RICE PRODUCTION TECHNOLOGIES FOR CLIMATE CHANGE

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ABSTRACT

Predicted levels of global warming will have a marked effect on the growth, yield, and quality of the crop. A number of experimental and simulation studies have been conducted to determine or predict the likely impacts of climate change on yields of major crops, including rice (*Oryza sativa*. L), the most important food crop in Asia. A summary of these simulation results by the Intergovernmental Panel on Climate Change indicated that the effects of climate change on crop yields will be different depending on the region or the current level of temperature. In low-latitude regions, crop yields may drop even with a 1 °C increase in air temperature from the current level. In mid-high latitude regions, negative effects of climate change may appear where air temperature rises by 3 °C or more. However, these predictions include large uncertainties not just in a magnitude but in the direction of the impacts.

The uncertainties in the predictions resulted from a number of sources, such as those in the carbon emission scenarios, global climate models and gaps between global and local climates. Options in land use, crops, varieties and management practices may also make climate change impacts very different. In addition, crop models themselves contain uncertainties. Many of the crop models were developed based on small-scale experiments typically those conducted in environmental controlled chambers. While these experimental results are highly valuable in understanding the mechanisms of crop responses to the environmental changes, extrapolating to the field or regional conditions under variable climatic conditions creates another major source of uncertainties in the prediction of the future crop production. Testing the climate change impacts on crop production at the field or regional scale is still difficult and no single method can give us an overall picture of the impacts. We need to combine knowledge obtained from different methods and at different temporal and spatial scales to understand the likely impacts of climate change.

Both positive and negative effects of climate change are expected: Increasing atmospheric CO_2 concentration will have a positive influence on crop growth and yield via promoting photosynthesis and reducing the water use due to reduced stomatal conductance. Increases in temperature may reduce the low temperature limitations on growth particularly in high-latitude and/or high altitude regions, but will shorten crop life cycle and increase occurrences of heat stress and water use. Depletion of water resources and/or changes in precipitation patterns may change crop calendar and the inter-season variability of crop production. These counteracting effects will determine the magnitude and even the direction of the impacts of climate change. Adaptation to climate change should there aim to reduce negative impacts of climate change and to explore opportunities to enhance positive effects.

The projected climate changes will also affect carbon metabolism including methane emission from the paddy field, which will further exacerbate global warming. Future rice agriculture will therefore face challenges to meet increasing demand and to mitigate emission of green house gases from the agriculture sector under changing climates.

How management opstions such as variety options, management options (eg water ane nitorgen) will influence crop production/productivity and greenhouse gas emission from arable land is our central concern, but agricultural practices are specific to the regions like the impacts of climate change. Climate change is the common problem around world, but how you adapt to it is locally specific. In agricultural sector, there is no single and/or simple package solution readily transferable from one region to another. Adaptation/mitigation measures should be “Tailor-made” and designing and evaluating options for each region are essential. To tailor adaptation/mitigation measures, the following three components should be well coordinated ; (1) database of climate, crop, soil and agricultural practices for monitoring changes in climate and crop production. (2) mechanistic understandings of the climate change impacts on crops and various agro-ecosystems, (3) seeds of adaptation/mitigation options or technologies. International collaboration across different climate zones and different disciplines will facilitate this coordination.

KEYWORDS

Adaptation, CO_2, Mitigation, Temperature, Uncertainties

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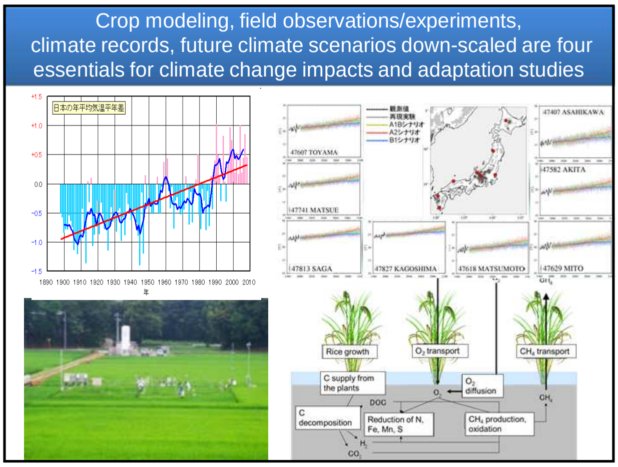
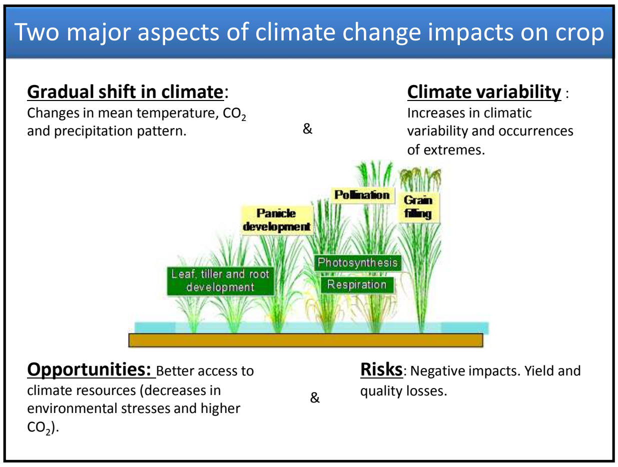
NIAES



Crop modeling, field observations/experiments, climate records, future climate scenarios down-scaled are four essentials for climate change impacts and adaptation studies



Two major aspects of climate change impacts on crop

Gradual shift in climate: Changes in mean temperature, CO_2 and precipitation pattern.

&

Climate variability : Increases in climatic variability and occurrences of extremes.

Opportunities: Better access to climate resources (decreases in environmental stresses and higher CO_2).

&

Risks: Negative impacts. Yield and quality losses.

Important processes/reponses that need better quantitative understandings （1）

Temperature responses

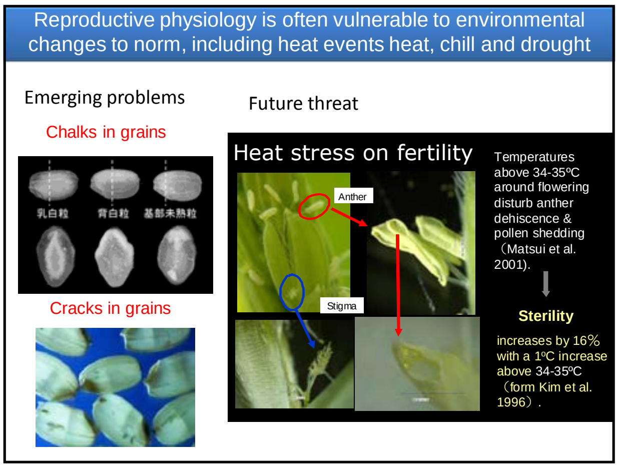
- Gradual shift in temperature

  Day/night temperature effects different ?

  (Peng et al 2004: Welch et al 2010 from field observations: chamber studies show lower grain set under high night temperature. Cheng et al 2009: Mohammad et al 2009).

- Extreme heat events

  Grain set is severely damaged by heat waves but still difficult to predict in open fields.-> Matsui et al (2007); Tian et al (2010); Hasegawa et al (2011)



Reproductive physiology is often vulnerable to environmental changes to norm, including heat events heat, chill and drought

Emerging problems

Chalks in grains

Cracks in grains

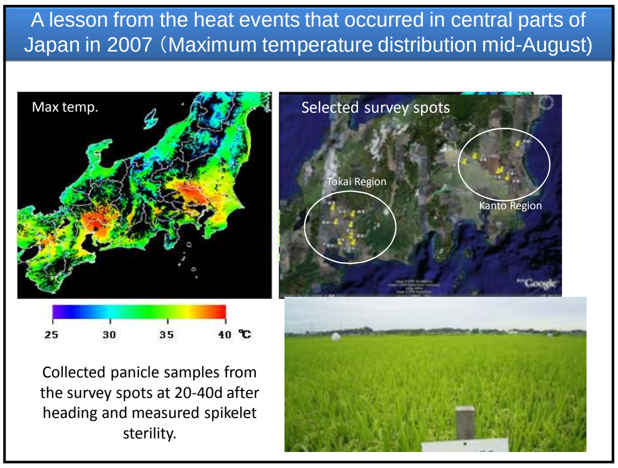
Future threat

Heat stress on fertility

Temperatures above 34-35ºC around flowering disturb anther dehiscence & pollen shedding （Matsui et al. 2001).

Sterility

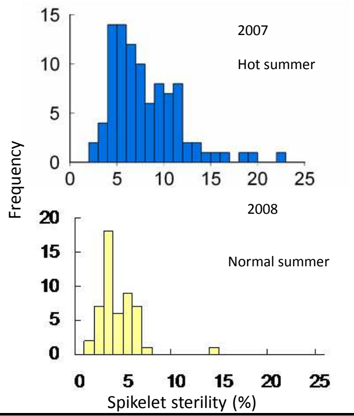
increases by 16% with a 1ºC increase above 34-35ºC （form Kim et al. 1996）.



A lesson from the heat events that occurred in central parts of Japan in 2007（Maximum temperature distribution mid-August)

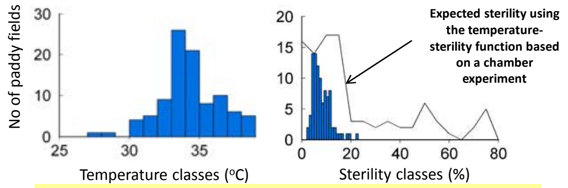
Collected panicle samples from the survey spots at 20-40d after heading and measured spikelet sterility.

Spikelet sterility distribution of two years (2007 & 2008)

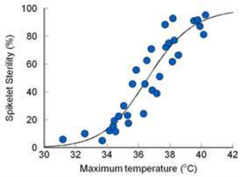


Hasegawa et al (2011) J. Agrc. Meteorol.

Frequency distribution of maximum air temperature around heading stage (5d mean) and spikelet sterility of the paddy fields studied

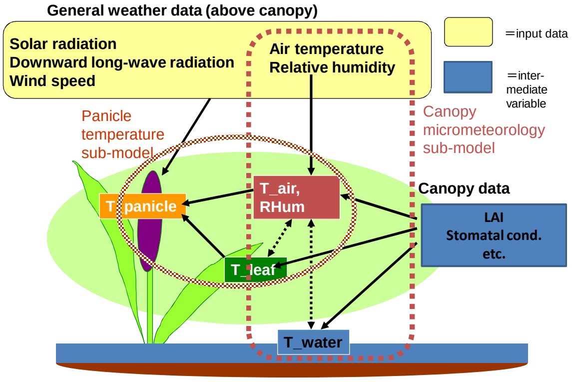


How can we fill the gap between chamber and field level observations?



Spikelet fertility and temperature relationship obtained in the temperature gradient chamber studies - Kim et al 1996 JJCS

IM²PACT (Integrated Micrometeorology Model for Panicle And Canopy Temperature).



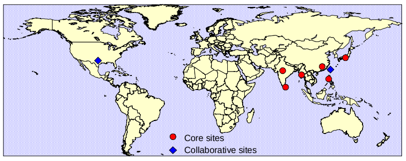
Yoshimoto et al 2005; 2011; J. Agric. Meteorol.

We still need canopy micro-meteorological conditions under a range of conditions

Heat stress is not simply a issue of an air-temperature but a combination of many environmental factors

The occurrence and severity of the stress can depend on humidity, wind speed, CO_2 and genotypes: Understandings of the crop damage under the open-field conditions will be pivotal in assessing climate change impacts and developing adaptation measures.

Network of the Multi-site Monitoring of Heat Stresses and Micrometeorological Conditions in the Rice Plants Communities under Various Climates is now starting.



(Yoshimoto et al 2012) J. Agric. Meteorol.

- An example of setting a temperature sensor in the field. Helps promote monitoring -> assisting what really matters.

Paddy micro-met measurement network using;

MINCER = Micrometeorological Instrument for Near Canopy Environment of Rice

✓Stand-alone

✓Accurate measurement by force-ventilated radiation shield

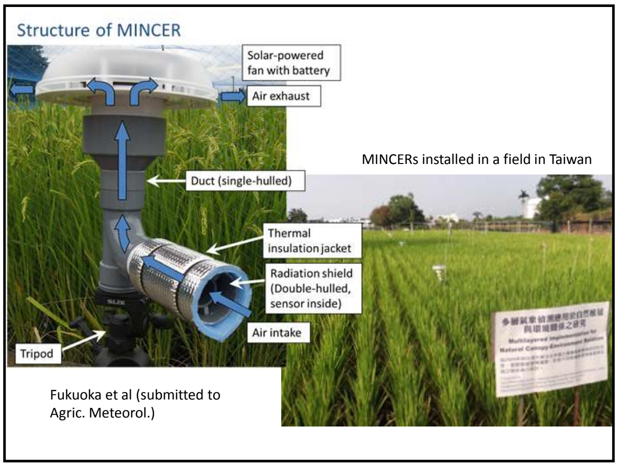
✓Electric fan powered by solar cells with rechargeable batteries

✓Tiny self-powered temperature and humidity logger

✓Light-weight

✓Low-price

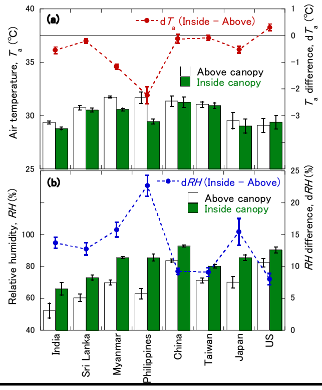
Structure of MINCER



MINCERs installed in a field in Taiwan

Fukuoka et al (submitted to Agric. Meteorol.)

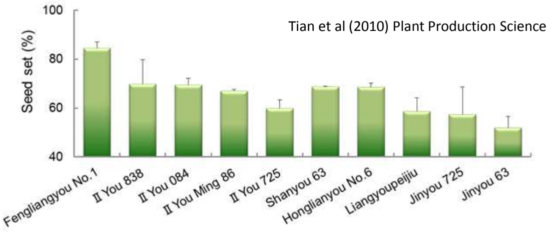
Air temperature and relative humidity above and inside the rice canopy at 8 MINCERnet sites



Yoshimoto et al (2012) J. Agric. Meteorol.

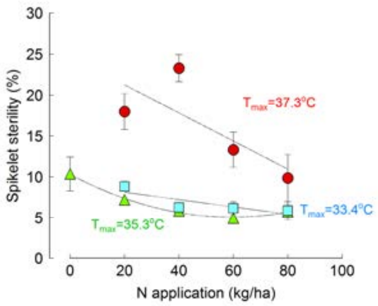
Panicle temperature and microclimate at flowering time in Jingzhou (Hubei, China) in the hottest period of 2006 and seed set % of 10 varieties.

Time	Temperature (°C)			Relative humidity (%)	Solar radiation (W m^{-2})	Wind speed (ms^{-1})
	Panicle(P)	Air(A)	P-A			
10:56–11:00 am	37.1	32.8	4.3	79.0	678	0.63
11:10–11:20 am	37.2	33.2	4.0	77.2	627	0.55
11:20–11:30 am	36.2	33.0	3.1	78.0	769	1.03



Tian et al (2010) Plant Production Science

Spikelet sterility of field-grown rice exposed to different temperatures at flowering in the record hot summer of 2007 and N application rate



Fields experiments conducted at NIAES in 2007 with different planting dates.

Hasegawa et al (2011) J. Agric. Meteorol.

y= 24.7 -0.172 x (R^2=0.32, n=20, $P<0.01$) for T_{max}=37.3
y= 10.3 -0.176 x +0.00148 x^2 (R^2=0.25, n=50, $P<0.01$) for T_{max} 35.3
y= 9.03 -0.0450 x (R^2=0.27, n=20, $P<0.05$) for T_{max}=33.4

Important processes/responses that need better quantitative understandings (2)

CO_2 responses of rice under field conditions

- N interaction (Kim et al. 2003 GCB)
- Down-regulation or acclimation
  (Seneweera et al 2002 FPB; Chen et al 2005 PCP)
- Genotypic differences
  (Shimono et al 2009 JXB: Yang et al 2009 AEE)
- Temperature interaction
  (Shimono et al 2008 GCB)

Open field evaluation of the impacts of climate change and efficacy of adaptation and mitigation measures

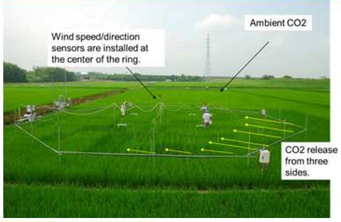
-Free-Air Concentration Enrichment, Test bed for the effects of elevated CO_2 on rice paddy under open fields conditions -

The first Rice FACE in Shizukuishi,
Lat/Lon: 39° 38′ N, 140° 57′ E
(1998-2008)

Tsukuba FACE, Ibaraki

Lat/Lon: 35° 58'28.57" N,
139° 59'36.98" E (2010-)

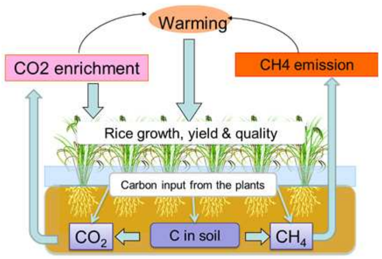
Diameter:17 m



CO_2 is released from windward sides of the ring, targeting 200 ppm above the ambient. In each CO_2 ring, 20 varieties, 3 N levels and 2 soil/temperature levels are nested as sub-plots.

Adaptation and mitigation should link together

-Adaptation measures should also be evaluated in terms of impacts on the environments-



CO_2 x soil/water temperature effects on CH_4 emission; Large warming effects (+2° C) by +44% (Tokida et al 2010, Biogeosciences)

40–60% of season-total CH_4 production originated from current-season photosynthates (Tokida et al 2011, Global Change Biology)

Carbon flow management through plant management under higher CO_2 and T.

Toward effective international collaboration

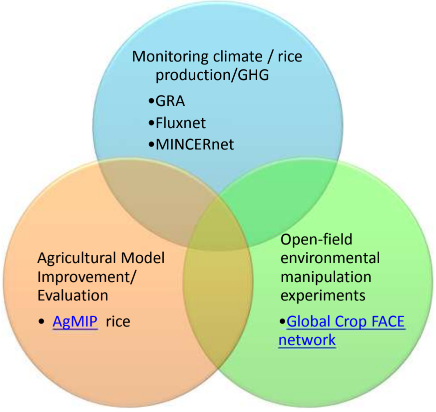
Agricultural practices are specific to the regions, and so are the impacts of climate change. Although climate change is the common problem around world, how you adapt to it is locally specific.

In agricultural sector, there is no single and/or simple package solution readily transferable from one region to another**.** ***Adaptation measures should be "Tailor-made" .***

To tailor adaptation measures, designing and analyzing adaptation options for each region are essential. To do so, three key elements needed;

1. Database (climate, crop, soil, agricultural practices)
2. Mechanistic understandings (models) of the climate change impacts on crops and various agro-ecosystems.
3. Seeds of adaptation options or technologies

Continuing and emerging efforts to link different disciplines



Monitoring climate / rice production/GHG

- GRA
- Fluxnet
- MINCERnet

Agricultural Model Improvement/ Evaluation

- AgMIP rice

Open-field environmental manipulation experiments

- Global Crop FACE network

Collaborators

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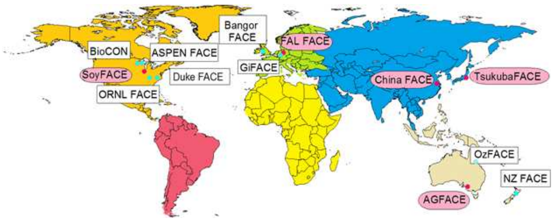
Mayumi Yoshimoto
Hidemitsu Sakai
Kentaro Hayashi
Tamon Fumoto
Tsuneo Kuwagata
Takeshi Tokda
Yasuhiro Usui
Chunwu Zhu
Nobuko Katayanagi
Zhao Guoyou

Global FACE site list as of 2010
(Replicated trials with a ring diameter> 8 m only)



Drawn based on http://public.ornl.gov/face/global_face.shtml and author's personal communication.
Pink Ellipses are crop FACE.
AGFACE, Australian Grains FACE Facility; BioCON, Biodiversity, CO2 and N; FACTS, Forest-Atmosphere Carbon Transfer and Storage; FAL, Federal Agricultural Research Centre; GiFACE, The University of Giessen FACE facility; ORNL, Oak Ridge National Laboratory; OzFACE, Australian tropical savannas FACE facility; SoyFACE, University of Illinois, Soybean FACE experimental facilityなど.

The Agricultural Model Intercomparison and Improvement Project (AgMIP)

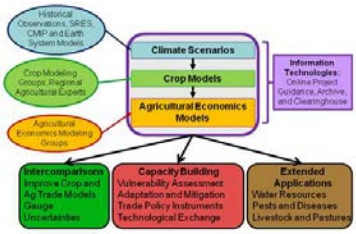


Figure 1: AgMIP components and expected outcomes.

Co-Leaders: Cynthia Rosenzweig, Jim Jones, and Jerry Hatfield

The rice team has been formed to initiate the evaluation of crop model uncertainties since August 2011.

Currently testing multiple rice models using four sentinel sites data;

1. Shizukuishi, Japan
2. Nanjing, China
3. Los Banos, Philippines
4. Punjub, India