The Uncertain Future of Biofuels in China and Impacts on the Food-Land-Water Nexus: A Multiscale Analysis

Zhan Wang, Jing Liu, Thomas Hertel

Presented by Zhan Wang

23rd Annual Conference on Global Economic Analysis, June 19, 2020

PURDUE UNIVERSITY | College of Agriculture

PURDUE UNIVERSITY GLASS
Global to Local Analysis of Systems Sustainability

Introduction

Motivation: Biofuel for China's sustainable development

- Biofuel would be an important energy source for China's sustainable development
  - Serve as a renewable energy source, increase energy self-sufficiency
  - Provide co-benefits on air pollutants and green-house gas emission reduction
  - Increase agricultural returns, promote rural development

Introduction

Motivation: Projections of biofuel in China

- Short-term projection: China's 13th five-year-plan on bioenergy development aims at increasing liquid biofuel production **by about 100% from 2015 to 2020**

Production and target of liquid biofuel in China

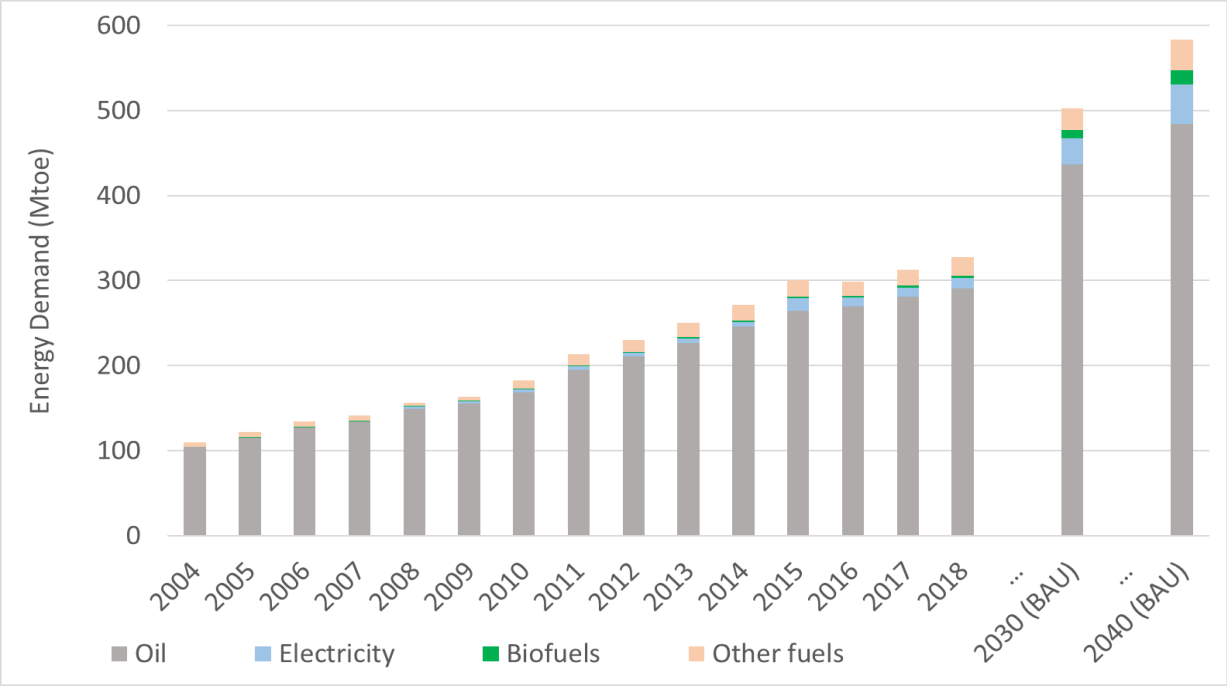
	2015	2018	2020 (planned)
Bioethanol	2.1 MT	3.2 MT	4.0 MT
Biodiesel	0.8 MT	1.0MT	2.0 MT

Data source: National Energy Administration of China (2016), Li (2019)

Introduction

Motivation: Future of Biofuel in China

- Long-term projection: under business as usual (BAU) scenario, China's energy demand for transportation sector increases **400% from 2017 to 2030, and 700% to 2040**.



China's Energy demand for transportation sector, 2004 - 2040

Data source: World Energy Outlook (WEO) (IEA (2006) – IEA (2019))

Introduction

- However, uncertainties exist for biofuel's future development

  Competition between energy crop and grain crops

  Population growth and economic development

Research questions

- How will biofuel expansion in China influence its food-land-water nexus?
- Especially, what will be the impacts at the national and local level?

Major contributions

- Explore the impact from economic framework: substitution between inputs, effect of market, linkage of prices
- Adopt a multi-scale approach, focus on national drivers' local response
- Develop a workflow of establishing region-specific multi-scale models

Literature review

Impacts of biofuel on crop production and input use in China

- Biofuel expansion would cause **food price increase and land use change** towards energy crop (Weng et al., 2019).
- To plant energy crop on marginal land could mitigate those negative effects, but requires considerable irrigation **water and fertilizer** input (Fu et al., 2019) (Chen et al., 2017), which may become constraints for biofuel expansion.
- Studies mainly focus on national / province level, lacking **spatial heterogeneity**.

Literature review

Impacts of biofuel on crop production and input use in China

- Biofuel expansion would cause food price increase and land use change towards energy crop (Weng et al., 2019).
- To plant energy crop on marginal land could mitigate those negative effects, but requires considerable irrigation water and fertilizer input (Fu et al., 2019) (Chen et al., 2017), which may become constraints for biofuel expansion.
- Studies mainly focus on national / province level, lacking spatial heterogeneity.

Spatial response of biofuel expansion's impacts

- With remote sensing data, researchers further estimated **spatially varied bioenergy potential** (Nie et al., 2019; Wang et al., 2013)
- Studies with engineering-style approaches. Impacts of **price change and input substitution** are insufficiently researched.

Methodology

- We established 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

- Origin and extension of SIMPLE models

  SIMPLE framework (Hertel, 2011)

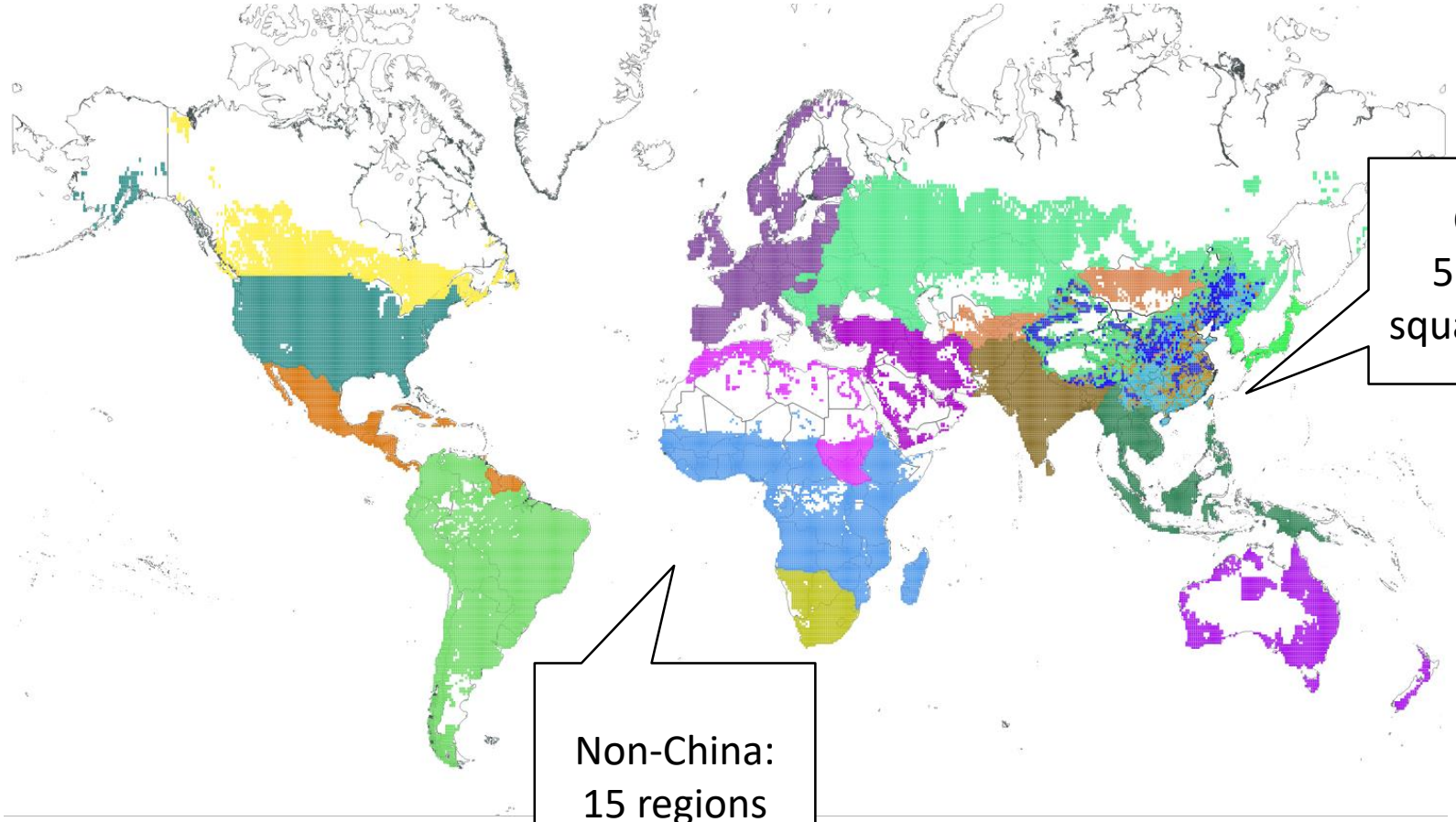
  SIMPLE model, regional aggregated version (Baldos & Hertel, 2012)

  SIMPLE-G model, grid-based version (Liu et al., 2017)

  Regional specific models with finer resolution: SIMPLE-G-US and SIMPLE-G-China

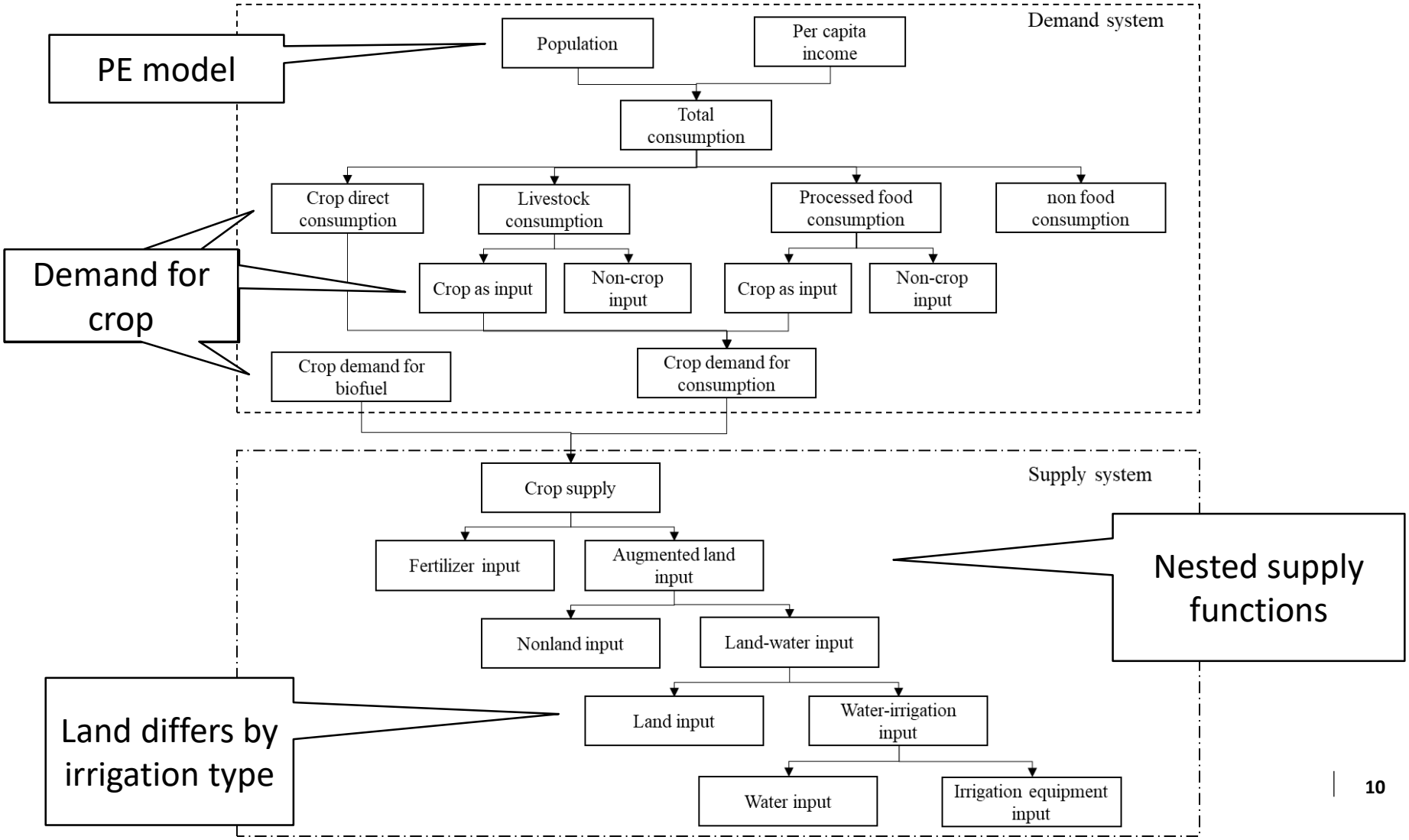
SIMPLE-G-China model introduction

- Crops aggregated to rice-equivalent
- Base year: 2017
- Spatial scope:



SIMPLE-G-China model introduction

- Model structure



SIMPLE-G-China model introduction

- Data sources

China specific

- Grid-cell level
  - **MODIS**: cropland
  - **Earthstat**: fertilizer use
  - **MICRA**: irrigation and harvest area
- Aggregated level
  - **China Statistical Yearbook**: output
  - **China Agricultural Products Cost-benefit Compilation of Information**: input and cost

All regions

- National/regional level
  - **FAO**: crop output, cropland
  - **World bank**: population, GDP, final consumption, CPI
  - **GTAP**: cost share (crop as input)
  - **WEO**: biofuel usage and demand projection

Experimental design

- We consider four future scenarios projecting from 2017 (baseline) to 2040:

  Business as usual (BAU): keeping current path of biofuel expansion

  Stated policies (STA): impacts from polices already announced but have not been implemented by base year

  Sustainable development (SUS): aiming at sustainable development goals

  Expansion is still (STL): no growth at the baseline level

- Scenarios have the same project exogenous change in population, per capita GDP, production technology and biofuel demand for non-China regions, only differ on crop demand for biofuel in China

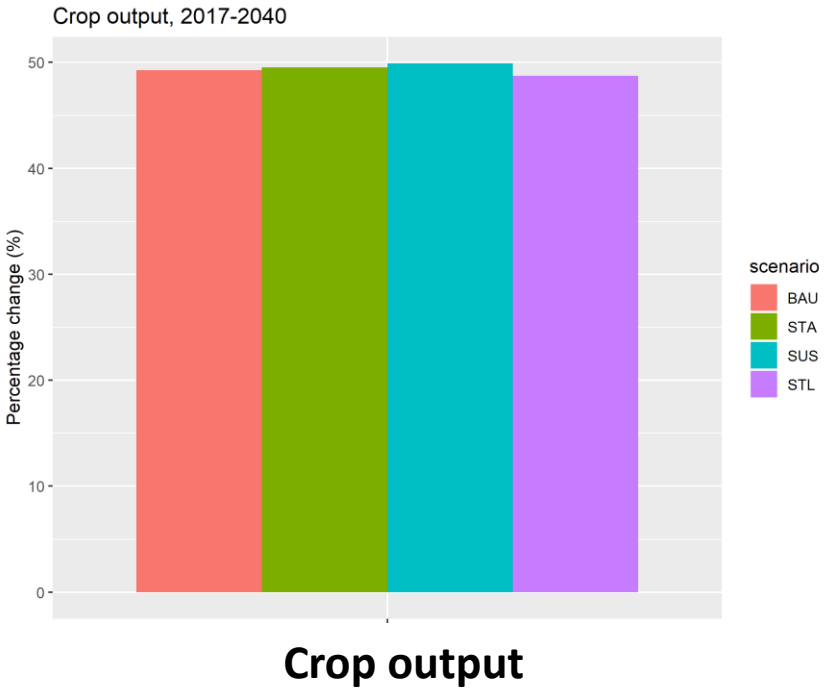
Exogenous shocks for China (% change from 2017)

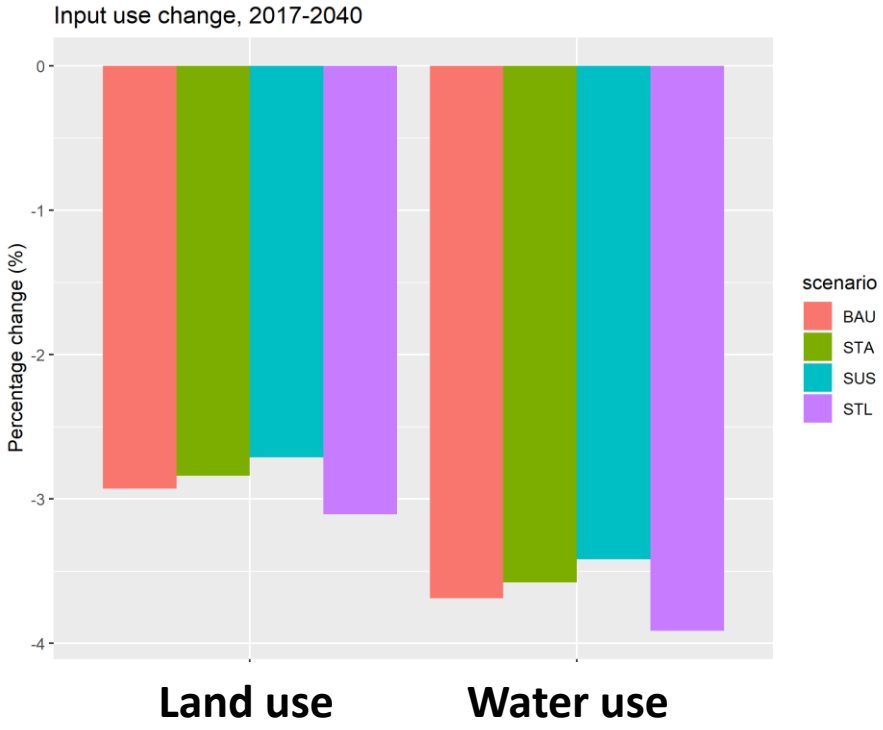
Scenarios	Population	Per capita GDP	TFP	Biofuel
BAU	2.33	273.77	Crop: 58.05, Livestock: 71.77 Processed food: 22.6	700
STA				1050
SUS				**1550**
STL				0

Projections source: Population, Per capital GDP and TFP: Hertel et al., (2014); Biofuel: IEA (2019)

Results

- National crop output would increase by 50%
- Inputs use would decrease slightly, by 2-5%, due to TFP growth
- Impacts of crop demand for biofuel also small (1-2%)

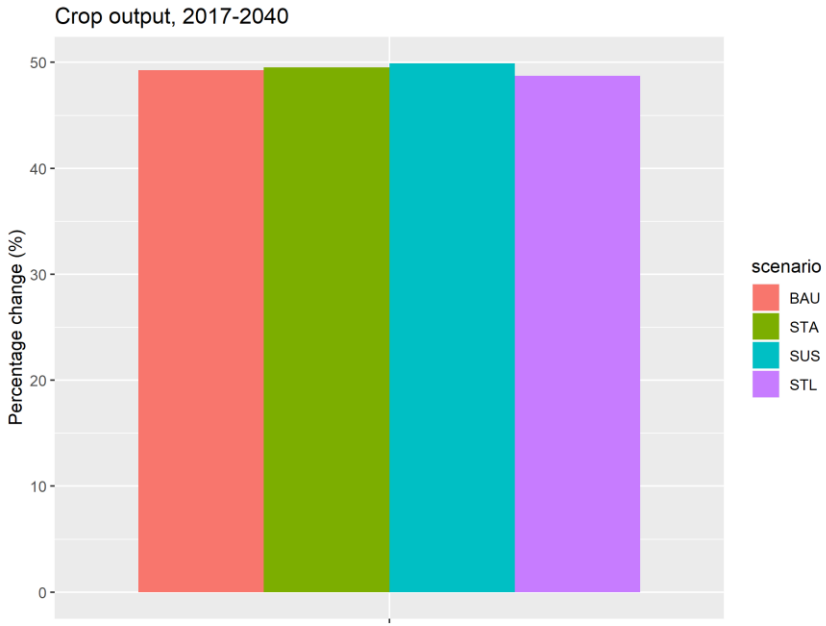




PURDUE UNIVERSITY | College of Agriculture

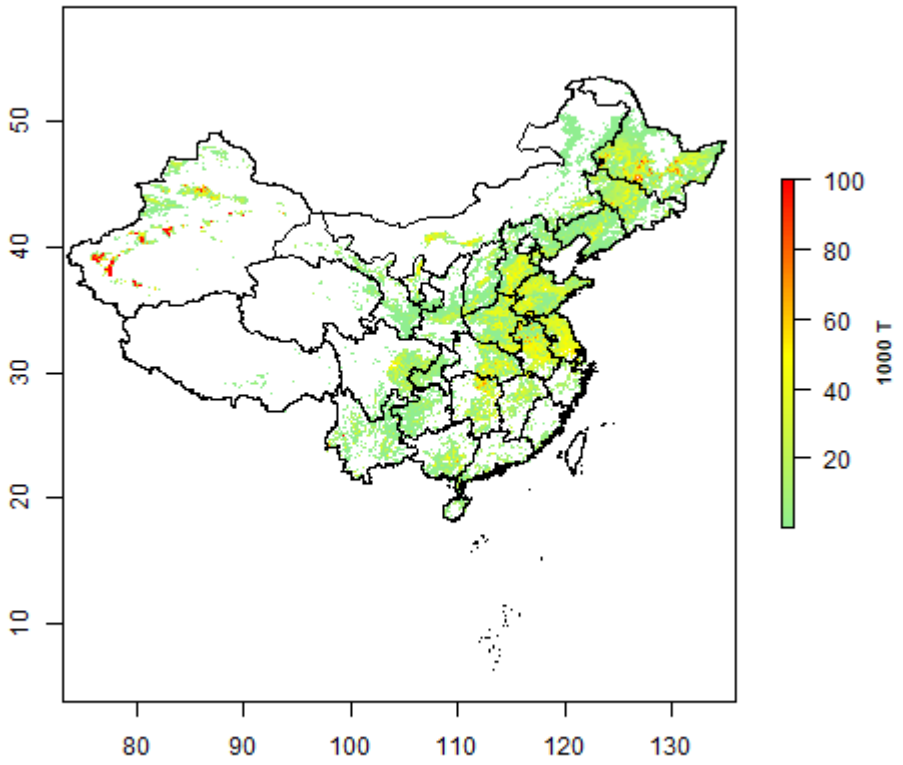
Results

- Projection further indicates spatial variance of output and input change.
- For crop production on irrigated land, impact would be potentially larger in north and northeast China.



Crop output

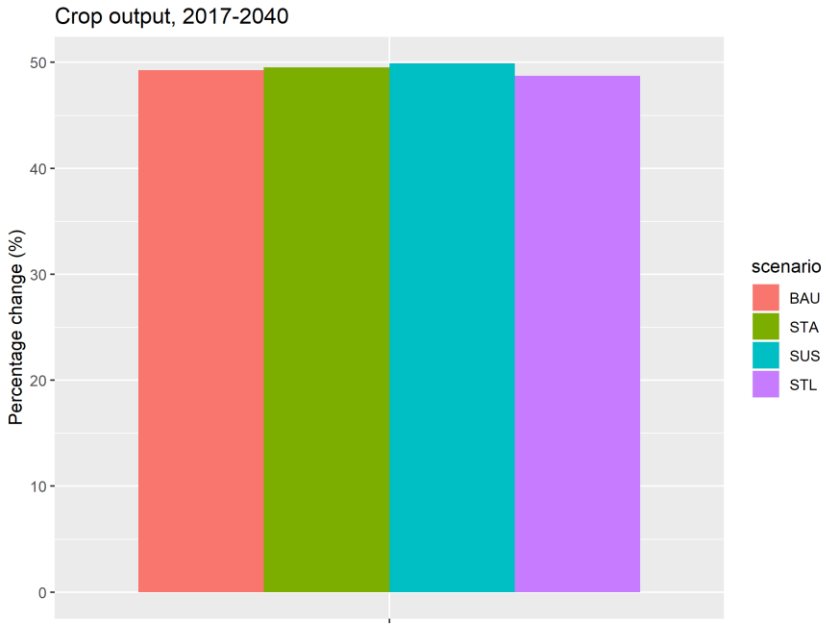
Crop output change on irrigated land (BAU)



PURDUE UNIVERSITY | College of Agriculture

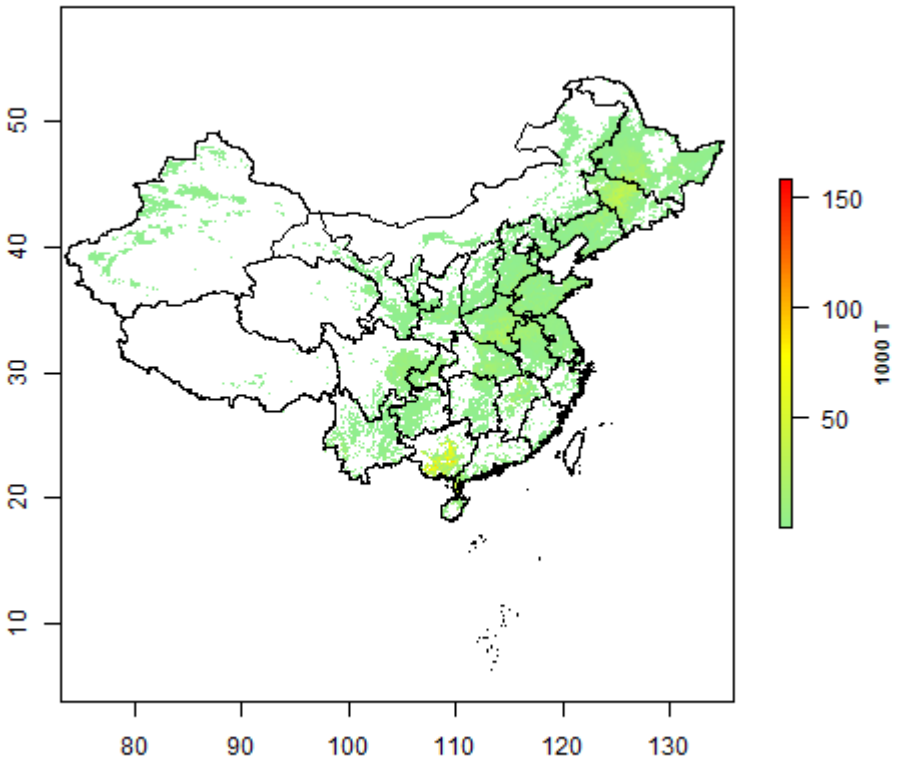
Results

- For crop production on rainfed land, spatial variance of impact still exist, but is milder.



Crop output

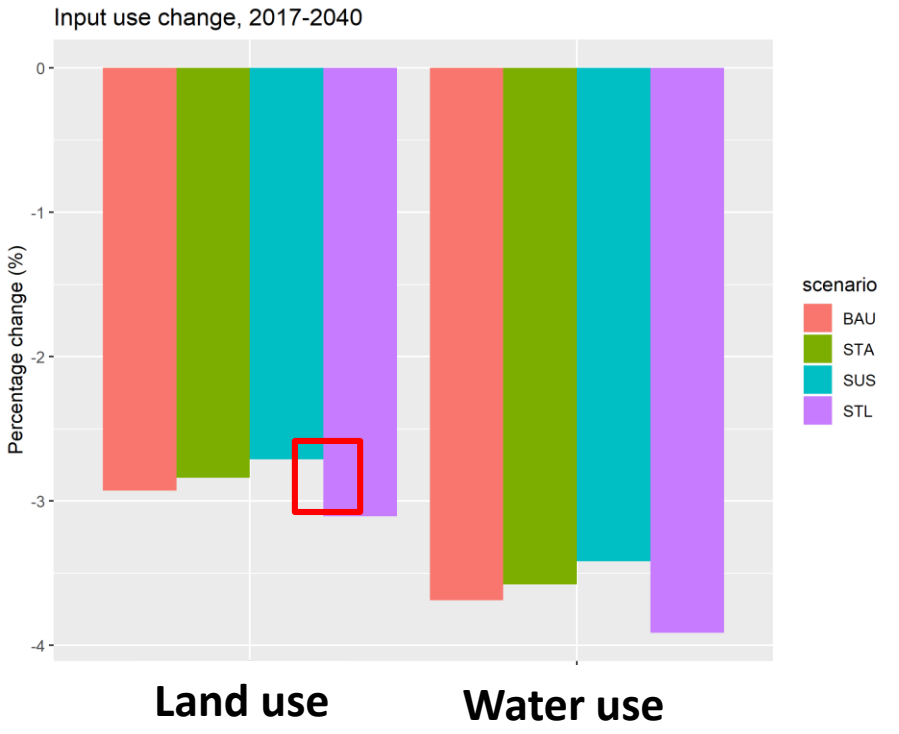
Crop output change on rainfed land (BAU)



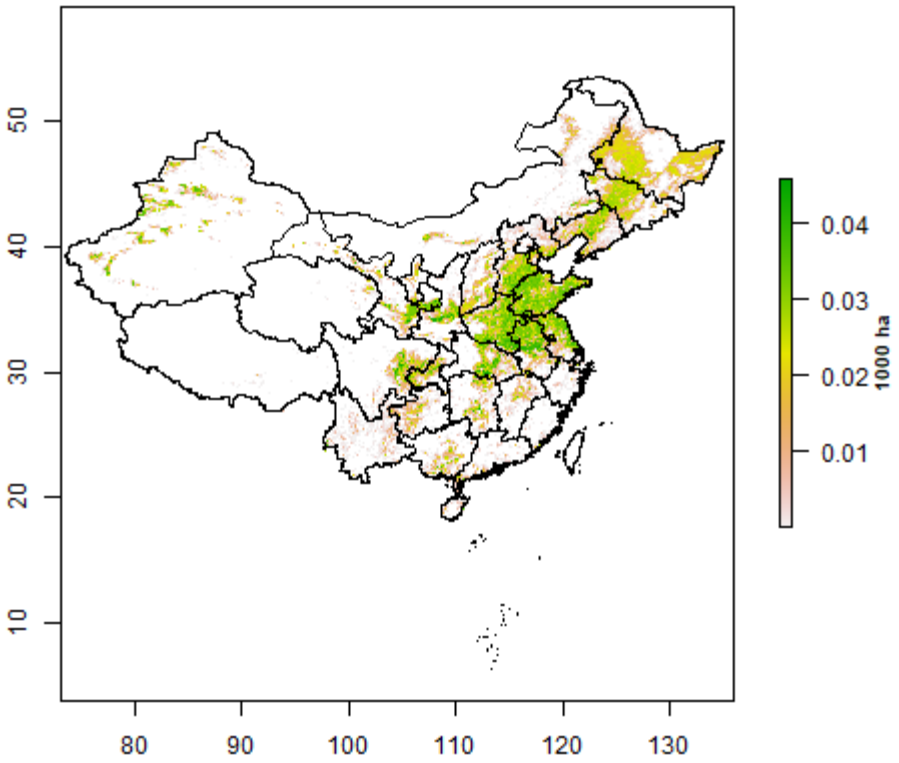
PURDUE UNIVERSITY | College of Agriculture

Results

- For impacts from biofuel demand only, we checked difference of cropland use change between SUS and STL scenarios. Results show slight spatial variance, mainly in north and northeast China.



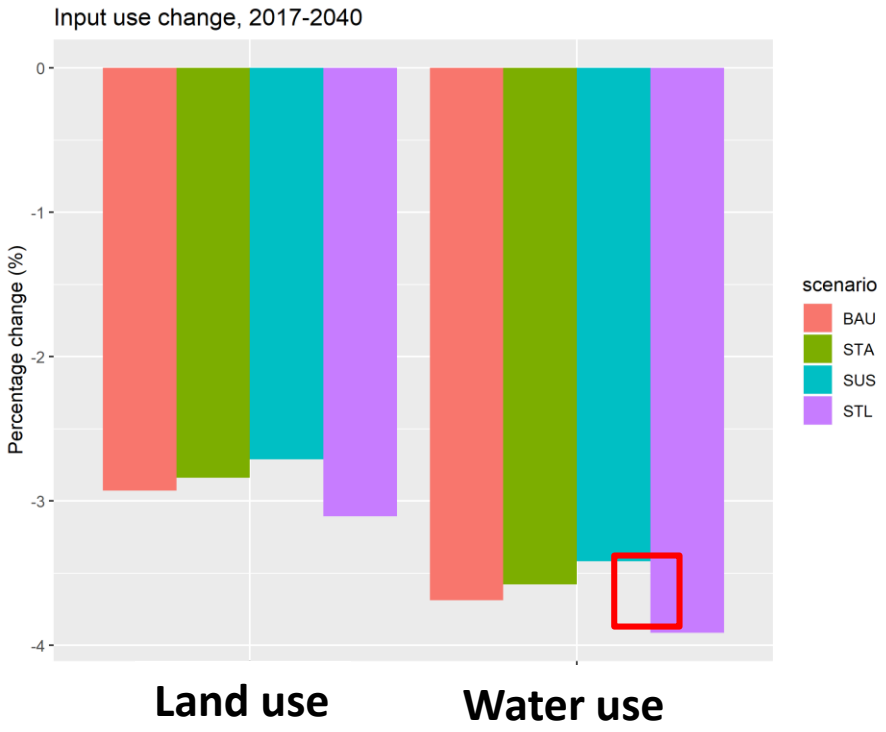
Difference in cropland use



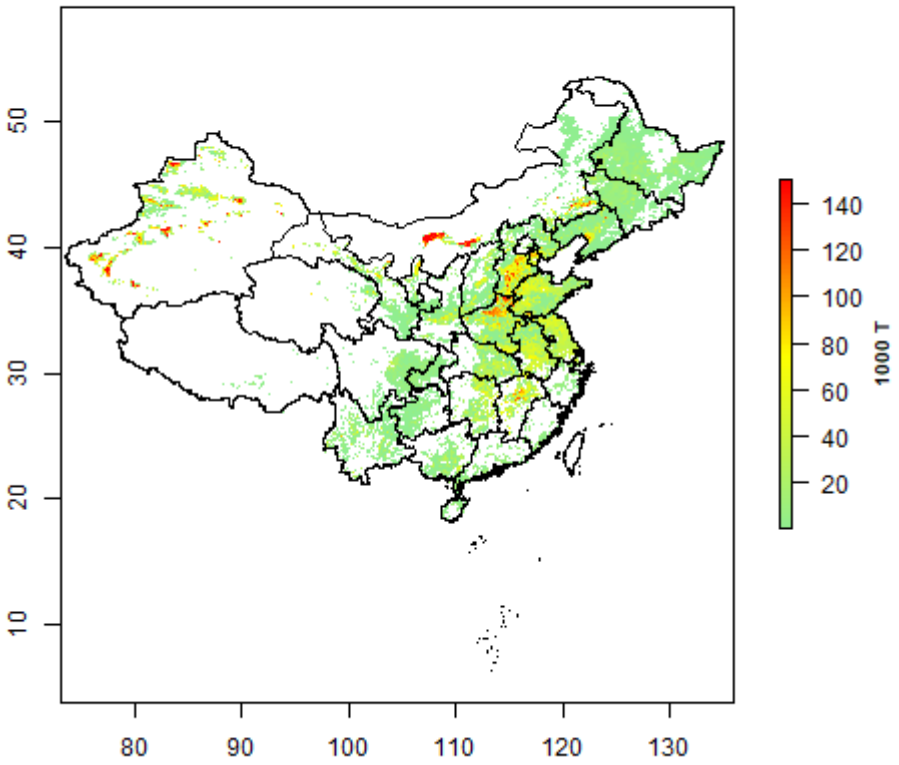
PURDUE UNIVERSITY | College of Agriculture

Results

- Water use change shows different spatial pattern, indicating the heterogeneity on local level.



Difference in water use



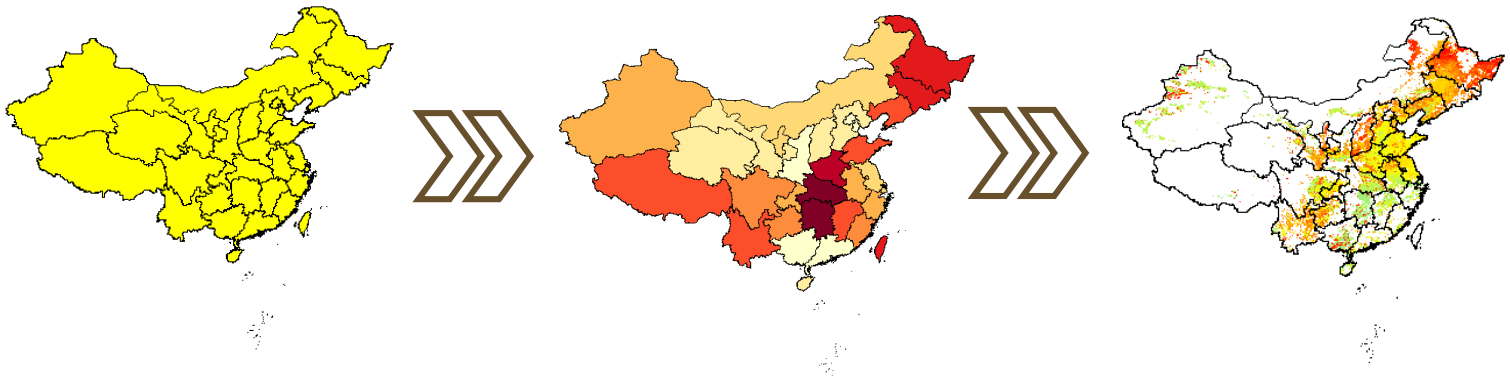
PURDUE UNIVERSITY | College of Agriculture

Conclusion

- Increasing crop production would be mainly driven by higher demand for livestock and processed food, due to **income growth** and **consumption structure change**. Crop demand for **biofuel** would only have moderate impacts, and is not the major concern of food security.

- **Technology** improvement would be key factor for sustainable agricultural production.

- **Multi-scale** research approach shows the **spatial heterogeneity** of impacts on the food-land-water system, which would contribute to region-specific policy design, and indicate the importance of fine scale analysis.



Next steps

- Estimate and calibrate key parameters at a finer resolution
  - Province -> City -> Grid-cell
- Introduce sub-national shocks
  - Agricultural TFP growth by province
  - Water constraint
  - Cropland planning
- Conduct experiments on spatially targeted policies

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.
- Chen, F., Ameen, A., Tang, C.-C., Du, F., Yang, X.-L., & Xie, G.-H. (2017). Effects of Nitrogen Fertilization on Soil Nitrogen for Energy Sorghum on Marginal Land in China. Agronomy Journal, 109(2), 636–645. https://doi.org/10.2134/agronj2016.06.0340
- Fu, H., Chen, Y., Yang, X., Di, J., Xu, M., & Zhang, B. (2019). Water resource potential for large-scale sweet sorghum production as bioenergy feedstock in Northern China. Science of The Total Environment, 653, 758–764. https://doi.org/10.1016/j.scitotenv.2018.10.402
- Hertel, Thomas W. (2011). The Global Supply and Demand for Agricultural Land in 2050: A Perfect Storm in the Making? 1. American Journal of Agricultural Economics, 93(2), 259–275.
- Hertel, T. W., Ramankutty, N., & Baldos, U. L. C. (2014). Global market integration increases likelihood that a future African Green Revolution could increase crop land use and CO2 emissions. Proceedings of the National Academy of Sciences, 111(38), 13799-13804.
- IEA. (2006). World Energy Outlook 2006. Paris. https://www.iea.org/reports/world-energy-outlook-2006
- ...
- IEA. (2019). World Energy Outlook 2019. Paris.
- Li, J. (2019). Current status and outlook of liquid fuel in China (in Chinese), https://www.iscc-system.org/wp-content/uploads/2019/07/1.-Junfeng-Li_NCSC_New-Policy-on-Ethanol-Gasoline-in-PRC.pdf
- 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 Energy Administration of China. (2016). The 13th five-year-plan on Bioenergy development. Beijing. http://zfxxgk.nea.gov.cn/auto87/201612/t20161205_2328.htm
- Nie, Y., Cai, W., Wang, C., Huang, G., Ding, Q., Yu, L., Li, H., & Ji, D. (2019). Assessment of the potential and distribution of an energy crop at 1-km resolution from 2010 to 2100 in China – The case of sweet sorghum. Applied Energy, 239, 395–407. https://doi.org/10.1016/j.apenergy.2019.01.214
- Wang, W., Liu, Y., & Zhang, L. (2013). The spatial distribution of cereal bioenergy potential in China. GCB Bioenergy, 5(5), 525–535. https://doi.org/10.1111/gcbb.12024
- Weng, Y., Chang, S., Cai, W., & Wang, C. (2019). Exploring the impacts of biofuel expansion on land use change and food security based on a land explicit CGE model: A case study of China. Applied Energy, 236, 514–525.

Thank You!

Zhan Wang

Department of Agricultural Economics

College of Agriculture, Purdue University, USA

zhanwang@purdue.edu

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“

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)

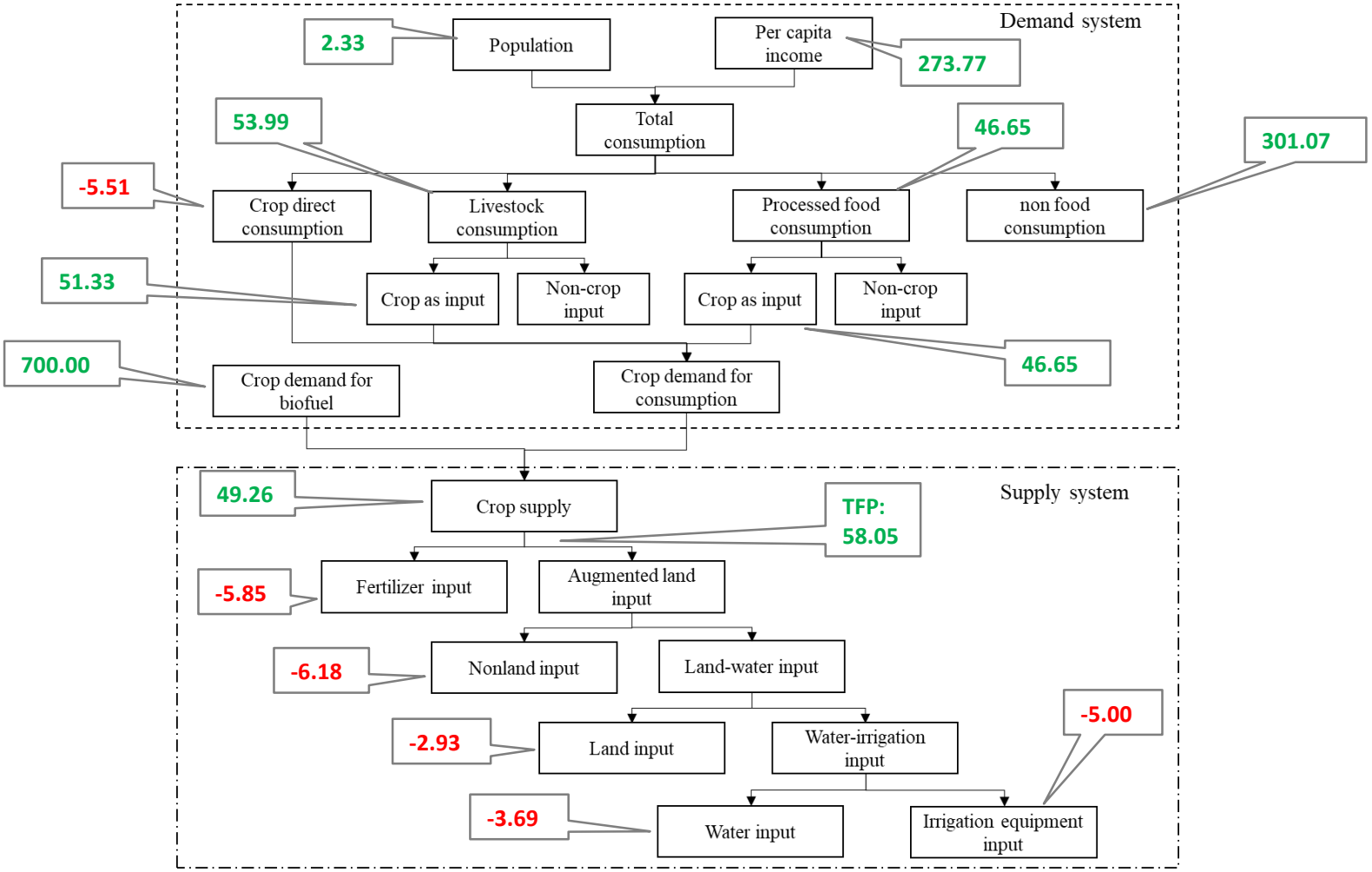
PURDUE UNIVERSITY | College of Agriculture

PURDUE UNIVERSITY GLASS Global to Local Analysis of Systems Sustainability

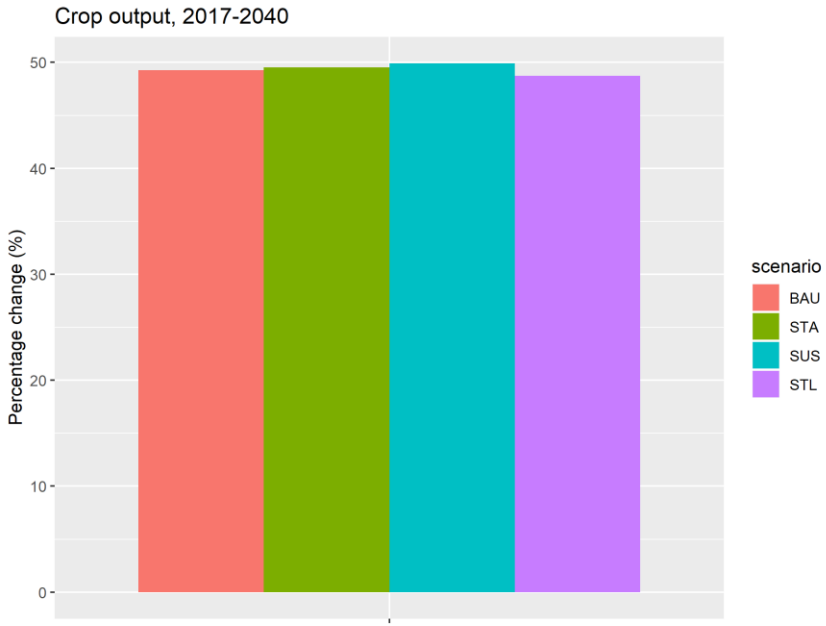
Appendix

Results

- Key driver of crop demand is crop as input for other food sector, due to income growth's impact on consumption structure
- Technology growths explains the decrease in agricultural inputs demand

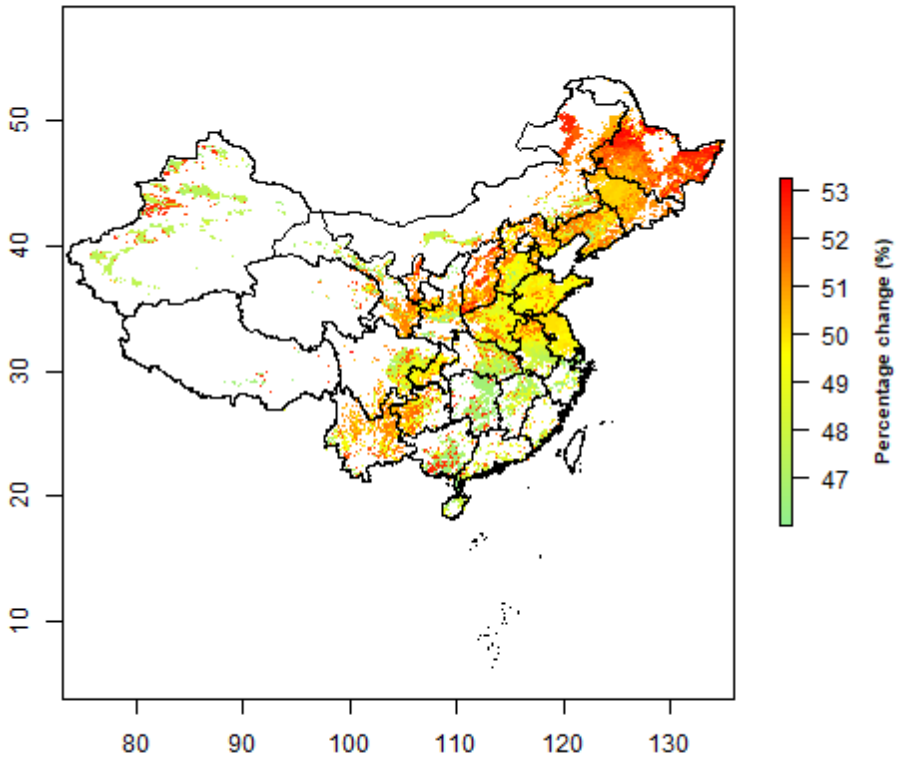


Results



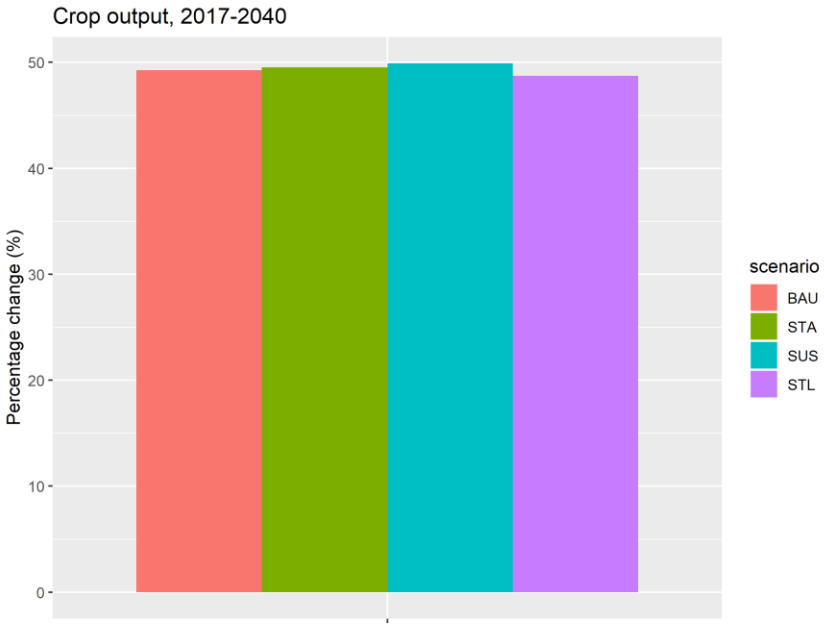
Crop output

%Change in irrigated crop output (BAU)



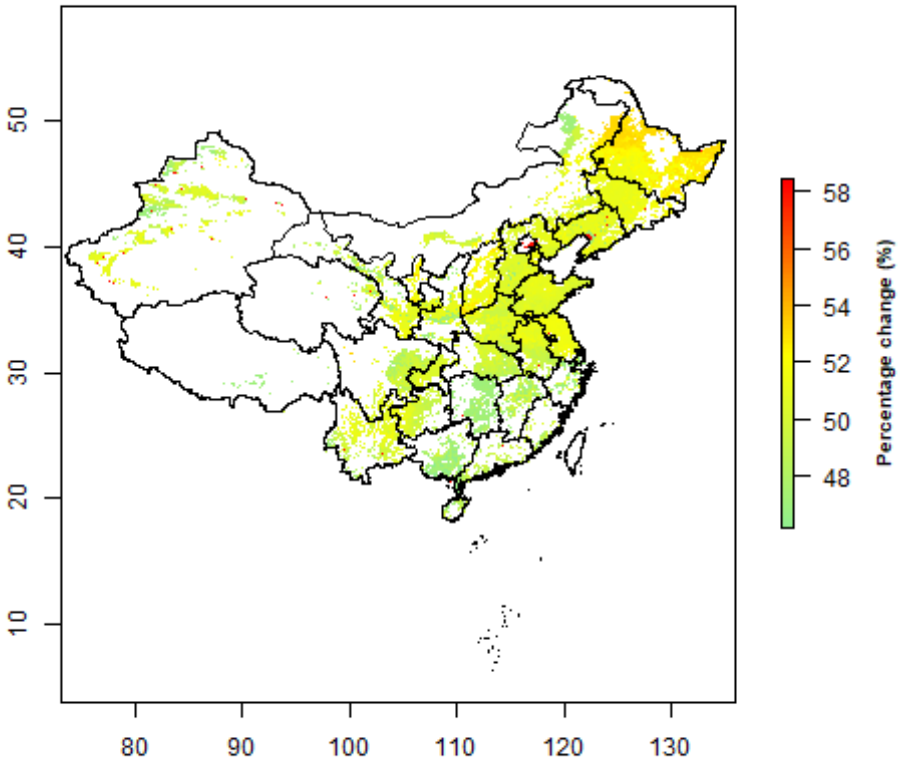
PURDUE UNIVERSITY | College of Agriculture

Results



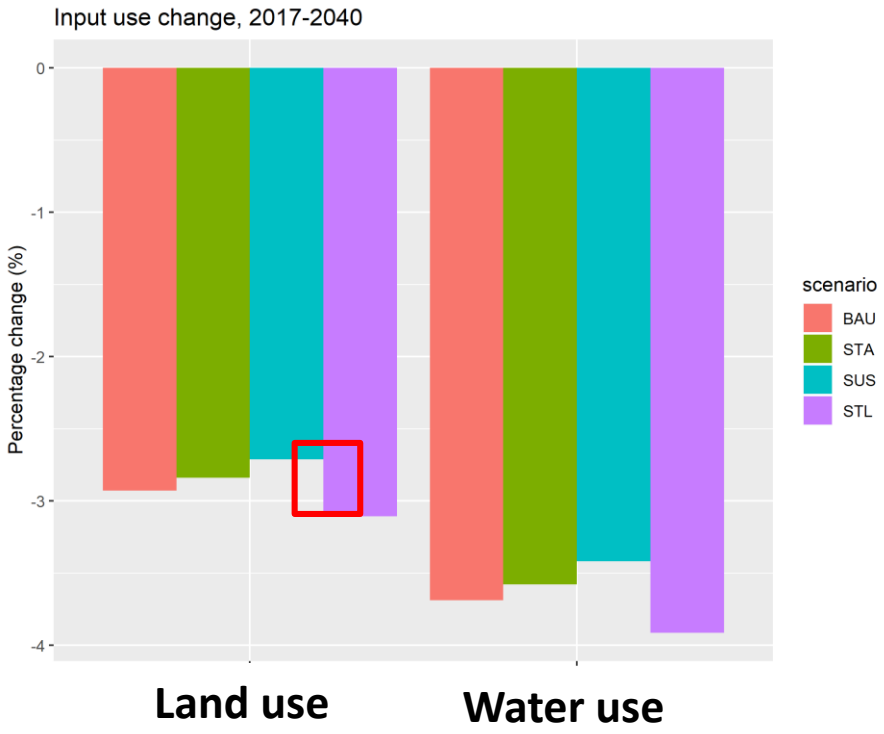
Crop output

%Change in rainfed crop output (BAU)

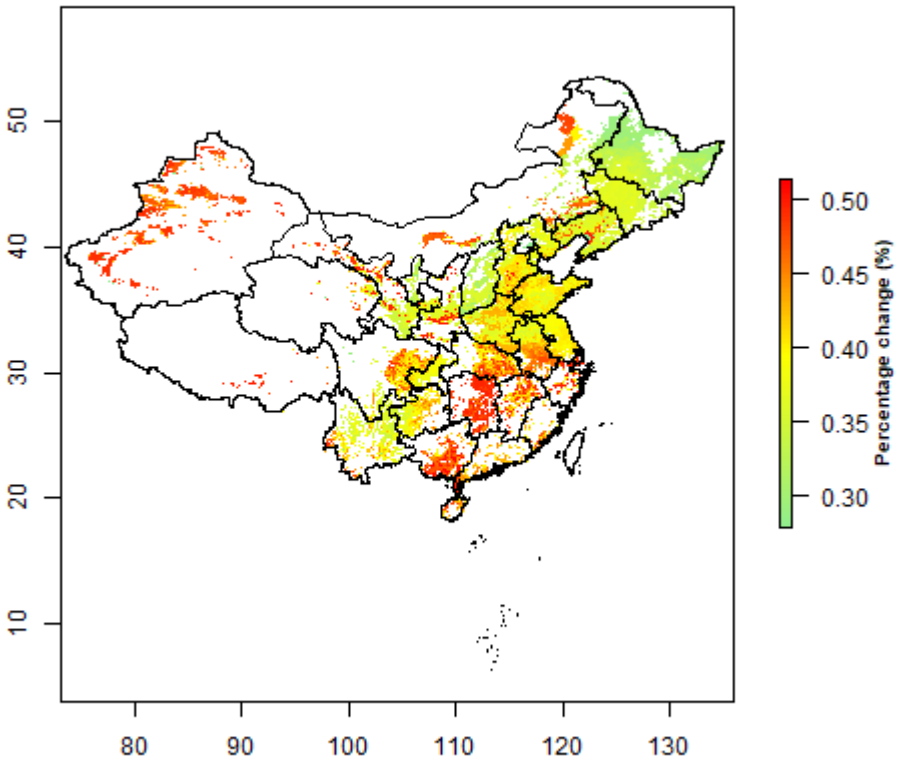


PURDUE UNIVERSITY | College of Agriculture

Results

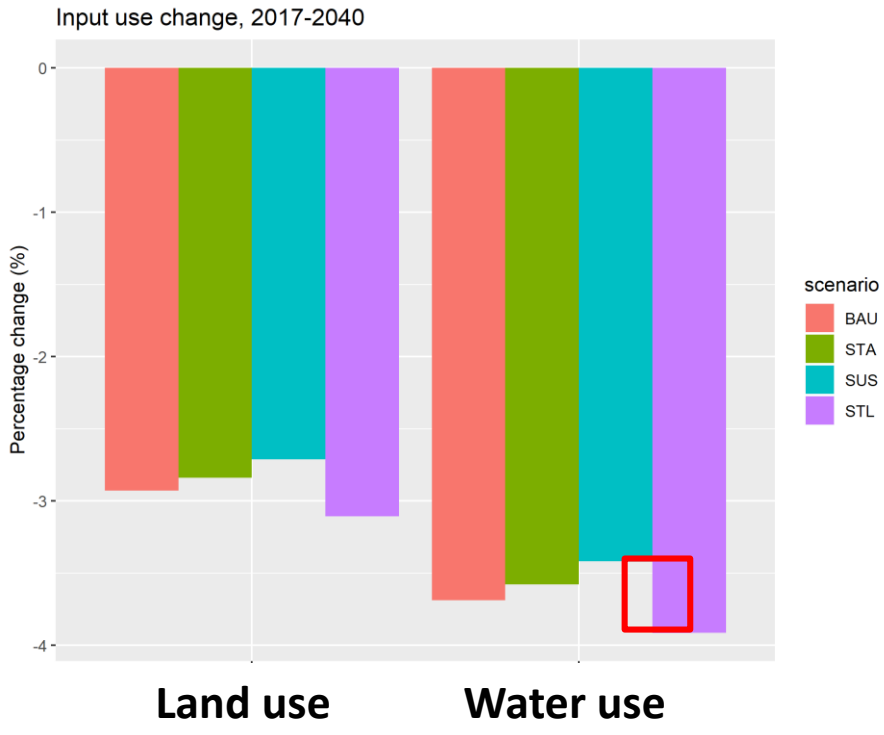


%Change in cropland use

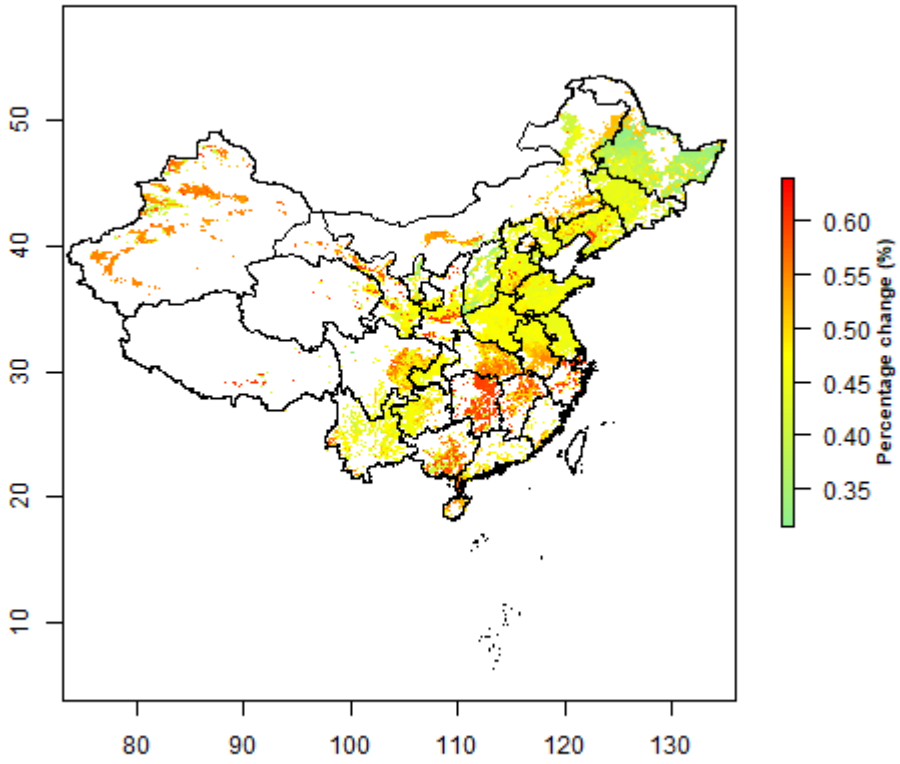


PURDUE UNIVERSITY | College of Agriculture

Results



%Change in water use



PURDUE UNIVERSITY | College of Agriculture