Climate change, groundwater depletion, and agricultural production in India

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India is the world's largest consumer of groundwater, with large-scale overexploitation for irrigation

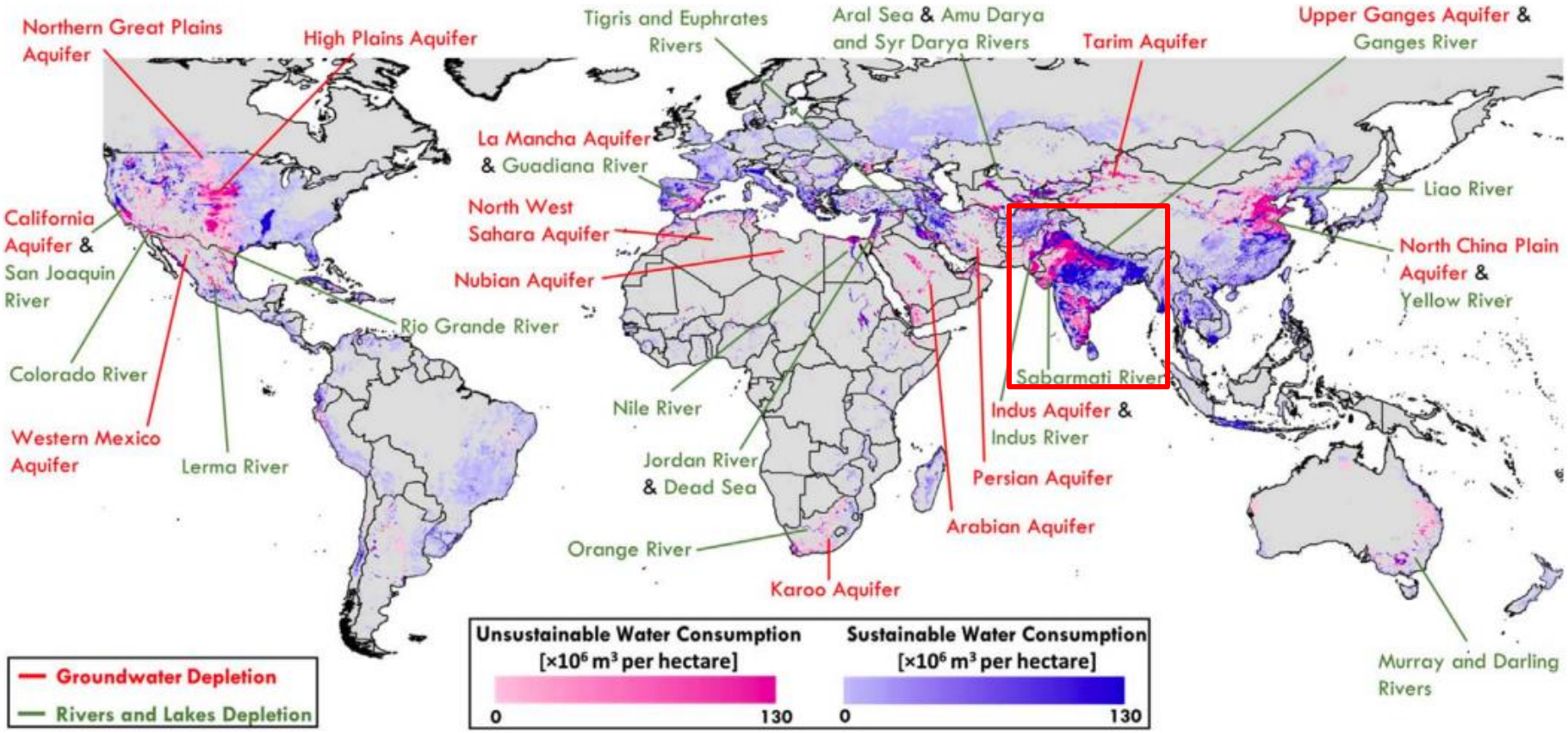
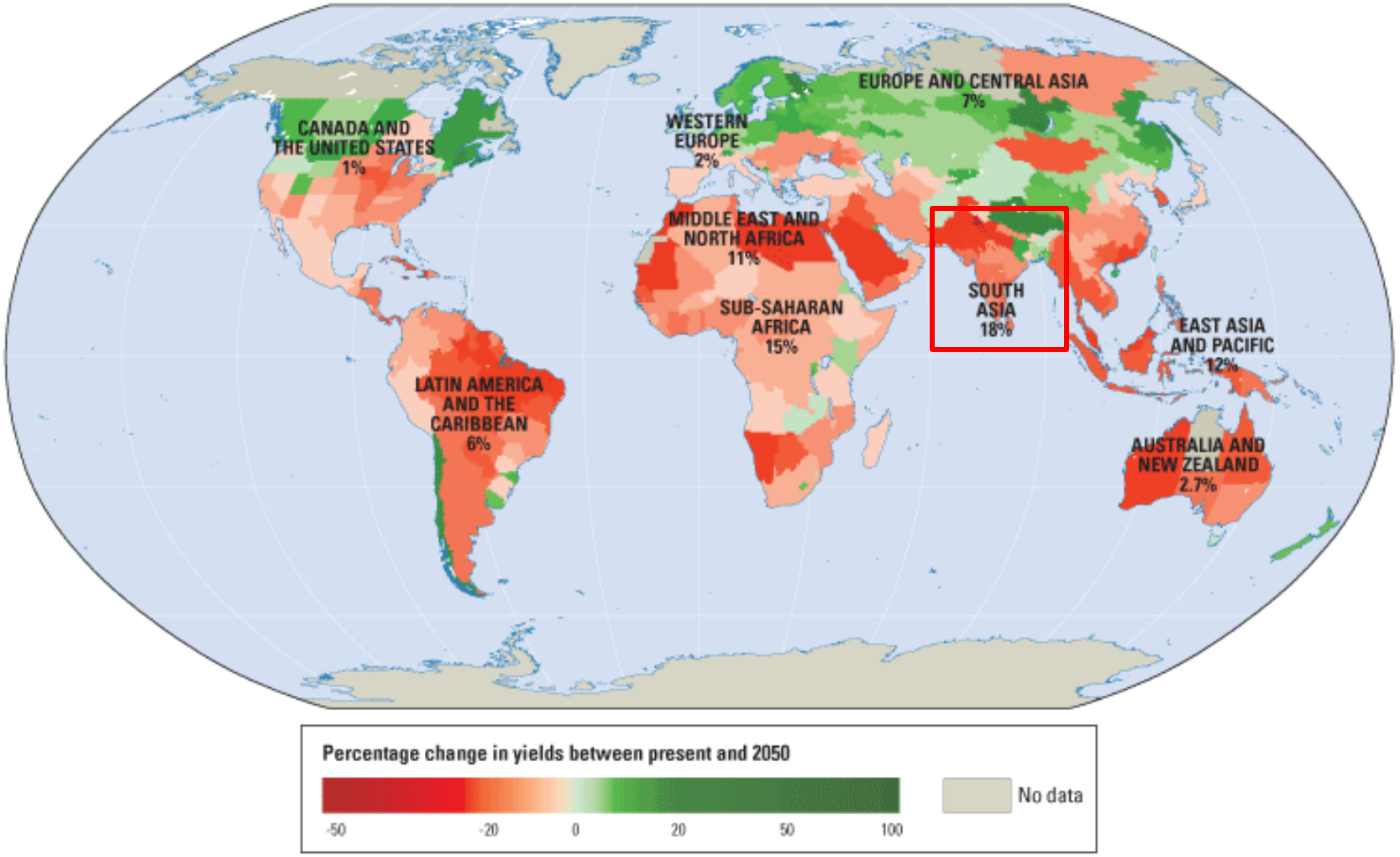


Figure 1. Global hotspots of unsustainable water consumption for irrigation. The map shows sustainable and unsustainable irrigation water consumption volumes and lists some of the freshwater stocks (aquifers, rivers, lakes) that are being depleted to grow crops (Richter 2014, Richey *et al* 2015, Jägermeyr *et al* 2017).

Figure modified from Rosa et al. 2019

Indian agriculture will face some of the largest negative impacts from warming temperatures

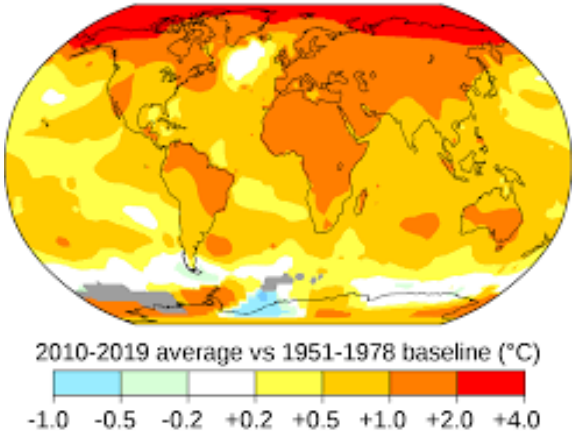


Sources: Müller and others 2009; World Bank 2008c.

What are the feedbacks among climate change, groundwater depletion, and agricultural production?

Groundwater Depletion

Climate Change



Agricultural Production

Outline

1. What are the feedbacks among climate change, groundwater depletion, and agricultural production?

2. Are there adaptation strategies that can reduce the negative impacts of groundwater depletion on agricultural production?

Prashanth Vishwanathan (IWMI) Flicker

Outline

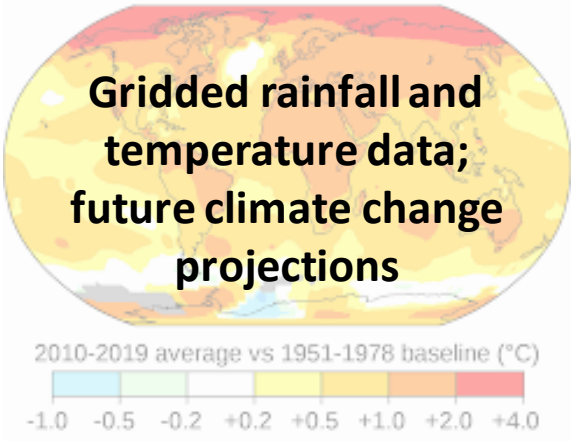
1. What are the feedbacks among warming temperatures, groundwater depletion, and agricultural production?

What are the feedbacks among climate change, groundwater depletion, and agricultural production?

Groundwater Depletion

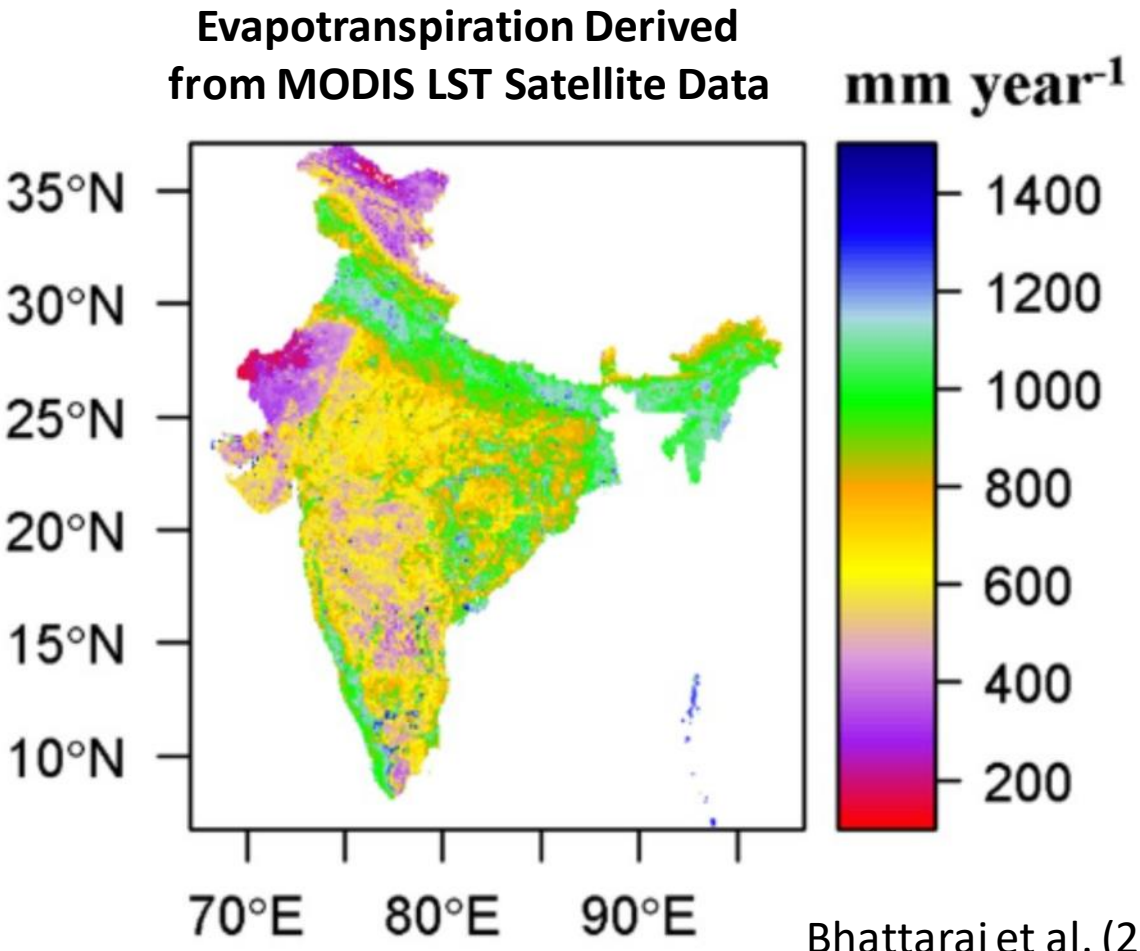
Groundwater depth from 20,000 test wells across India (CGWB)

Climate Change



Agricultural Production

We developed a remote sensing measure of crop water stress (ET/PET) and linked this with well depth and weather data across India

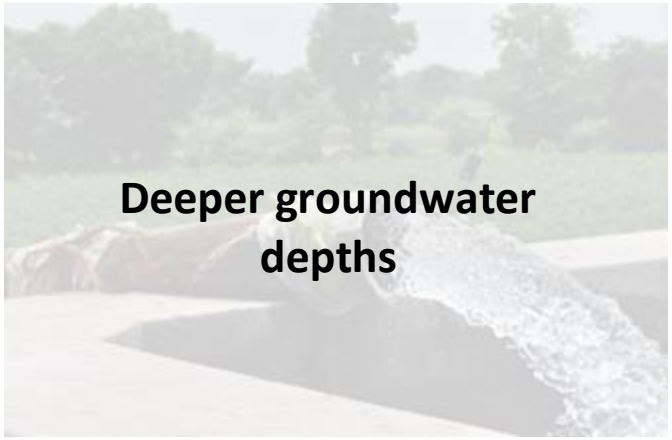


Bhattarai et al. (2019).
Remote Sensing of Environment

Main Research Questions

- What are the impacts of warming temperatures and groundwater depletion on crop water stress?

Warming temperatures and groundwater depletion increase crop water stress



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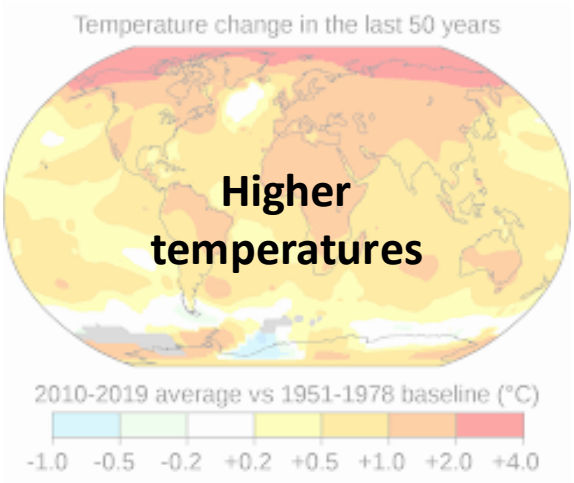

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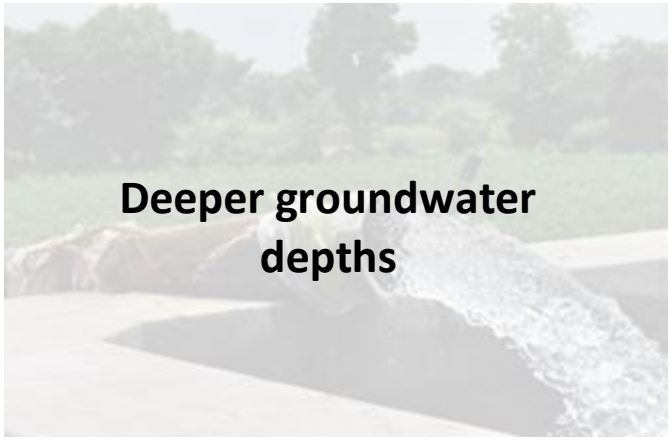
But the effects of warming temperatures and groundwater depletion on crop water stress is small, suggesting that farmers are able to adapt to meet crop water demand



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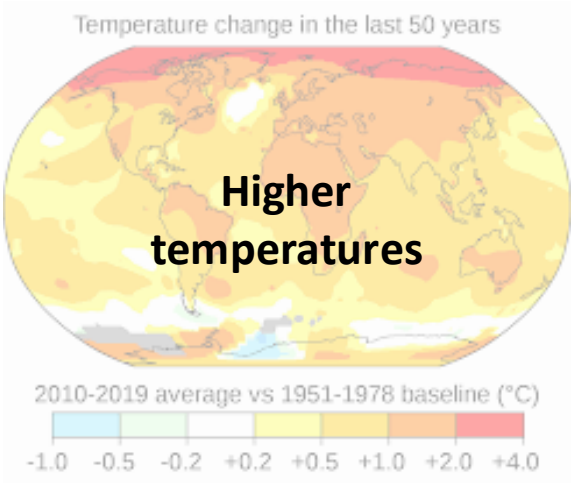

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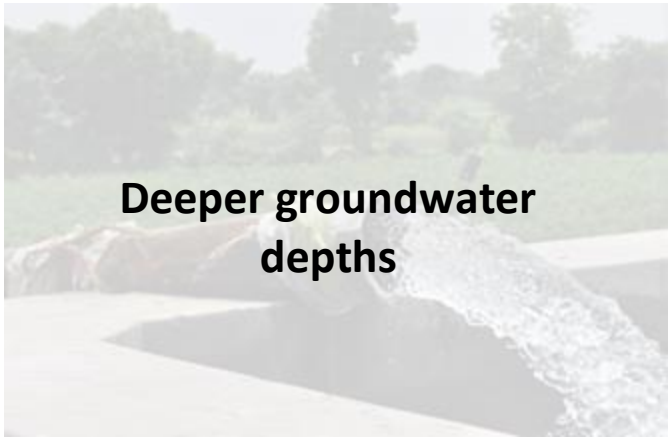
Main Research Questions

- What are the impacts of warming temperatures and groundwater depletion on crop water stress?

- What is the impact of warming temperatures on groundwater depletion?

Warming temperatures are associated with increased groundwater depletion, suggesting farmers increase irrigation use to meet crop water demand



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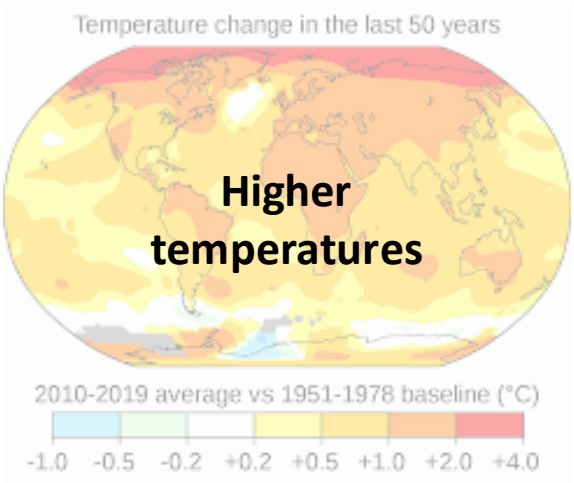
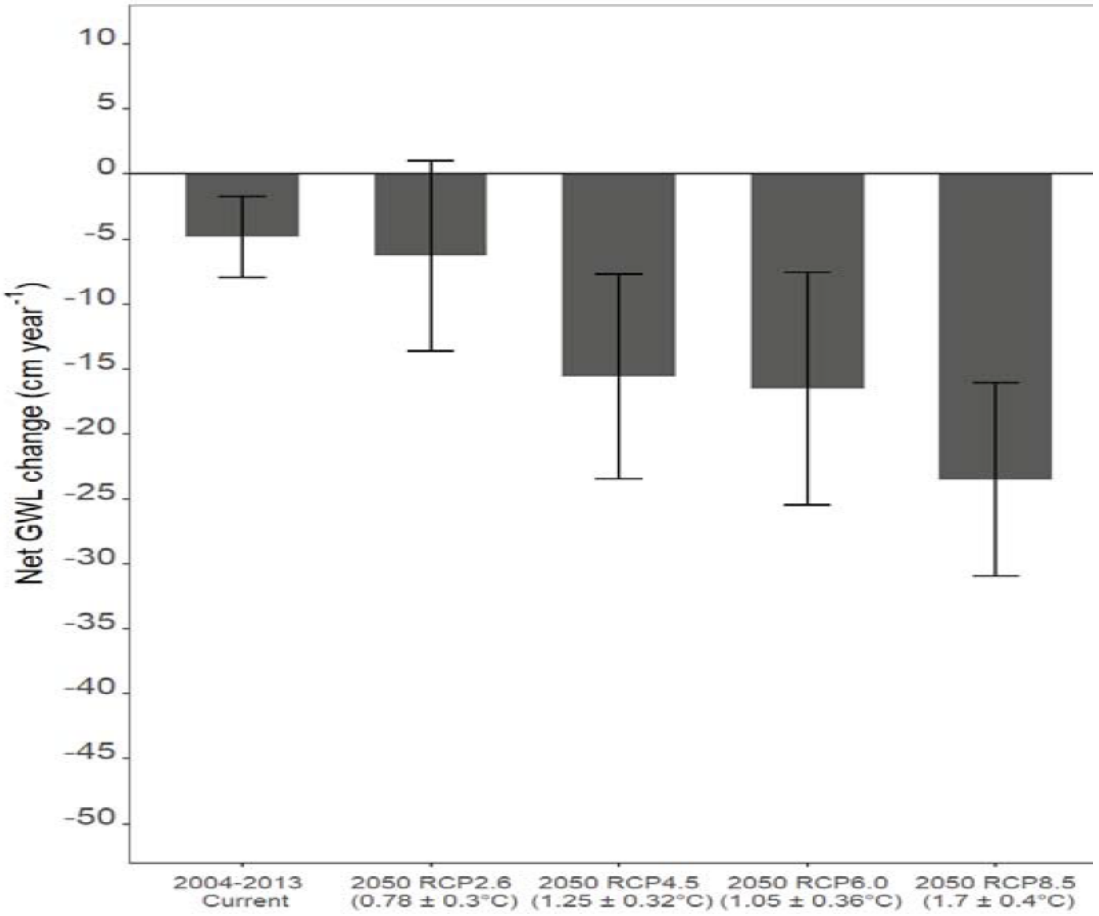
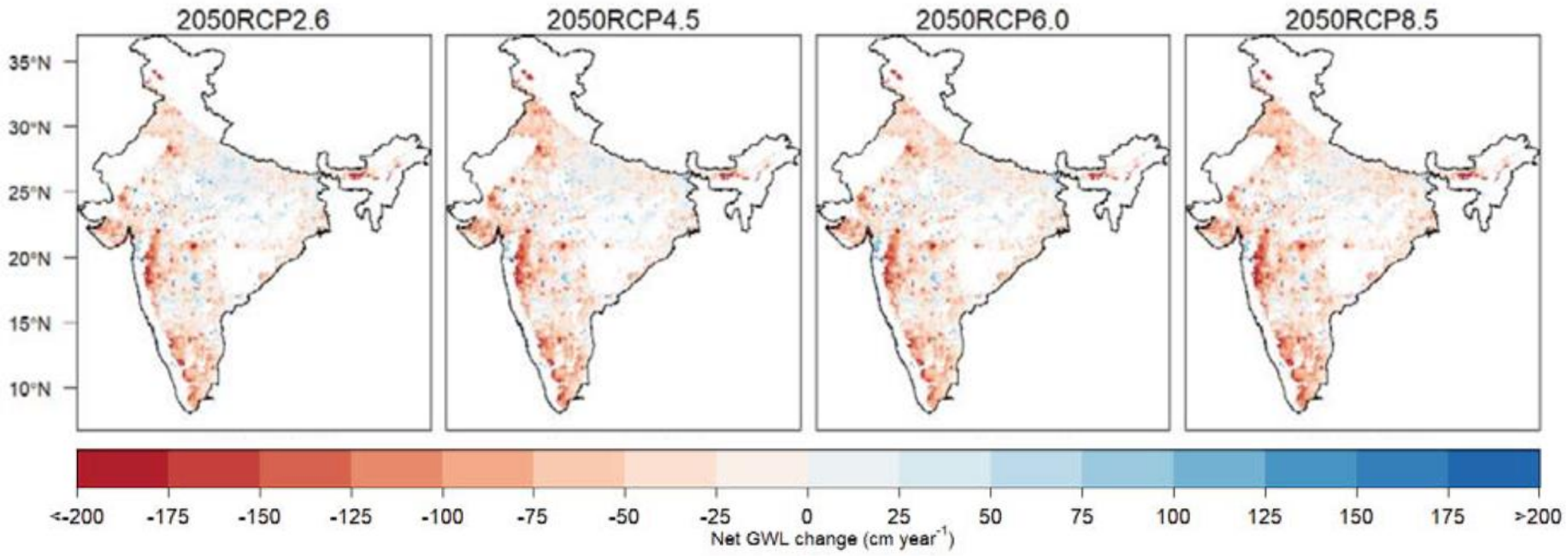


If we project our estimates to 2050 considering projected climate change, groundwater depletion rates could quadruple compared to current rates



Bhattarai et al. (In Preparation)

Resulting groundwater depletion will not be evenly distributed across the country



Bhattarai et al. (In Preparation)

Outline

1. What are the feedbacks among warming temperatures, groundwater depletion, and agricultural production?

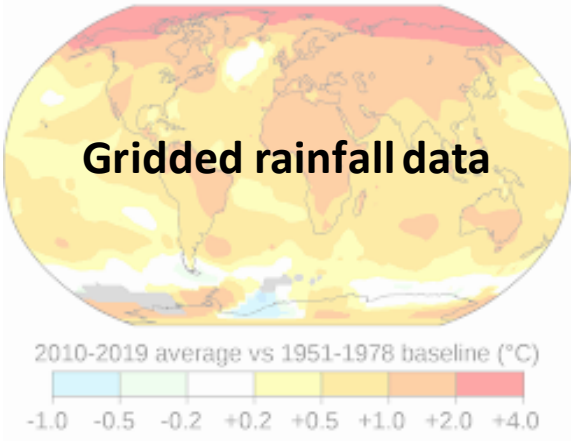
2. Are there adaptation strategies that can reduce the negative impacts of groundwater depletion on agricultural production?

What are the feedbacks among climate change, groundwater depletion, and agricultural production?

Groundwater Depletion

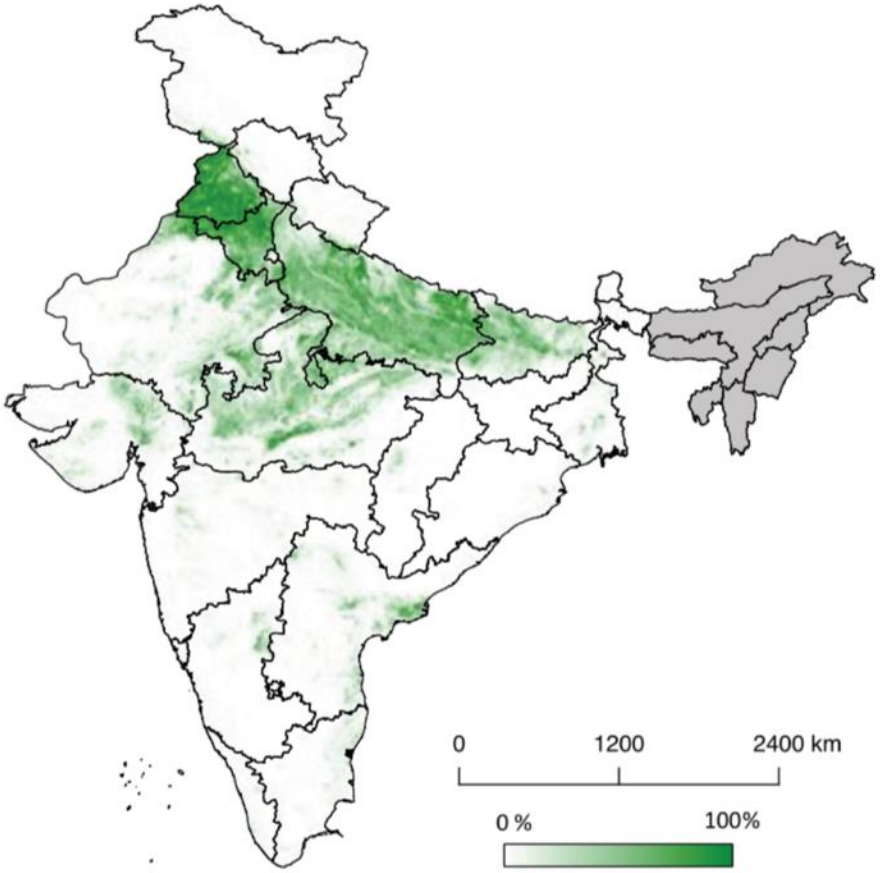
Village-level irrigation source data; projections of groundwater stress

Weather



Agricultural Production

We developed a remote sensing measure of crop production (winter cropped area) and linked this with weather data and village-level data on irrigation from Indian census data

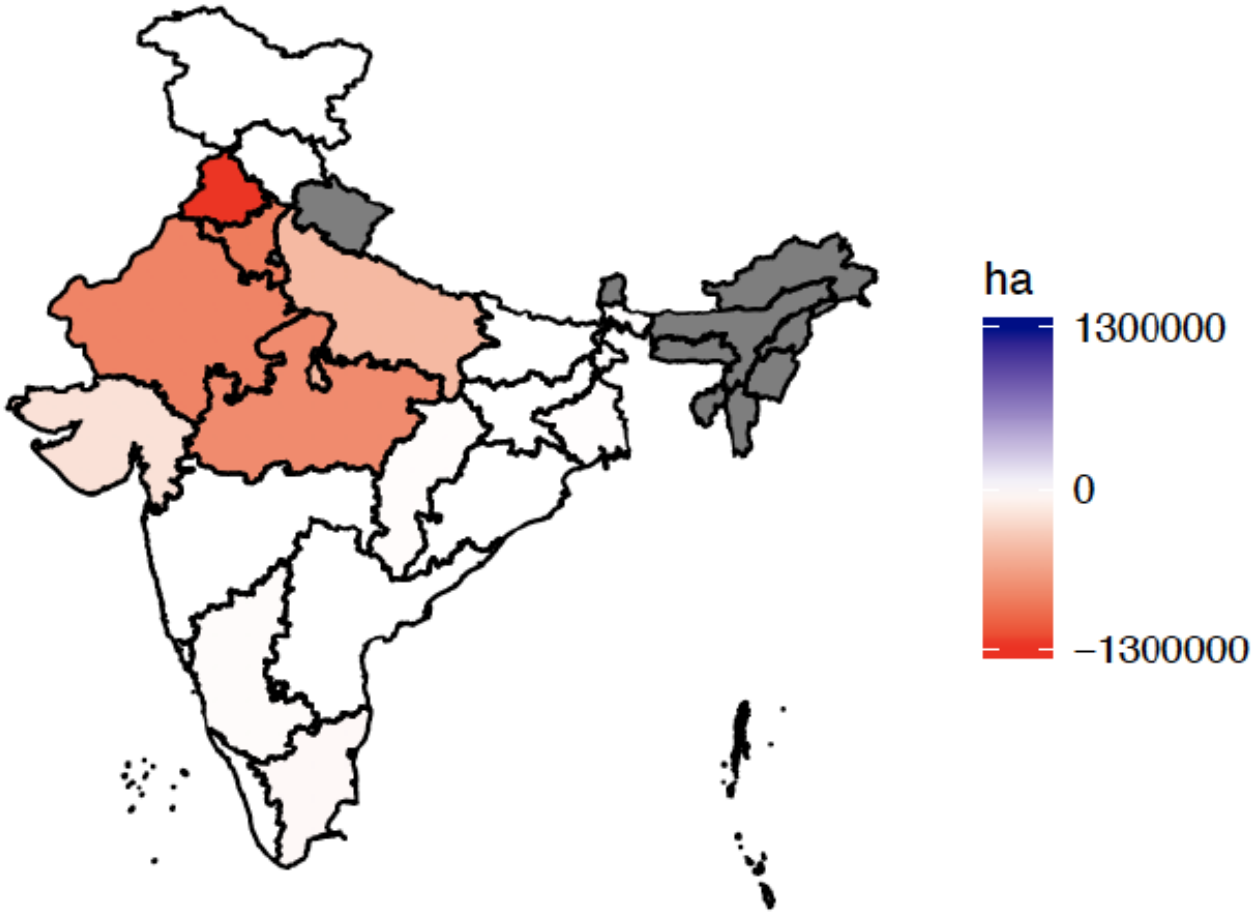


Jain et al. (2017). Remote Sensing

Main Research Questions

- What are the potential impacts of groundwater depletion on winter cropped area?

If all groundwater is lost from over-exploited regions, India could lose up to 20% of winter cropped area (upper bound estimate)



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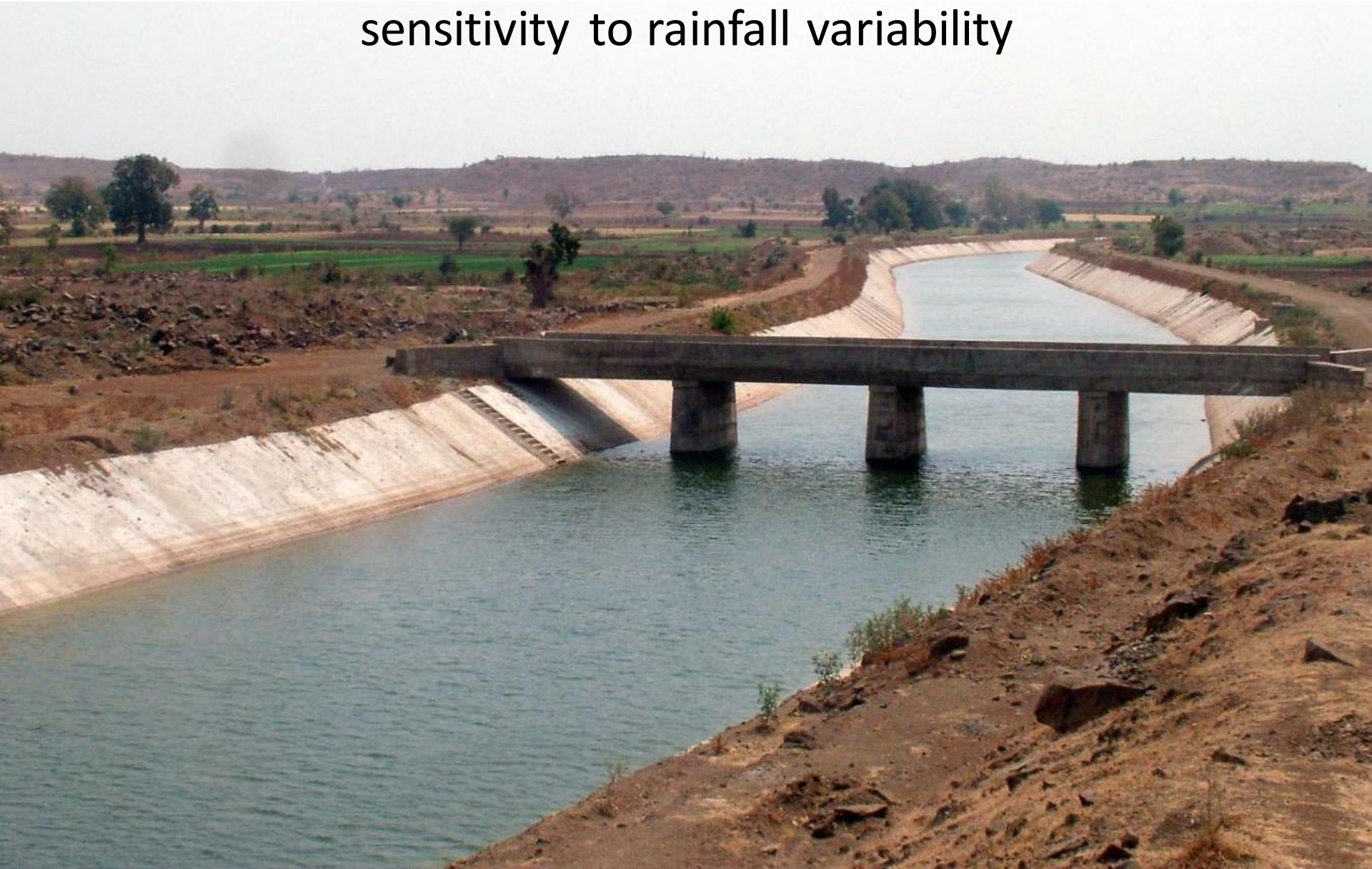
Main Research Questions

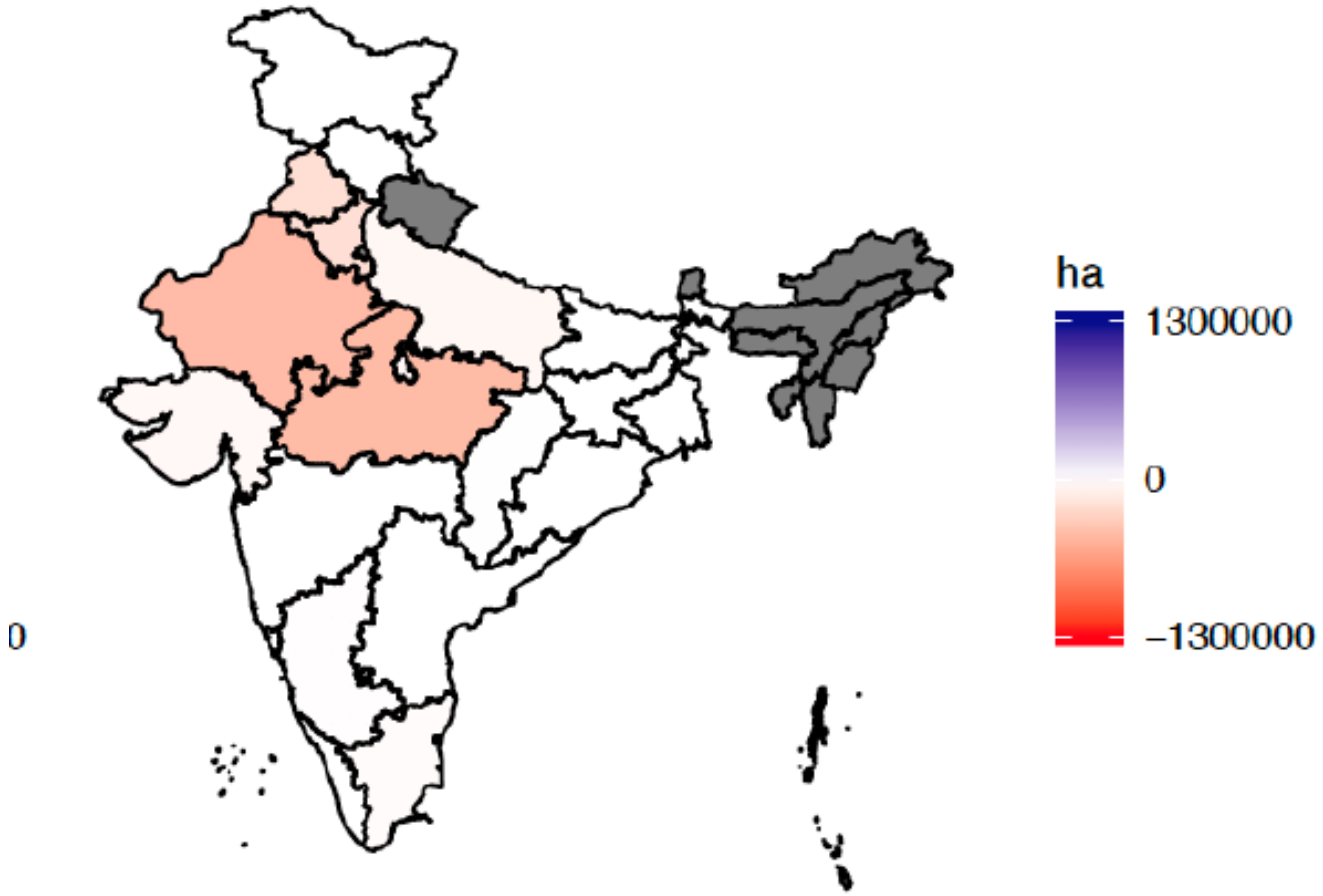
- What are the potential impacts of groundwater depletion on winter cropped area?

- What is the capacity of canal irrigation to mitigate this loss?

Compared to groundwater irrigation, canal irrigation is largely associated with less winter cropped area and increased sensitivity to rainfall variability



If all lost groundwater is replaced with canal irrigation, India could still lose up to 7% of winter cropped area



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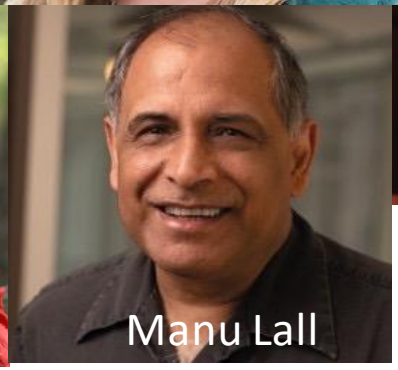
Take home messages for SIP

- Warming temperatures could exacerbate India's groundwater crisis by increasing irrigation demand to reduce crop water stress, so it could be important to take this increased demand into account when planning where SIP will be most beneficial

Take home messages for SIP

- Warming temperatures could exacerbate India's groundwater crisis by increasing irrigation demand to reduce crop water stress, so it could be important to take this increased demand into account when planning where SIP will be most beneficial

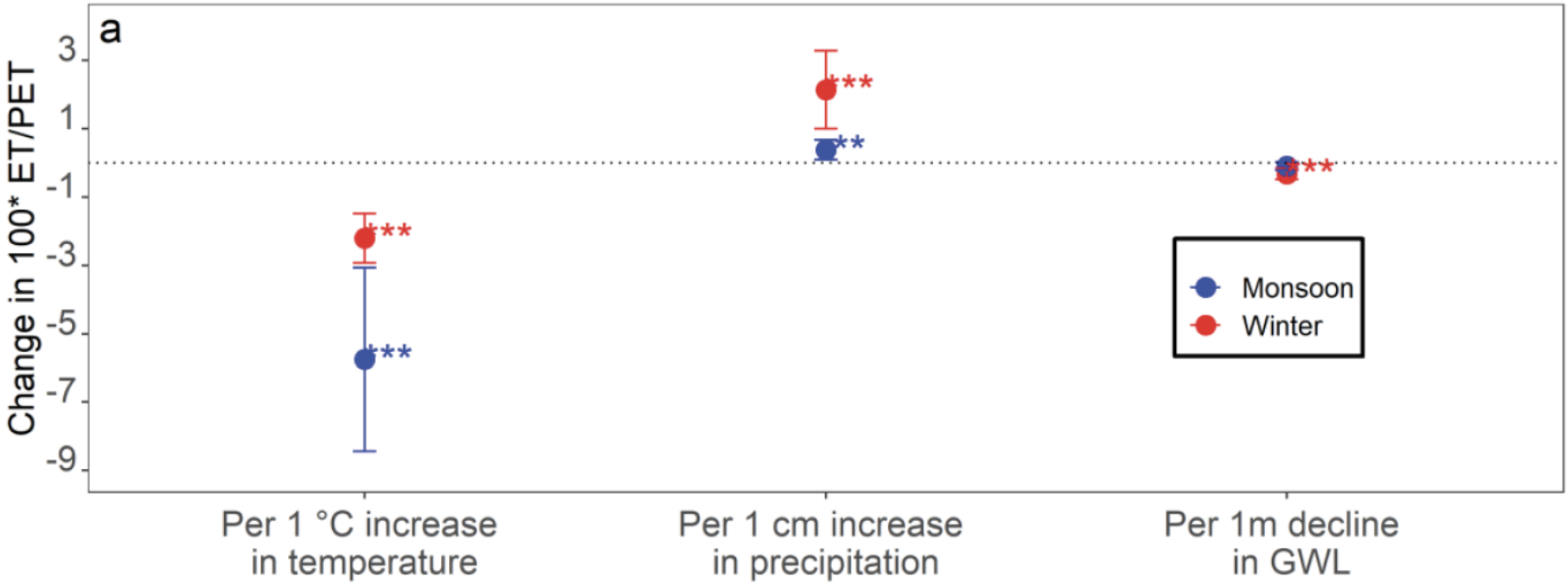
- If access to groundwater is lost from overexploited regions, the largest impacts to winter agricultural production will be in central and northwest India – it could be important to take this into account when planning where SIP will be most beneficial



LCLUC

Land Cover/Land-Use Change Program

New Investigator Program (NIP)
Early Career Award



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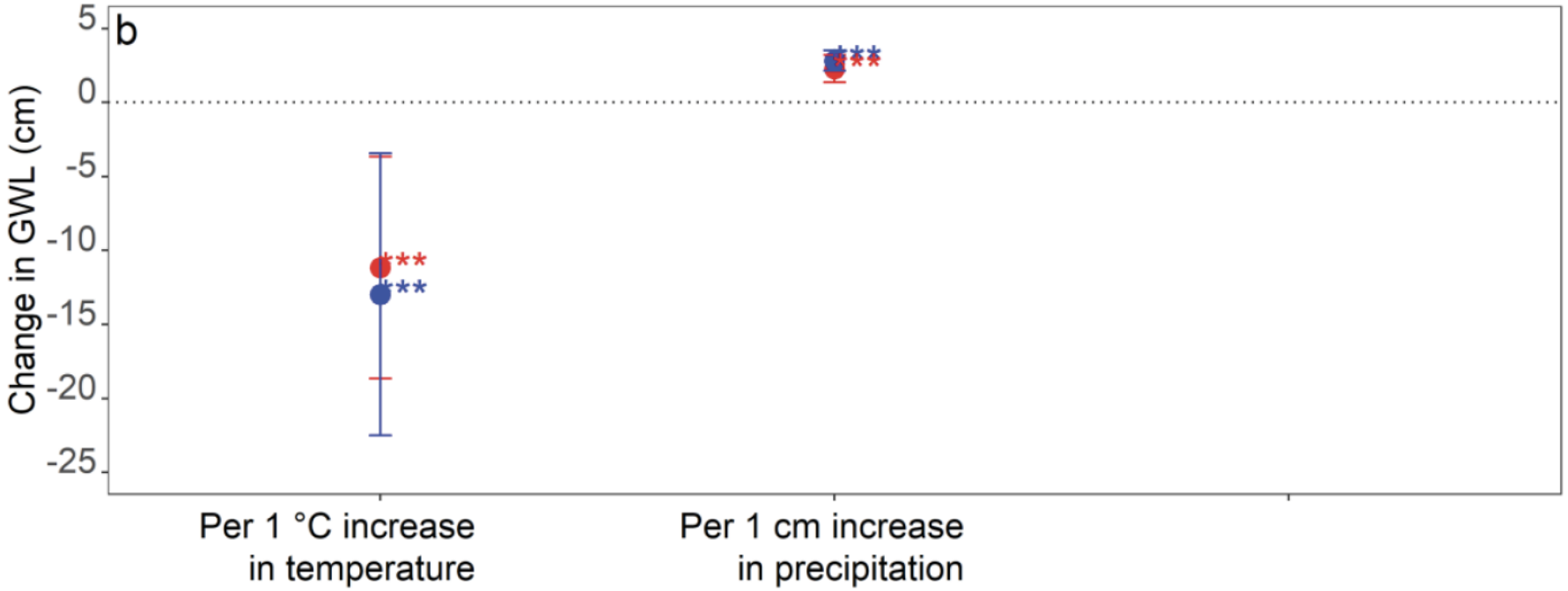

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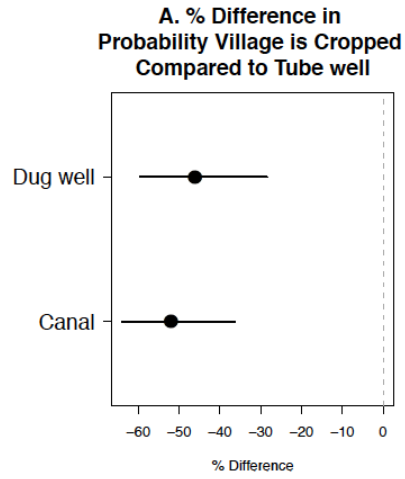
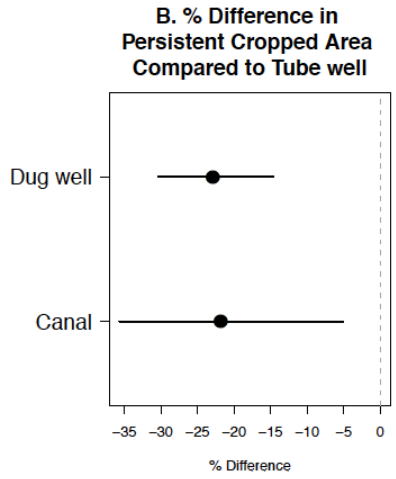
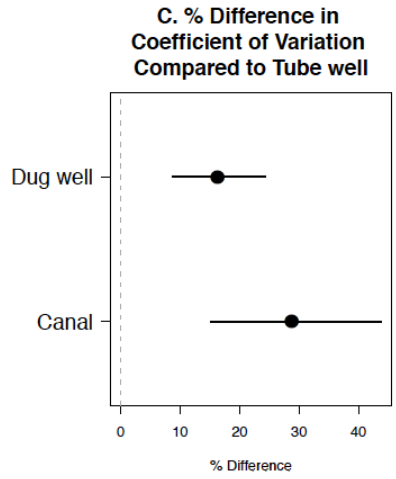
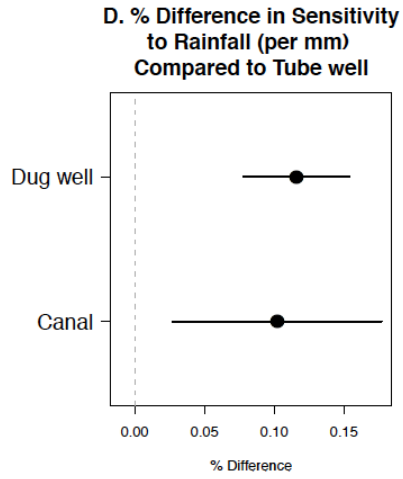
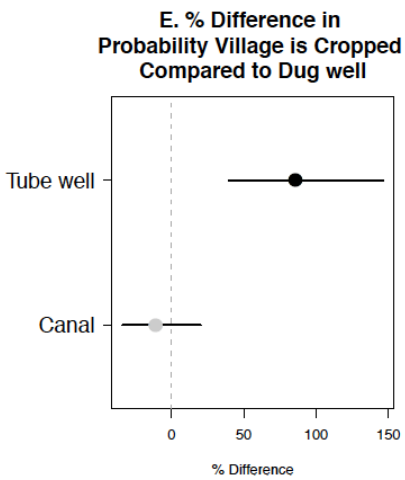
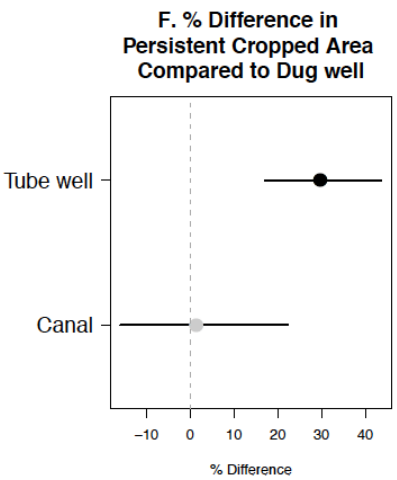

A. % Difference in Probability Village is Cropped Compared to Tube well
Dug well
Canal
−60 −50 −40 −30 −20 −10 0
% Difference

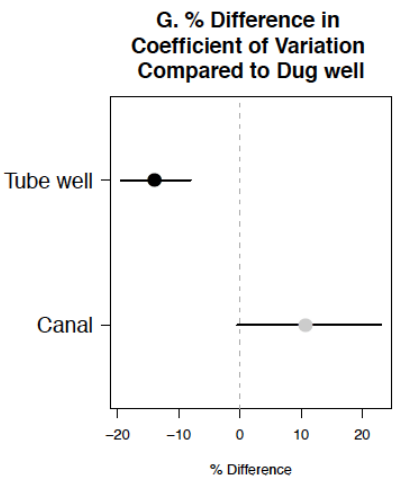

B. % Difference in Persistent Cropped Area Compared to Tube well
Dug well
Canal
−35 −30 −25 −20 −15 −10 −5 0
% Difference

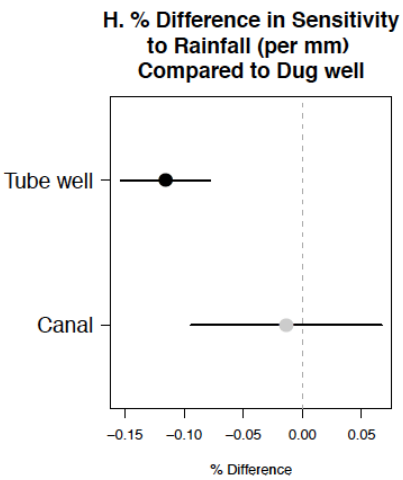

C. % Difference in Coefficient of Variation Compared to Tube well
Dug well
Canal
0 10 20 30 40
% Difference


D. % Difference in Sensitivity to Rainfall (per mm) Compared to Tube well
Dug well
Canal
0.00 0.05 0.10 0.15
% Difference

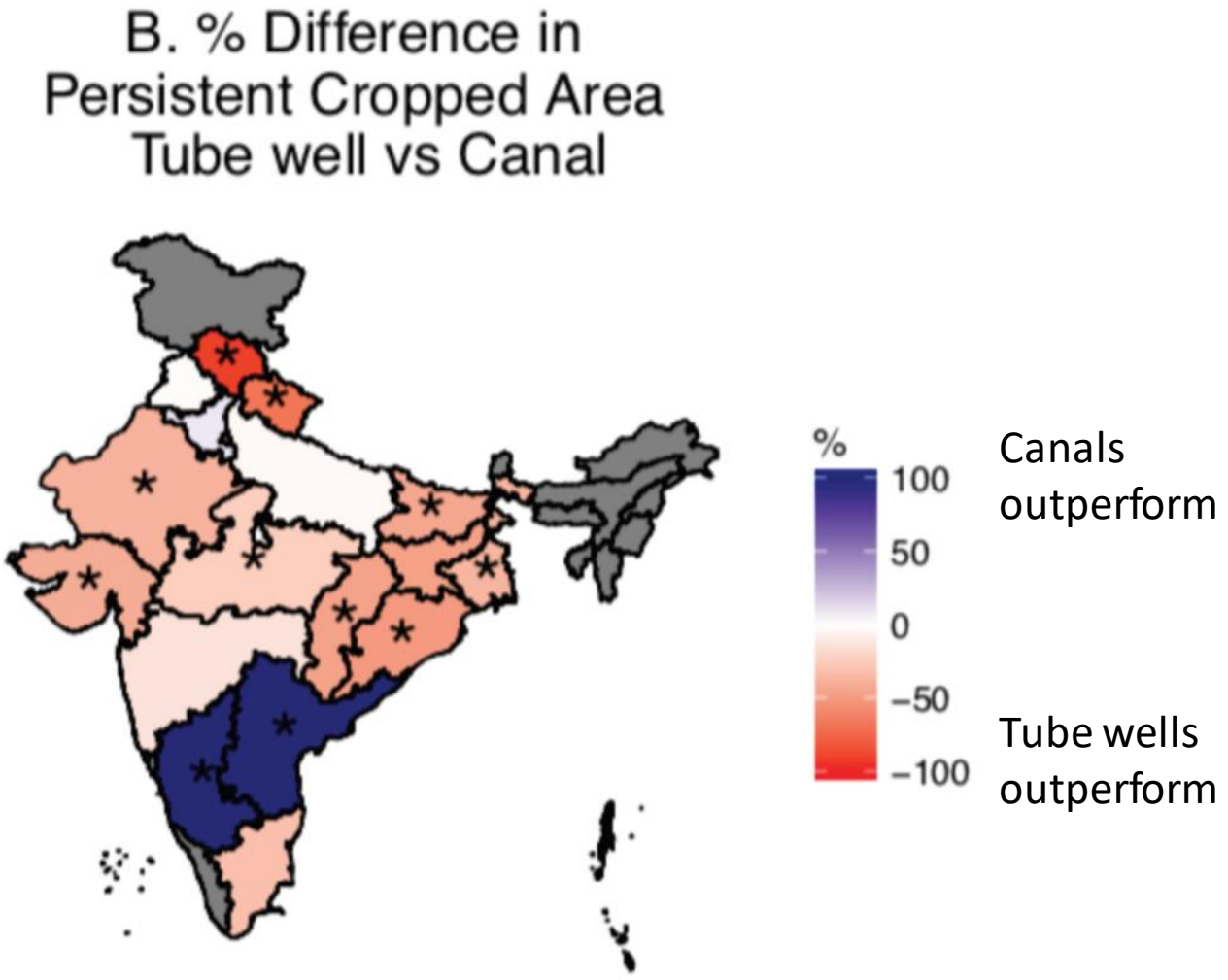

E. % Difference in Probability Village is Cropped Compared to Dug well
Tube well
Canal
0 50 100 150
% Difference


F. % Difference in Persistent Cropped Area Compared to Dug well
Tube well
Canal
−10 0 10 20 30 40
% Difference


G. % Difference in Coefficient of Variation Compared to Dug well
Tube well
Canal
−20 −10 0 10 20
% Difference


H. % Difference in Sensitivity to Rainfall (per mm) Compared to Dug well
Tube well
Canal
−0.15 −0.10 −0.05 0.00 0.05
% Difference

But this is not true across all of India – particularly in South India



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