Adaptation pathways to maintain global wheat production through the 21st century

Akemi Tanaka, Kiyoshi Takahashi, Yuji Masutomi, Naota Hanasaki, Yasuaki Hijioka, Hideo Shiogama, and Yasuhiro Yamanaka

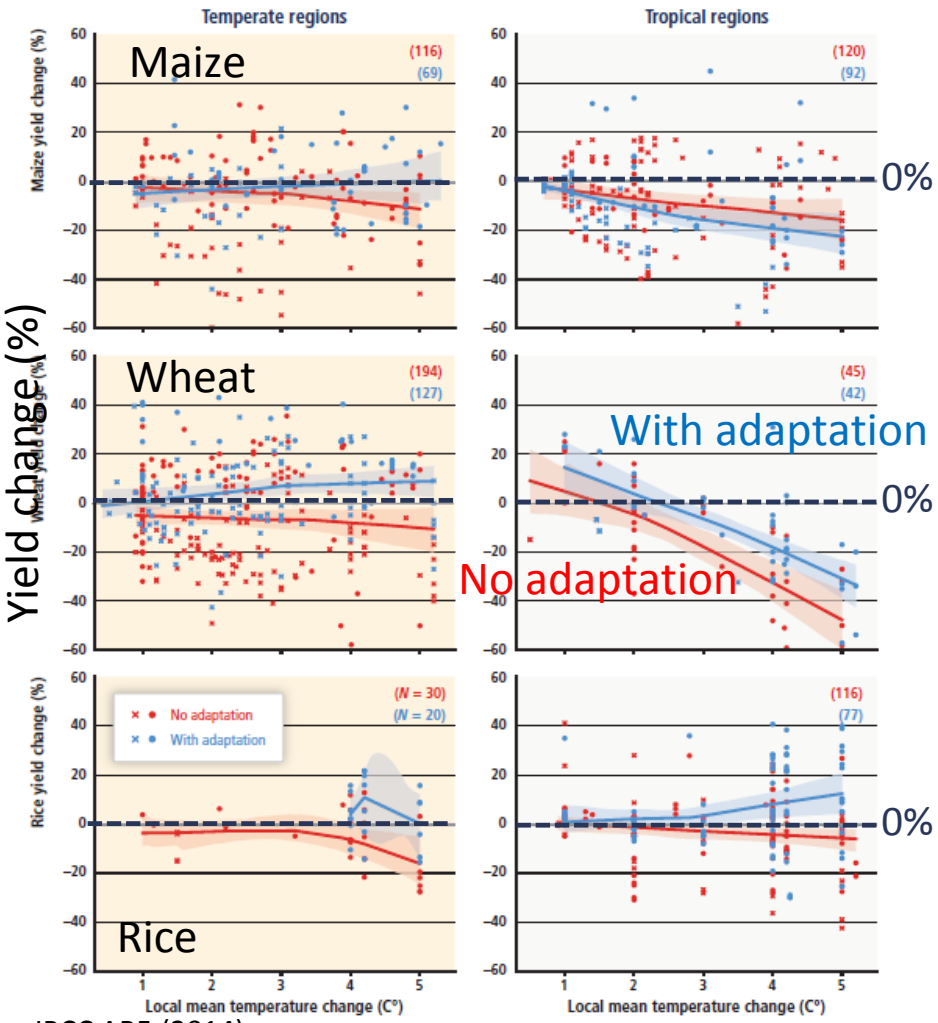
Tanaka et al. (2015): Adaptation pathways of global wheat production: Importance of strategic adaptation to climate change. *Scientific Reports*, 5, 14312.

AIM ASIA-PACIFIC INTEGRATED MODEL

NIES JAPAN

Introduction

Few studies have assessed the course of adaptation along with the progress of climate change for each of the current major food producing countries



IPCC AR5 (2014)

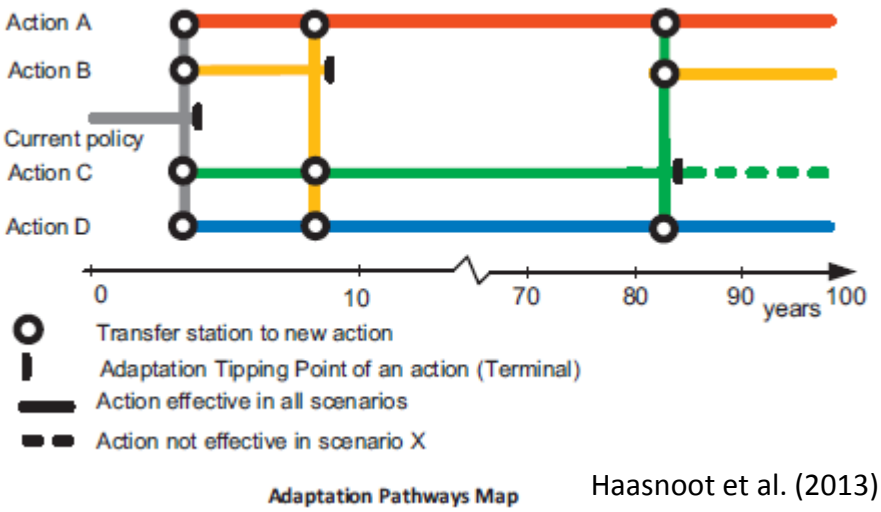
- Agricultural adaptation is expected to reduce the negative impacts of climate change on crop yields
- Various options of adaptation:
  - ✓ Shifting planting date
  - ✓ Switching crop varieties
  - ✓ Expanding irrigation etc.
- Many studies assessed the situation that the adaptations are fully implemented or not implemented at all (especially at global scale)

- How do we analyze the timing and intensity of adaptations to be implemented?

"**Adaptation pathways**" are helpful for illustrating the timing and intensity of adaptation required

- Adaptation pathways are:

  temporal sequences of adaptations



Haasnoot et al. (2013)

- Previous studies proposed adaptation pathways to show potential sequences of actions to explore robust adaptive plans in regional scale

To show the timing and intensity required to maintain global food production,

- Focus on describing adaptation pathways by sequential introduction of the minimum necessary adaptation for the current major food producing countries

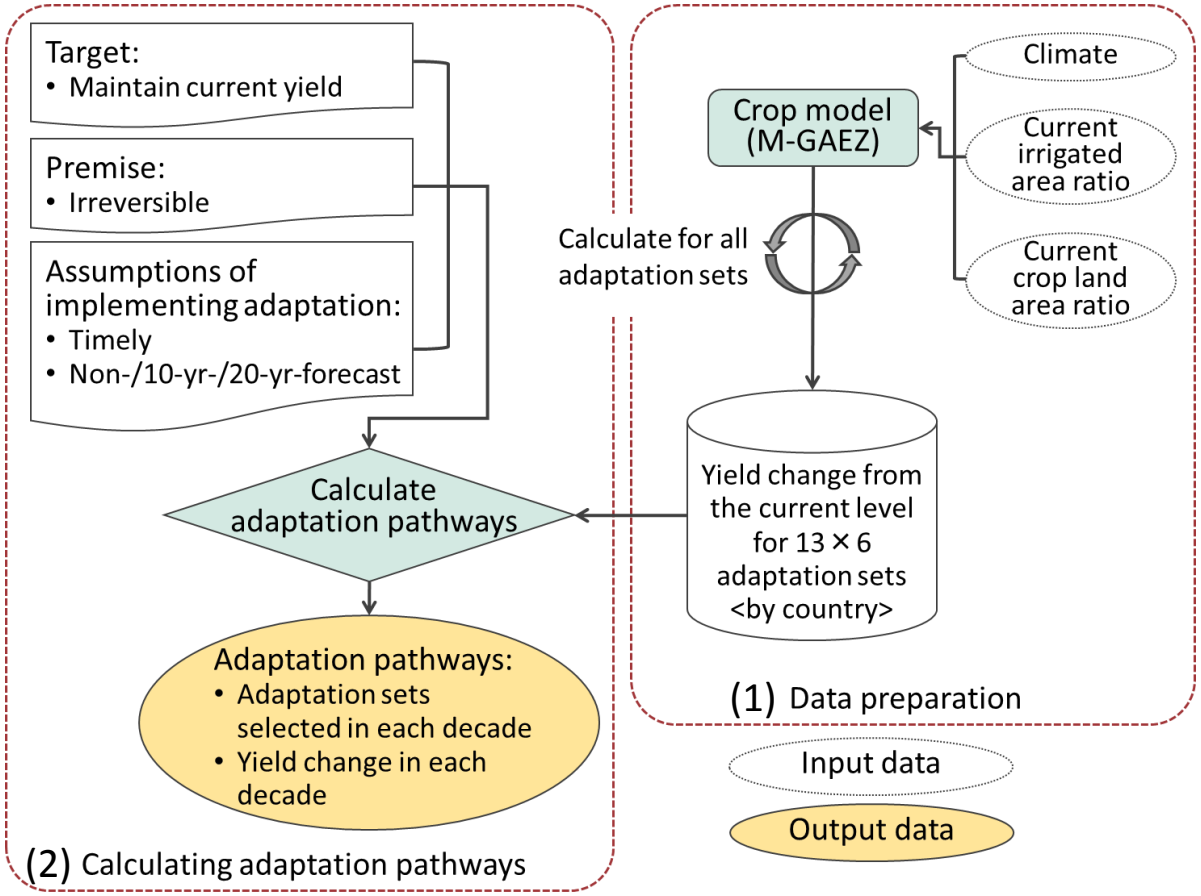
Objective

Develop nation-wise adaptation pathways for global production of wheat (a staple crop worldwide) through the 21st century

- For the current major wheat-producing countries
  - China, India, the United States, Russia, France, Canada, Germany, Turkey, and Pakistan
- Adaptation pathways from the 2010s to 2090s based on sequential implementation of adaptation to maintain the levels of yield in the 1990s
- Primarily used the RCP8.5 scenario (a high greenhouse gas emissions scenario)

Methods

- Two adaptation options:
  - Expanding irrigated area ratio (13 adaptation levels)
  - Switching crop varieties and developing new varieties (6 adaptation levels)



- In each decade, implement an adaptation set* that attains minimum increase in yield from the 1990s (i.e., select from among adaptation sets with yield change ≥0% from 1990s)
- Adaptation levels are irreversible

- Climate model: MIROC-ESM
- Crop model: M-GAEZ model

*adaptation set: combination of adaptation option and adaptation level

Adaptation levels

- Level 0 is no adaptation
- The intensity of adaptation increases with the rise in the adaptation levels

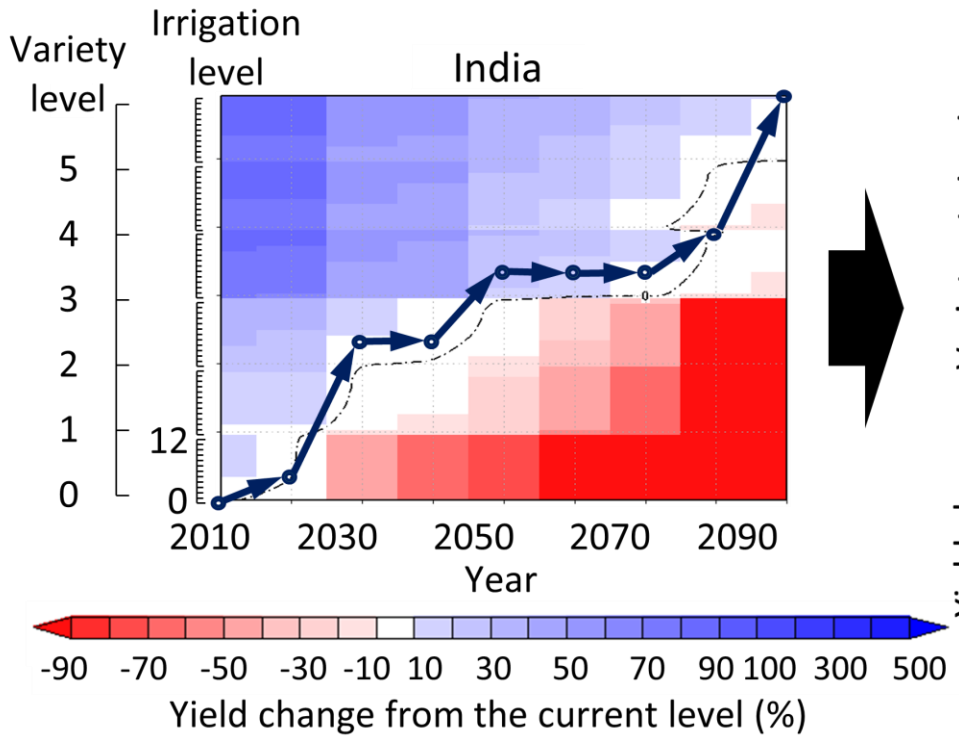
Level	Description	
Irrigation levels		**Expand irrigation:**
0	No adaptation (current irrigated area ratio)	
1 to 10	Increasing irrigated area ratio by 10% per level (Only for crop lands where irrigated ratio in the present > 0)	Only for current irrigated crop lands
11	• Increasing irrigated area ratio by 100% for crop lands where irrigated ratio in the present > 0 • Increasing by 20% for presently non-irrigated crop lands	For current irrigated crop lands + current rain-fed crop lands
12	The same as Level 11 except increasing by 50% for presently non-irrigated crop lands	
Crop variety levels		**Selectable varieties:**
0	No adaptation (only 4 minor varieties of the present optimal cultivar are selectable)	Only existing varieties
1	Original 16 varieties defined in the M-GAEZ model are selectable	
2 to 5	A set of 16 new heat-tolerant varieties* added to the selectable varieties in the previous level are selectable	Existing varieties + newly developed varieties

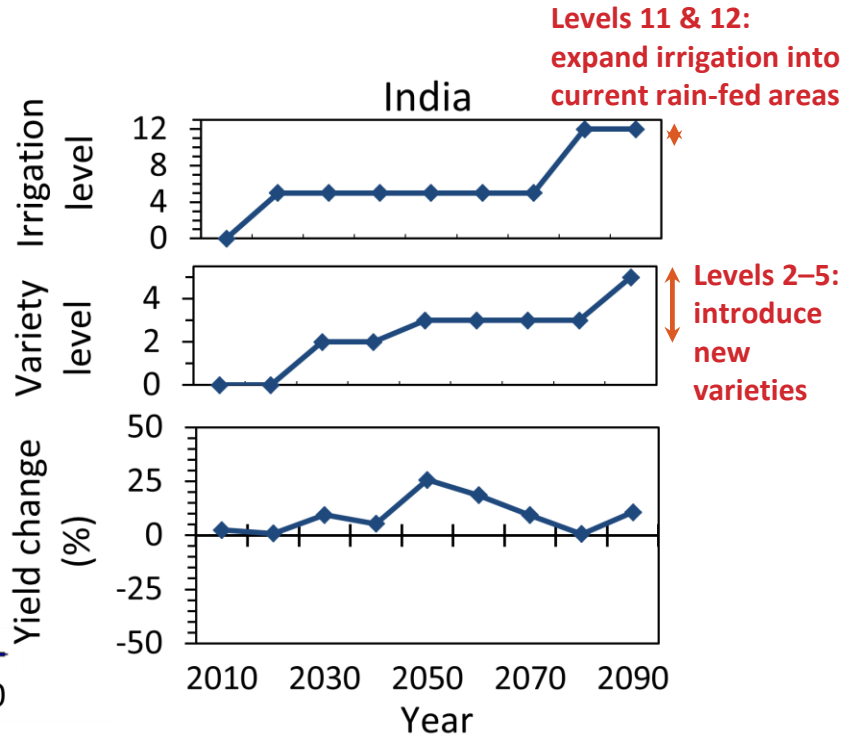
*The new crop varieties were set based on a sensitivity analysis with M-GAEZ model

Results

Adaptation pathways to maintain current wheat yield

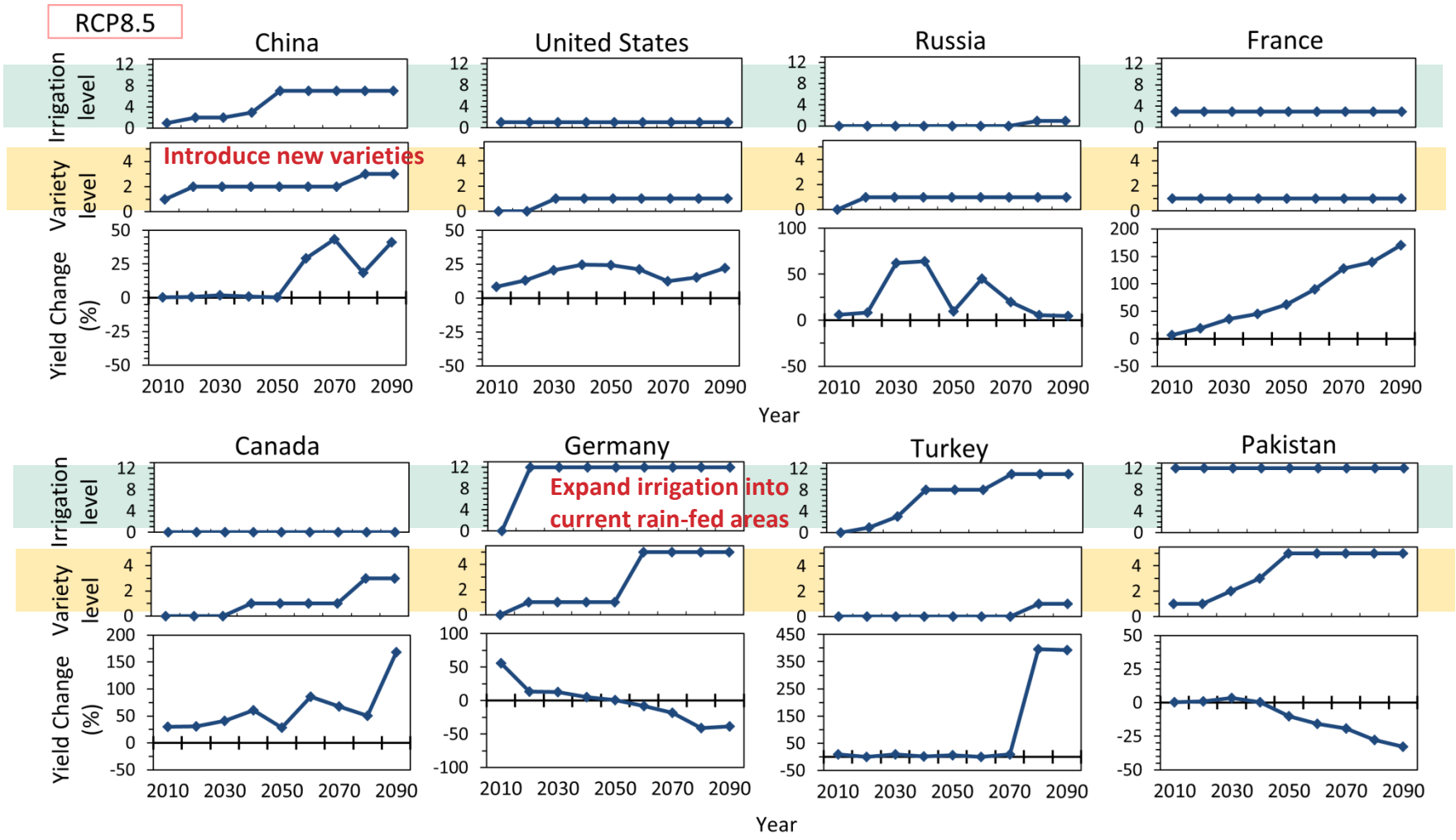
RCP8.5





- **<u>Only a limited number</u>** of the adaptation sets could maintain wheat yield near the current level (yield change ≈ ±10%)
- Late implementation of adaptation leads to a large amount of yield decrease; early implementation leads to an unnecessary yield increase

Adaptation pathways for the current major wheat-producing countries



- Adaptation pathways differ markedly among the countries

Discussion

Consideration of step-by-step adaptation pathways

- We assumed that:
  - A large amount of adaptation could be implemented within a decade
  - Required adaptation is always implemented timely

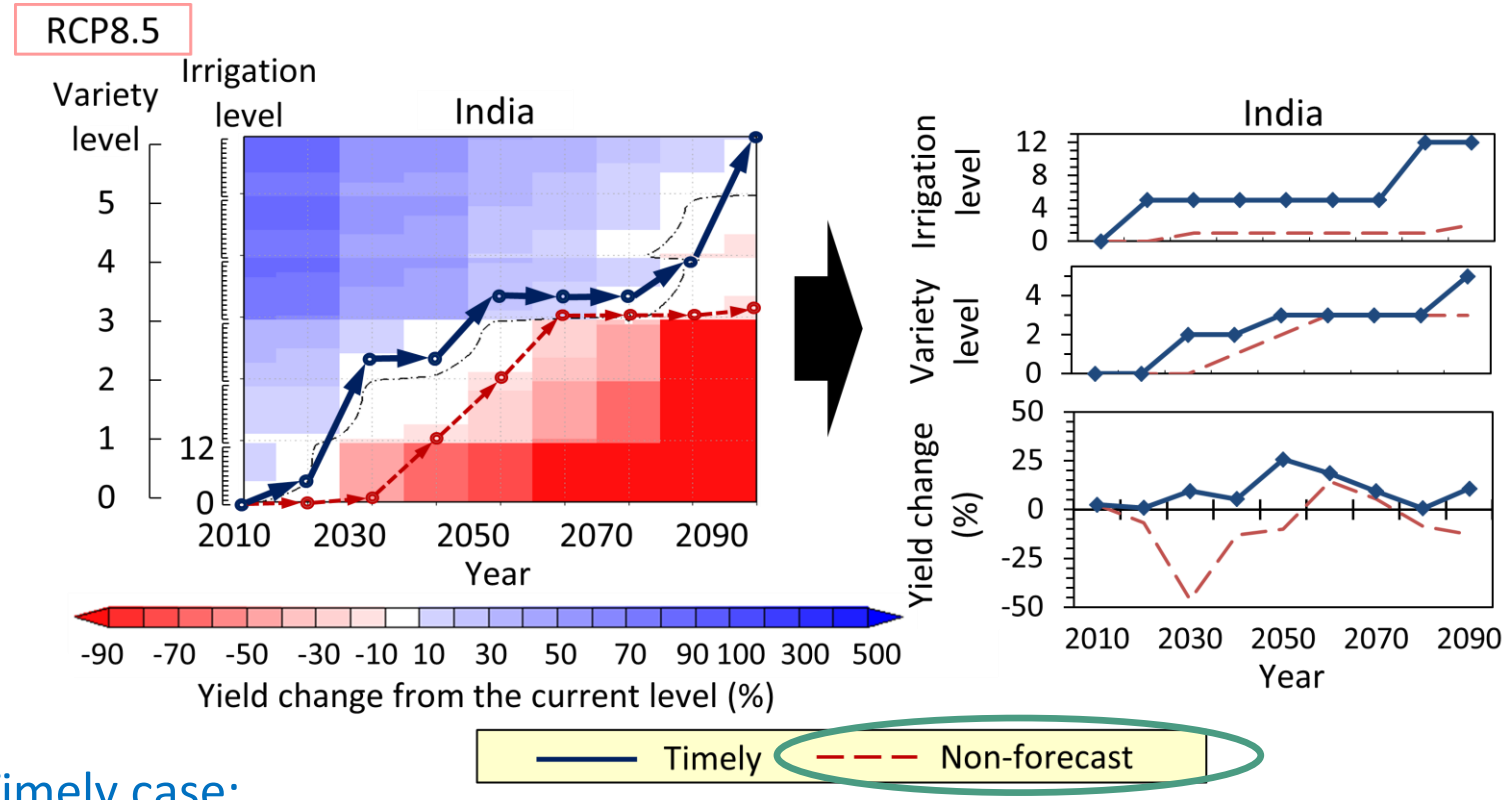
- However, when we imagine a series of adaptation processes (plan -> develop -> introduce), we have to consider that:
  - The feasible rate of adaptation
  - The lead time to implement an adaptation

    (i.e., the time lag between planning and implementation of adaptation)

Step-by-step adaptation pathways

- ✓ Limited in the amount of adaptation implemented to one level per decade
- ✓ A lead time to implement adaptation (10 years) is considered

- The negative impact of NOT forecasting necessary adaptation is remarkable when the lead time is considered



Timely case:

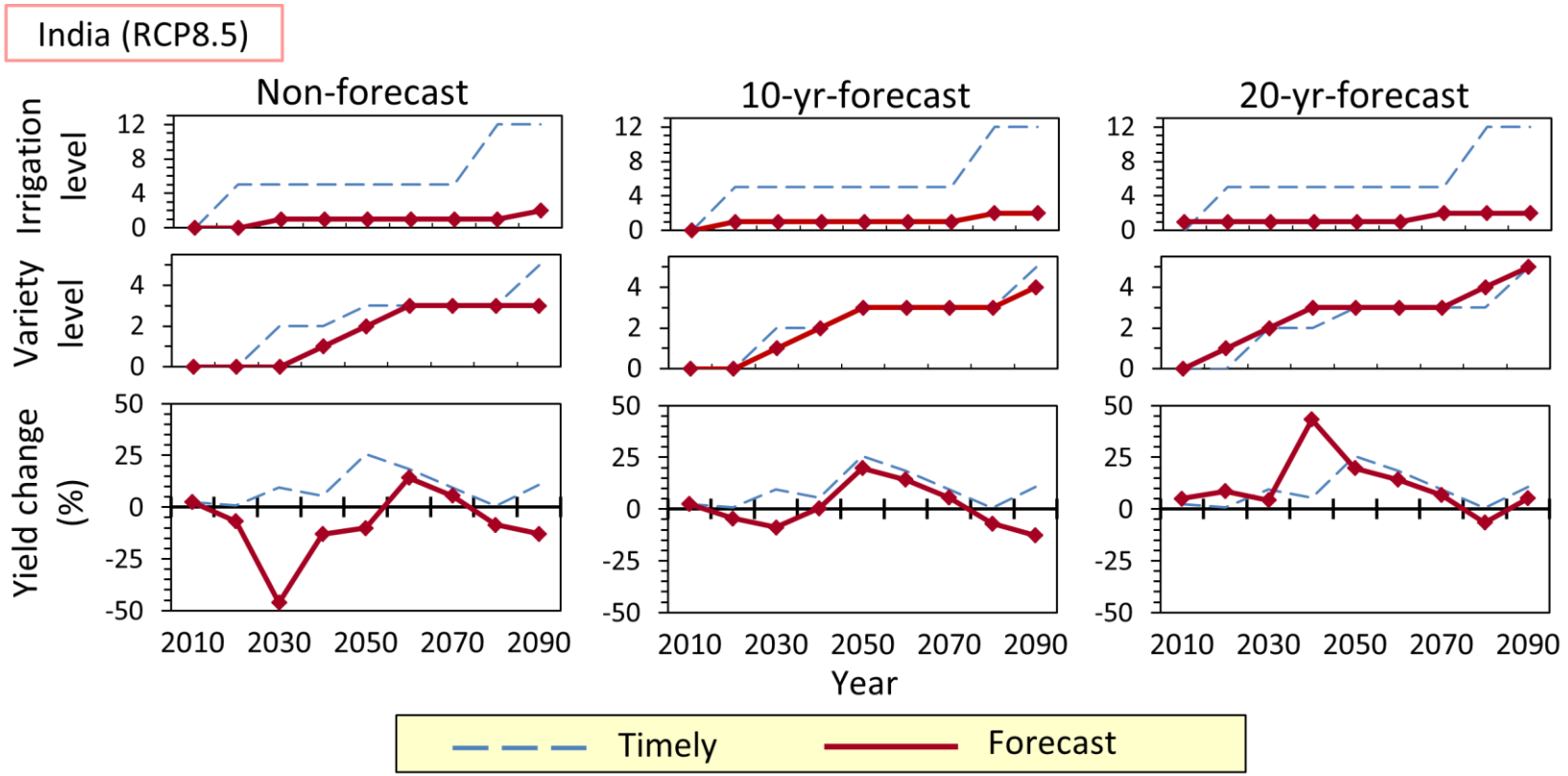
a large amount of adaptation can be implemented timely

Non-forecast case:

step-by-step adaptation pathways without forecasts

- adaptation required in a decade is implemented in the next decade, because the adaptation starts to be developed in the current decade

- If forecasts of necessary adaptations are available, the decrease in yield could be moderated



Forecasting the adaptation necessary in the future is important to achieve the benefit of the adaptation

Conclusions

- We developed adaptation pathways for the current major wheat-producing countries to maintain current wheat yield through the 21st century
- We found that:
  i. Adaptation pathways differ markedly among countries
  ii. The negative impacts of climate change could be moderated by implementing adaptation steadily according to forecasting necessary future adaptations, as compared to missing the appropriate timing to implement adaptations

Toward future research:

- Consider socio-economic conditions (e.g. increase in demand for food)
- Consider adaptation costs and technological progress
- Refine the assumptions of adaptation levels
- Conduct more comprehensive analyses to identify robust adaptation pathways