodology

Focus: basins with water transfer from SNWTP

Basin ID	Name	Route	Province
Water transferred from			
BID021	Chang Jiang, main-stem section: Region 6	Eastern	Jiangsu
BID023	Chang Jiang, main-stem section: Region 8	Central	Hubei
Water transferred to			
BID018	Chang Jiang, whole tributary: Region 3	Central	Hubei, Henan
BID055	Huang He, main-stem section: Region 2	Eastern, Central	Shandong, Henan
BID075	Hai Ho, main-stem section: Region 1	Eastern, Central	Beijing, Tianjin
BID076	Hai Ho, last upstream section: Region 2	Eastern, Central	Hebei



Methodology

Model baseline

- Based on 2017 data, reflecting the world with SNWTP water transfer

Experimental design:

- Simulate baseline without SNWTP in both 2017 and 2050 (consider macro-drivers and simulated changes in water supply by the WBM model)

- Impacts of SNWTP in 2017 and 2050 under three counterfactual scenarios

    1. No SNWTP in 2017 vs. observed water transfer
    2. No SNWTP in 2050 vs. assuming designed capacity of stage 1 (S1)
    3. No SNWTP in 2050 vs. assuming Maximum capacity (Max)

Data

Socio-economic drivers: percentage change by 2050

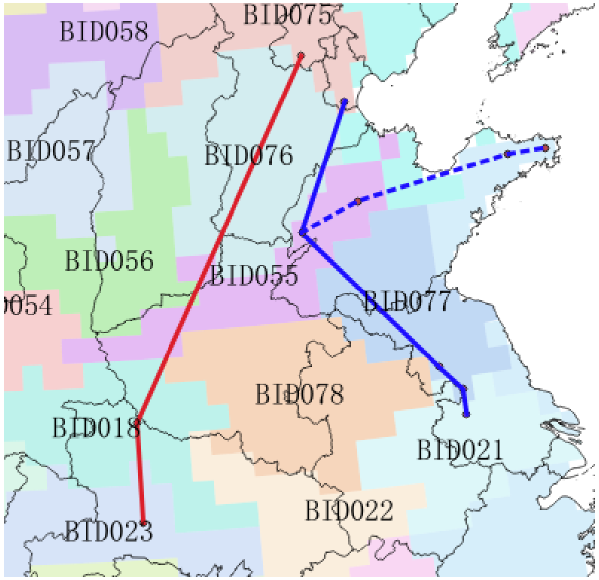
Region	Population	Per capita income	TFP (Crop)	TFP (Livestock)	TFP (Processed food)	Biofuel
Eastern Europe	-11.22	362.47	31.36	40.70		0.00
North Africa	39.78	210.20	88.53	-9.44		0.00
Sub Saharan Africa	121.56	242.38	29.23	14.83		0.00
South America	24.65	134.02	76.70	136.29		160.19
Australia/New Zealand	40.70	69.95	60.29	14.83		663.84
European Union	3.69	55.16	98.54	17.89		132.41
South Asia	31.36	395.62	46.32	74.98		630.84
Central America	31.79	118.73	46.79	136.29	**33.96**	160.19
Southern Africa	23.43	134.78	73.85	14.83		0.00
Southeast Asia	29.65	228.51	69.95	117.32		326.92
Canada	24.24	39.32	71.61	14.83		109.61
USA	24.24	39.32	71.61	14.83		116.02
China	**3.35**	**563.08**	**92.85**	**117.32**		**1875.78**
Middle East	48.72	39.32	59.25	-7.93		0.00
Japan/Korea	-6.39	89.75	103.74	14.83		0.00
Central Asia	37.07	384.83	31.36	40.70		0.00

Source: annual growth rate of population, per capita income and TFP: Hertel et al., 2014; annual growth rate of biofuel: calculated from World Energy Outlook projection

Data

Amount of water transferred by SNWTP (million m^3 / year)

Basin ID	2017 Baseline	S1	Max
Water transferred from			
BID021	-6511	-8937	-14817
BID023	-4492	-9700	-13000
Water transferred to			
BID018	795	1900	2546
BID055	1239	2741	4409
BID075	2156	2200	3948
BID076	491	3500	5691



Source: Ministry of Water Resources, (2003b, 2003a).
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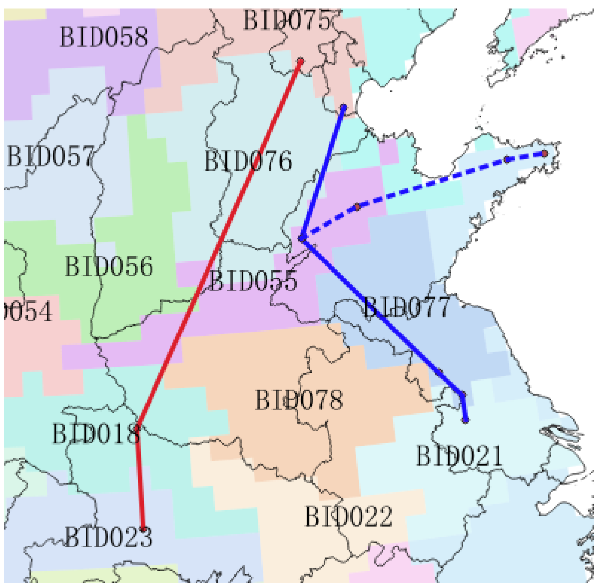
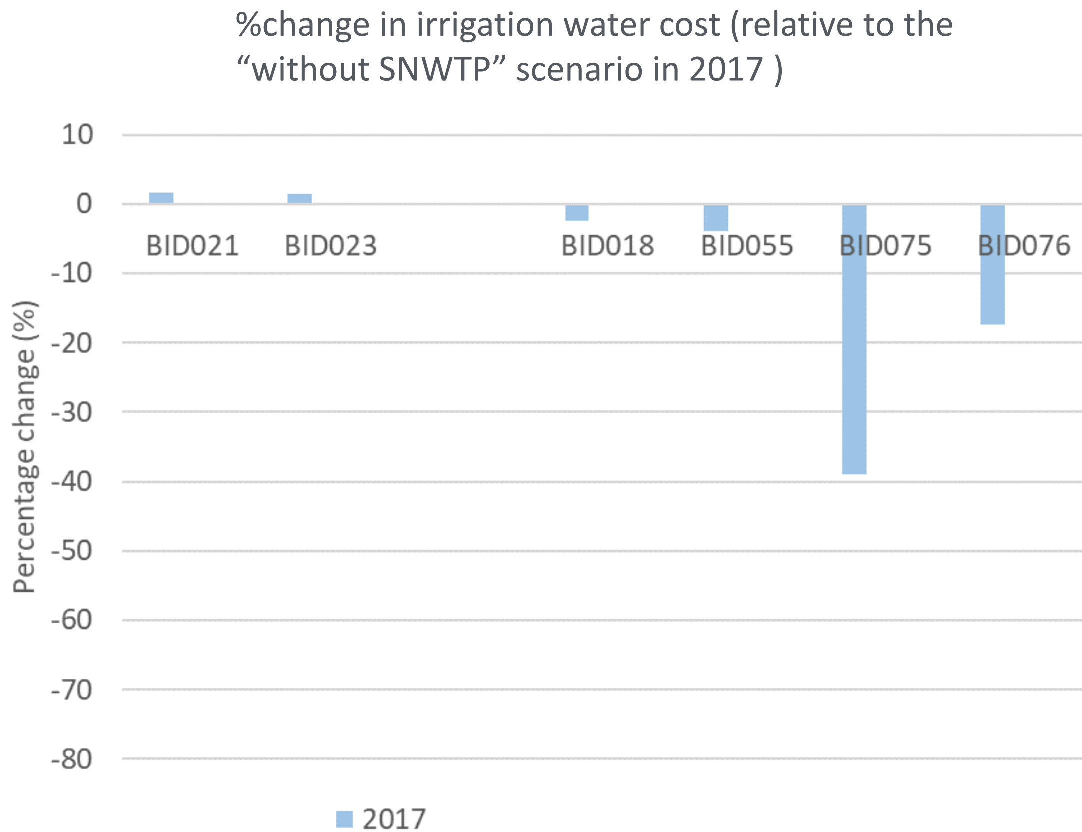
Results #1: impacts on irrigation cost

- SNWTP helps reduce the cost of irrigation in water receiving basins





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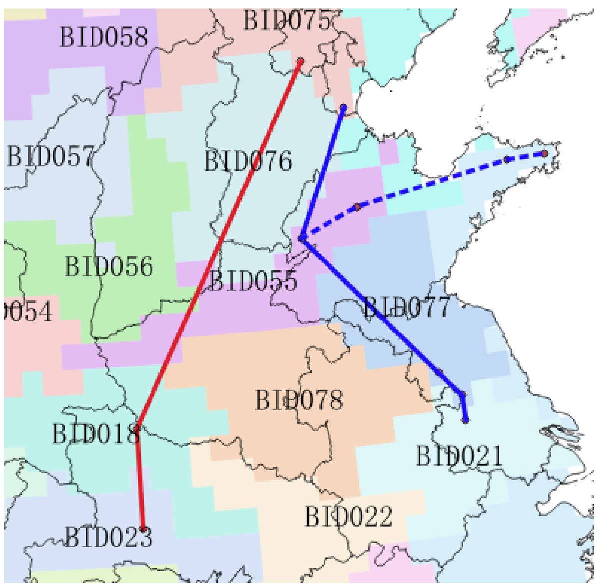
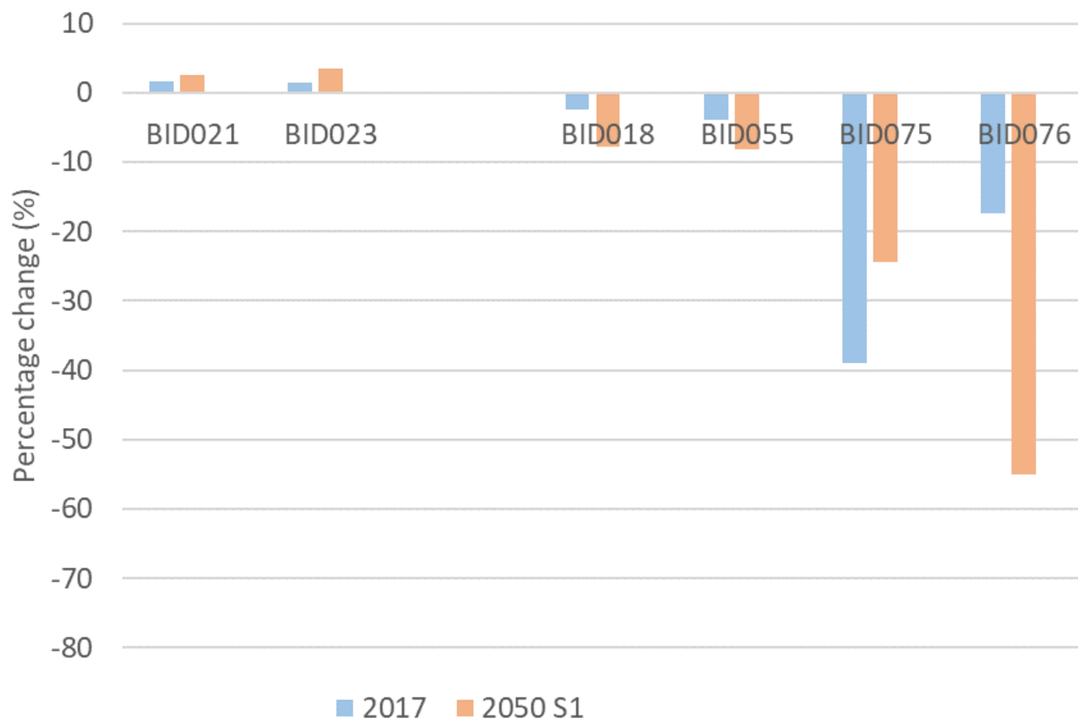
Results #1: impacts on irrigation cost

- SNWTP helps reduce the cost of irrigation in water receiving basins
- The cost-saving effect depends both on water supply and water transfer



%change in irrigation water cost (relative to the "without SNWTP" scenario in 2017 vs. 2050)



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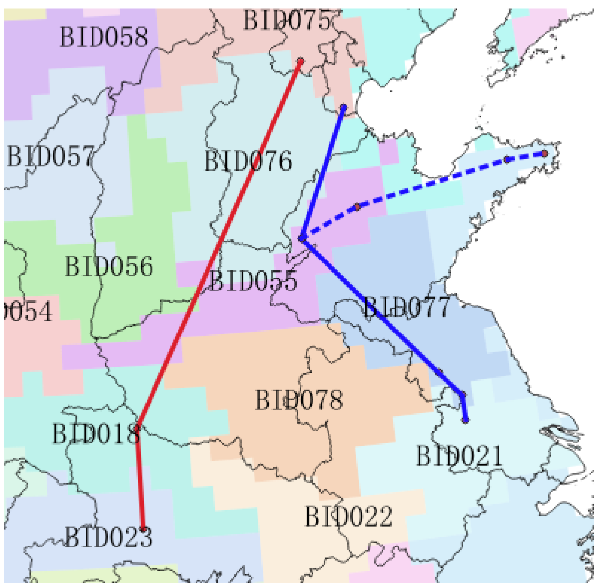
Results #1: impacts on irrigation cost

- SNWTP helps reduce the cost of irrigation in water receiving basins
- The cost-saving effect depends both on water supply and water transfer
- The impact is stronger as the amount of water transfer increases



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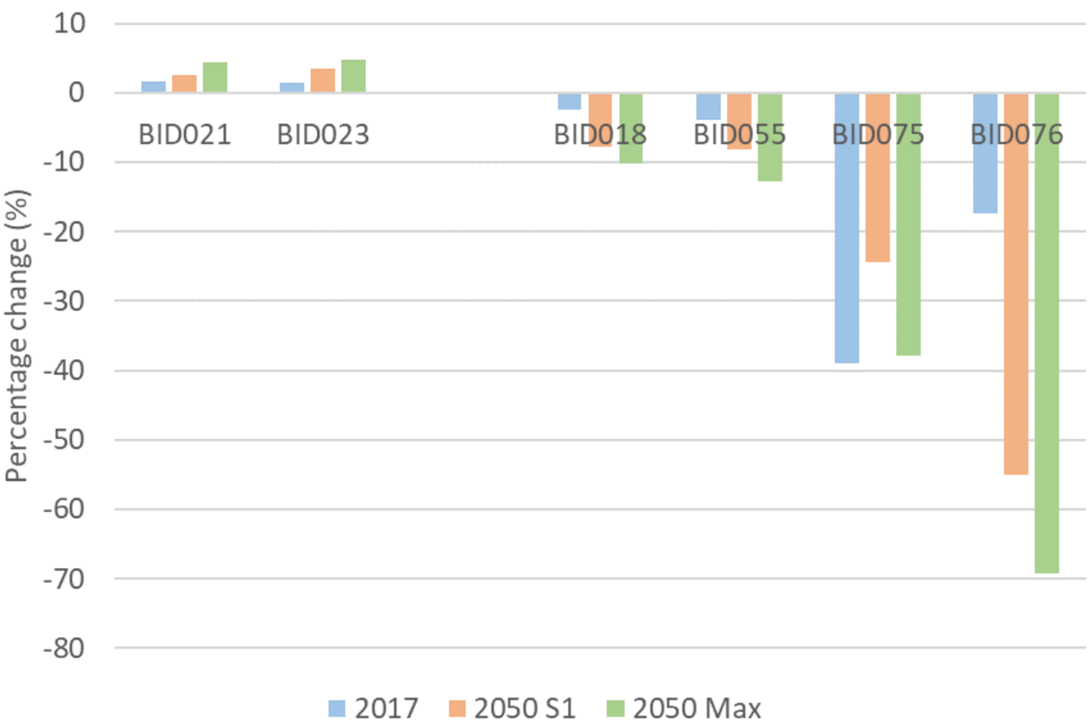

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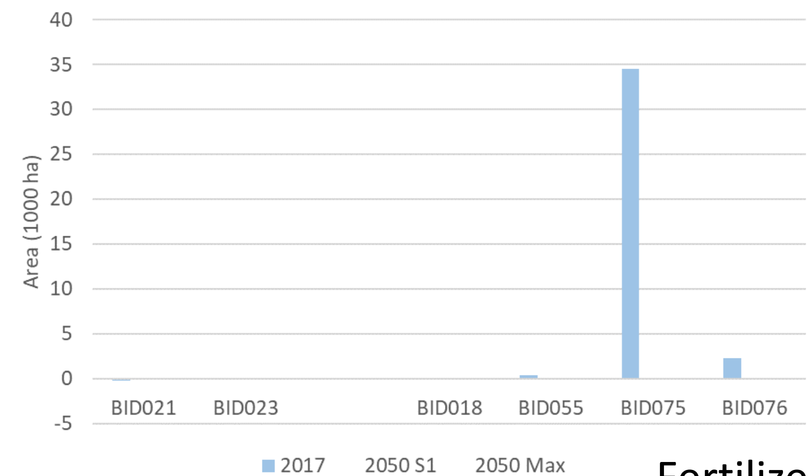
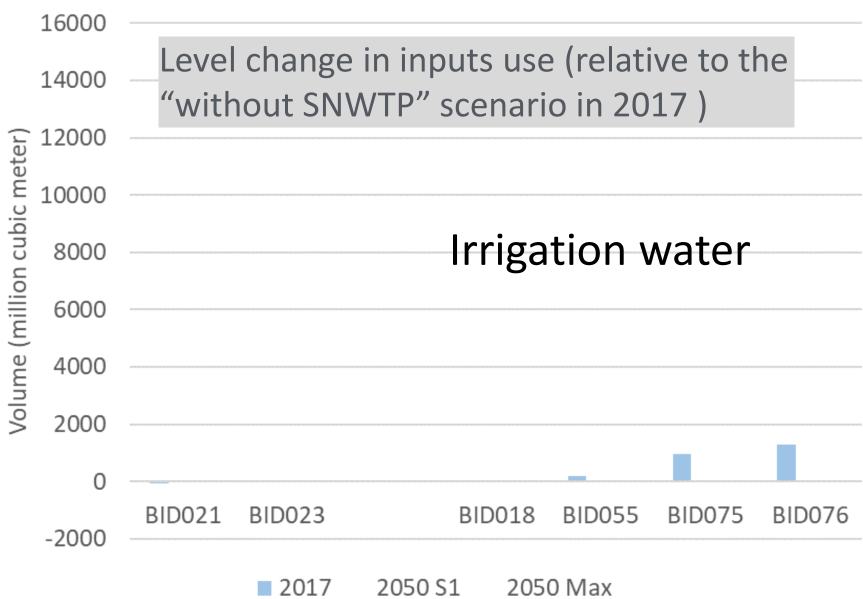
Results #2: impacts on input use

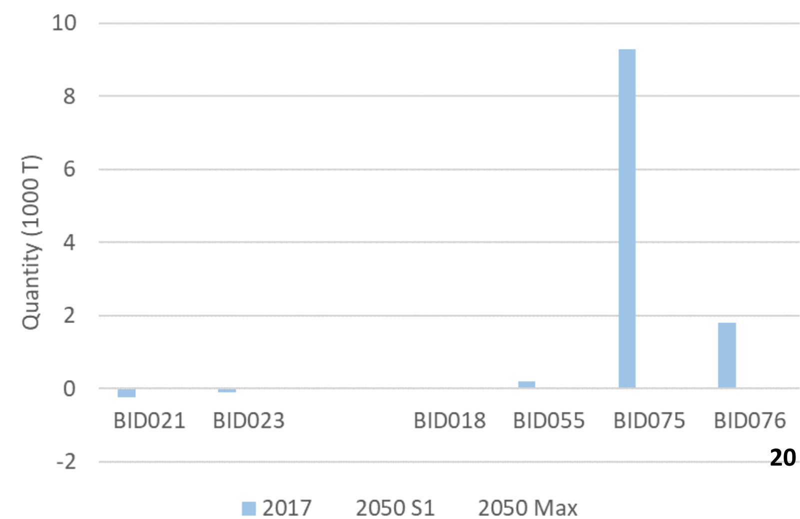
- With SNWTP, irrigation as well as the use of other inputs increase in water receiving basins

Cropland





Fertilizer



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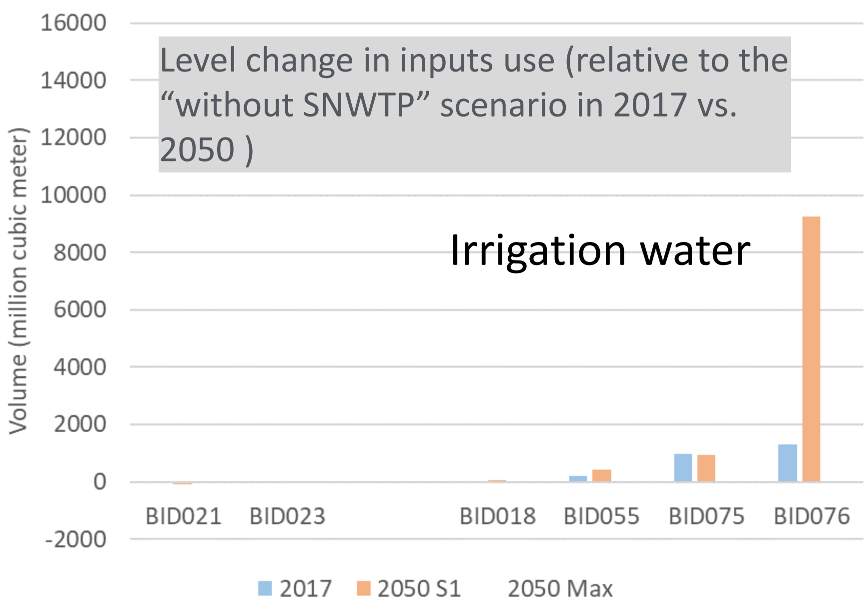
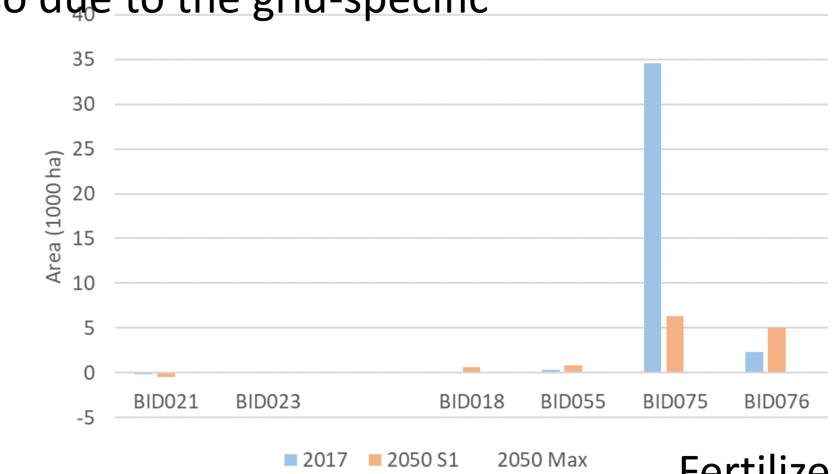
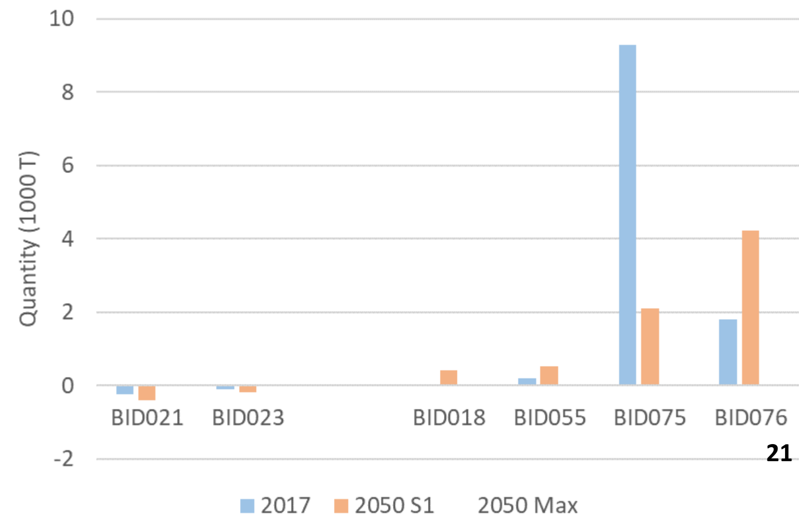
Results #2: impacts on input use

- With SNWTP, irrigation as well as the use of other inputs increase in water receiving basins
- The extent of increase varies by basin also due to the grid-specific substitution between inputs







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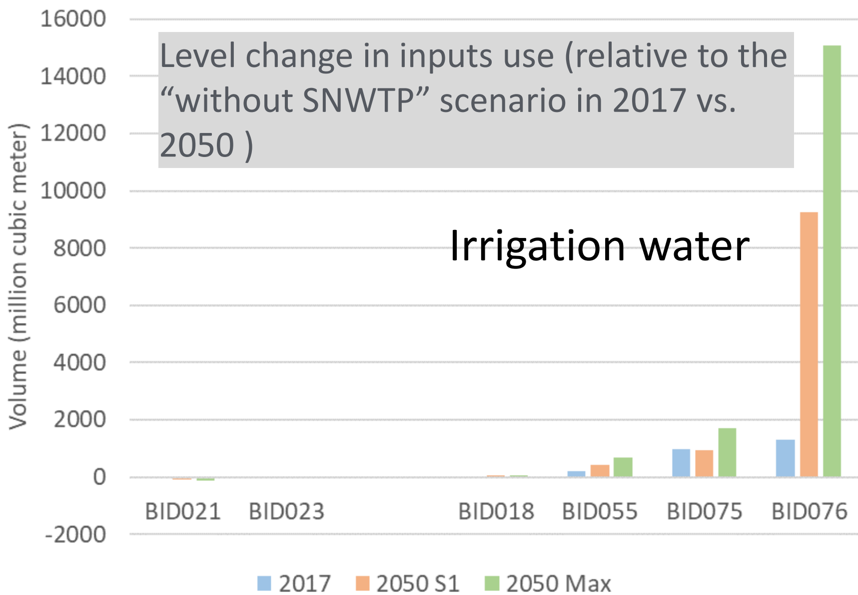
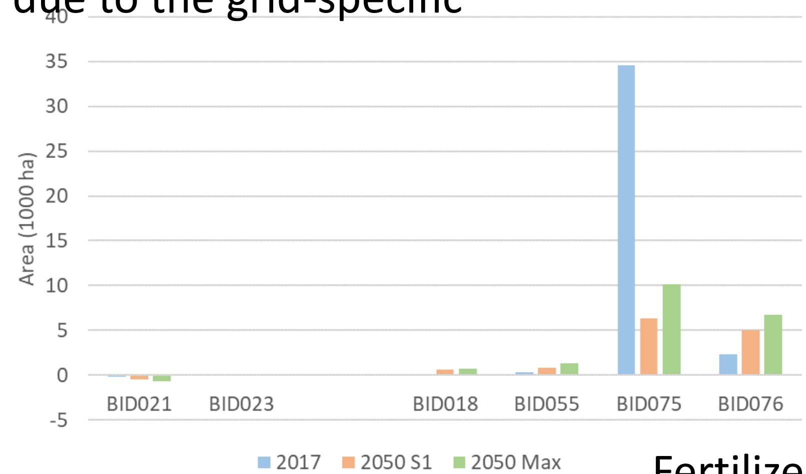
Results #2: impacts on input use

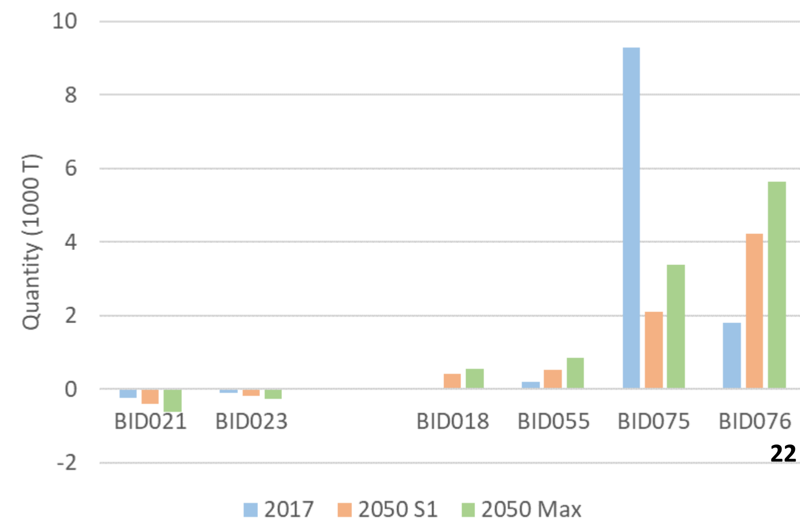
- With SNWTP, irrigation as well as the use of other inputs increase in water receiving basins
- The extent of increase varies by basin also due to the grid-specific substitution between inputs
- Holding other drivers constant,
  more water transfer => more input use



Cropland



Fertilizer



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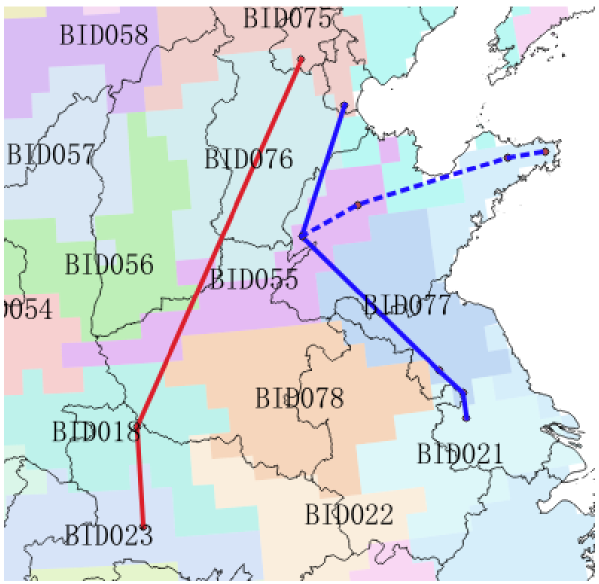
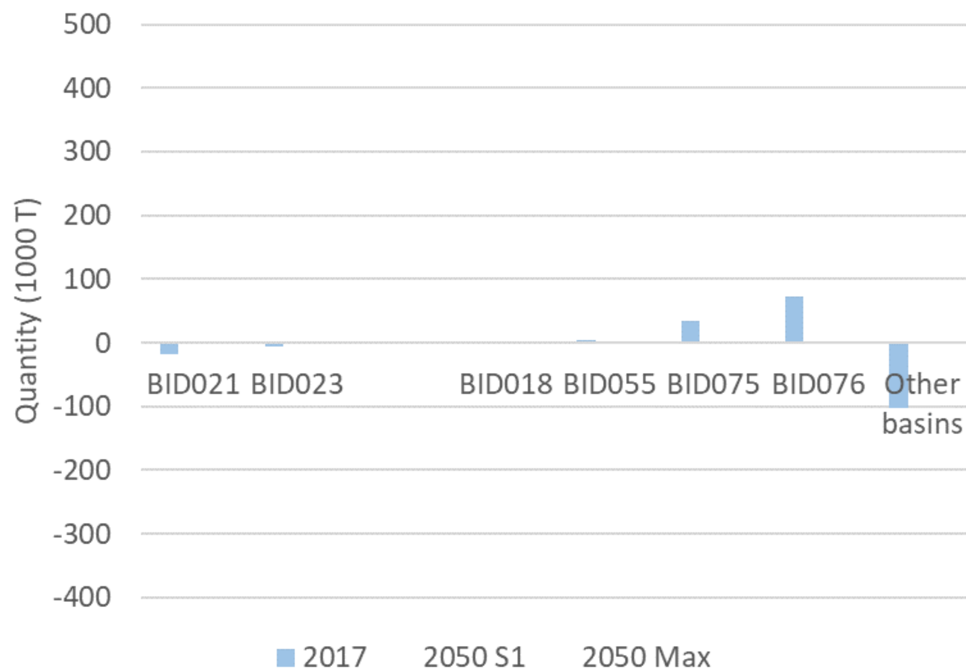
Results #3: impacts on crop output

- Crop output in water receiving basins increases accordingly
- SNWTP alters the spatial pattern of crop production

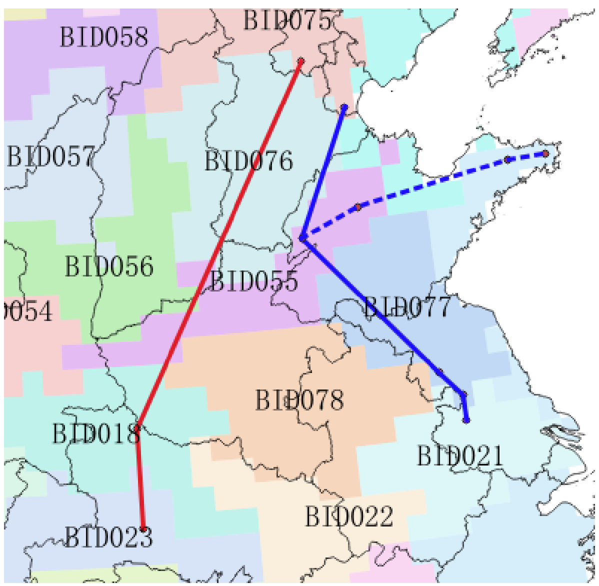
Level change in crop output (relative to the “without SNWTP” scenario in 2017)



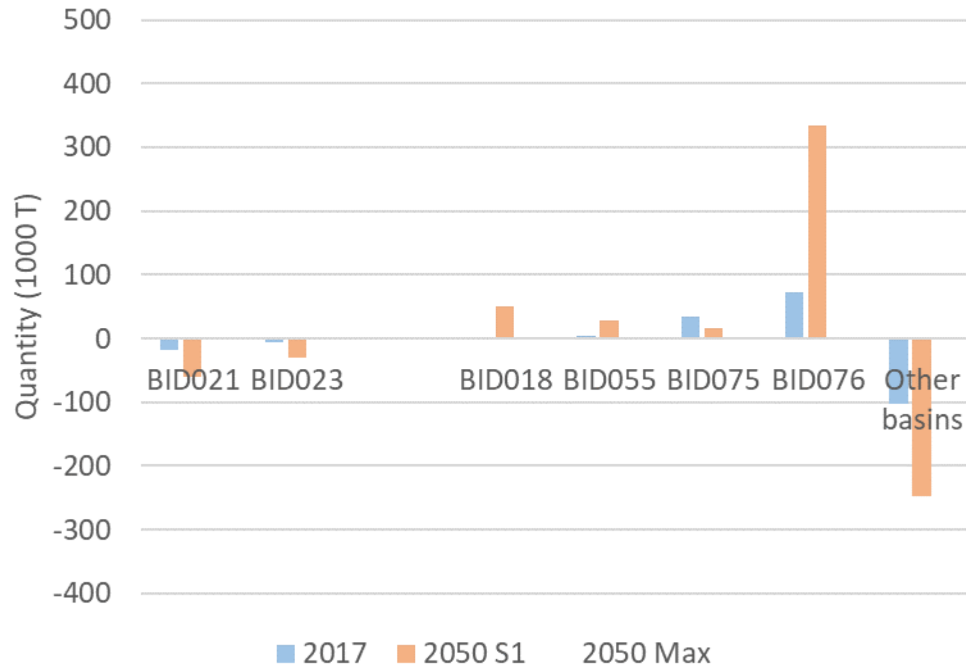


Results #3: impacts on crop output

- Crop output in water receiving basins increases accordingly
- SNWTP alters the spatial pattern of crop production
- Similar as input use, the impact on output varies



Level change in crop output (relative to the “without SNWTP” scenario in 2017 vs. 2050)



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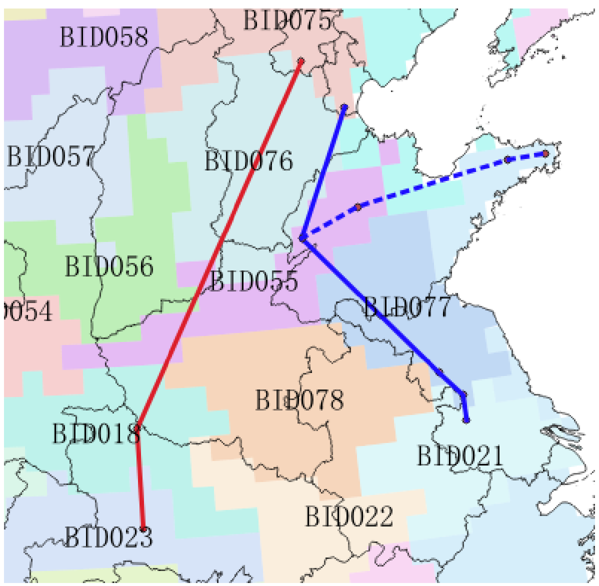
Results #3: impacts on crop output

- Crop output in water receiving basins increases accordingly
- SNWTP alters the spatial pattern of crop production
- Similar as input use, the impact on output varies
- … but more water transfer boosts production



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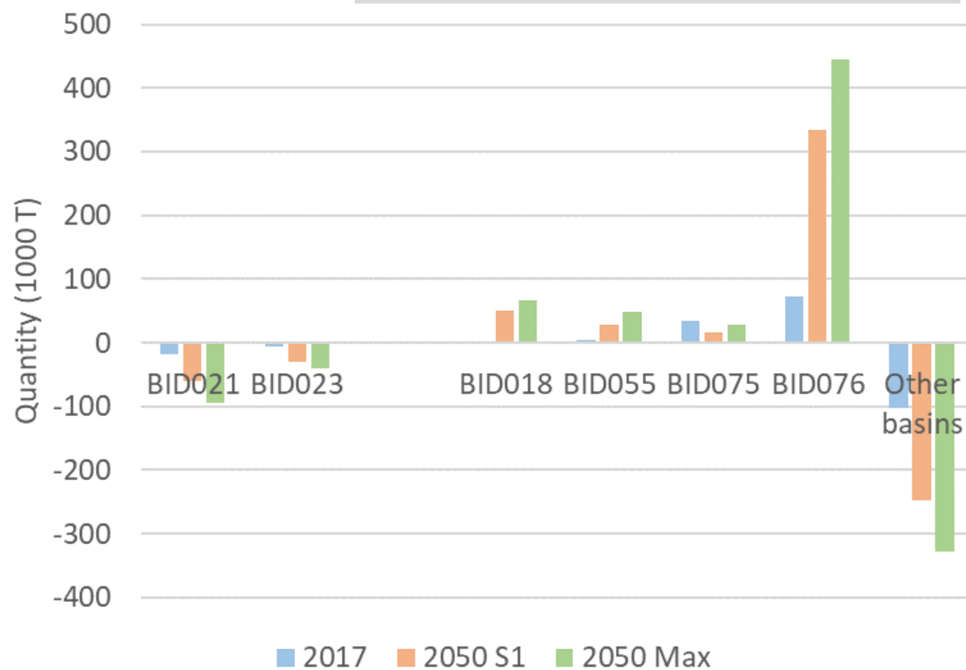

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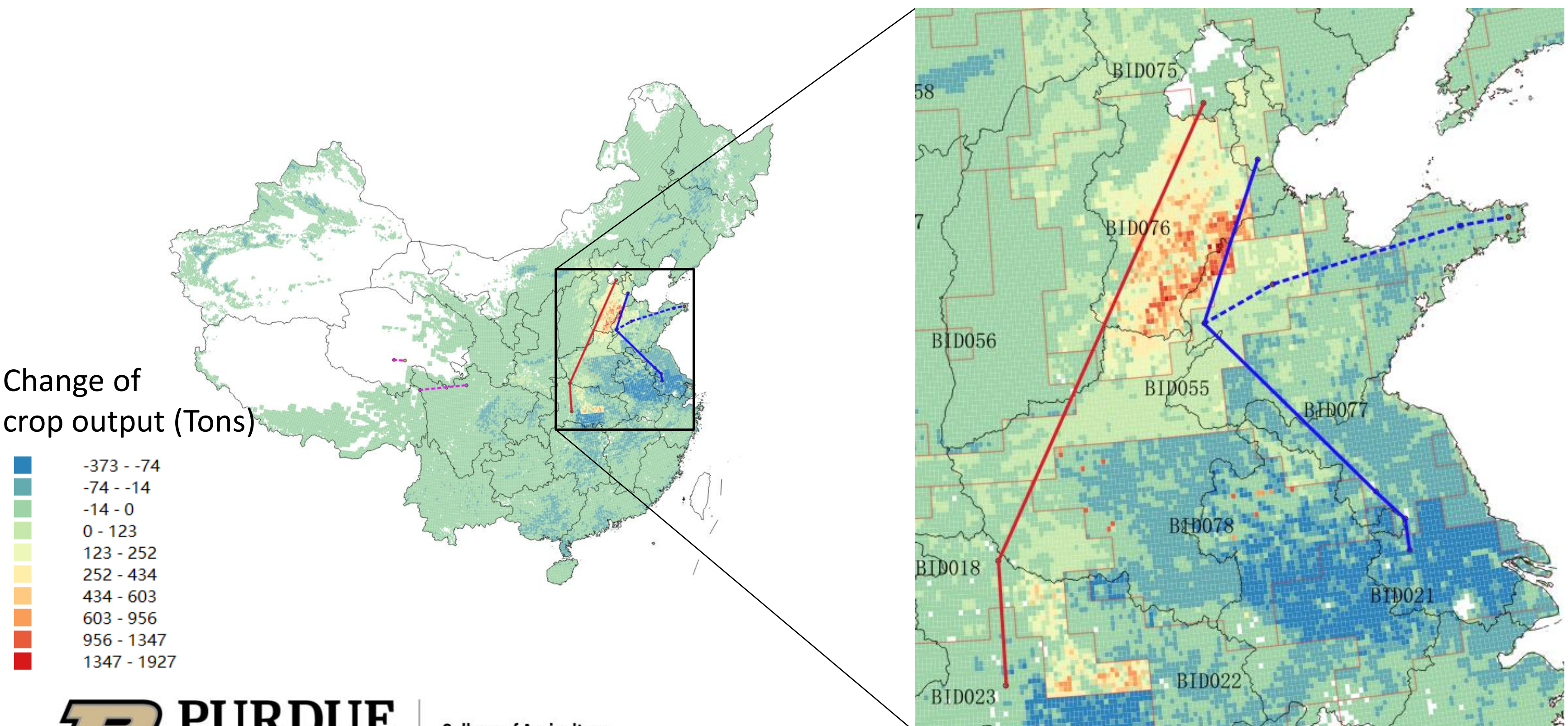
Results #3: impacts on crop output by grid

- Fine-scale modeling reveals sub-basin details



Conclusion

- SNWTP reduces **irrigation cost** in water receiving basins, encourages **inputs use** and boosts crop **production**.
- The impacts are **larger** as the amount of water transferred **increases**, and as competition for water becomes more intense in **2050**.
- SNWTP affects water **receiving** basins more than water **donating** basins. Non-SNWTP basins are moderately affected through **market linkages**.
- **Trade-offs** between sustainability goals! Increasing water supply could trigger cropland expansion and additional fertilizer use, causing other environmental issues.
- Impacts of SNWTP **vary across space**, indicating importance of **local policy**.

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Thank You!

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More information about studies with multi-scale approach is available at Purdue’s Global to Local Analysis of Systems Sustainability (GLASS) initiative group (https://mygeohub.org/groups/glass)