Impact Assessment of Climate Change on Rice Production in Asia in Comprehensive Consideration of Uncertainties in Future Climate projections

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Contents

• Part I
  – Impact assessment

• Part II
  – Adaptation policy assessment
Part I

Impact assessment
Introduction I
-Uncertainties in impact assessment-

GCM
RCM

Climate projections

Impact model
(Crop model, water resource model, etc.)

Outputs

(Fischer et al., (2005))
1st Key Question

• How much impact does climate change have in comprehensive consideration of uncertainty in future climate projections?
Introduction II
- CO2 fertilization effect -

High CO2 concentration

Enhance photosynthesis: positive

Climate change: negative
2nd Key Question

• Is net effect of elevated CO2 concentration positive or negative?
  – In the 2020s, 2050s, and 2080s
Method
- How to take uncertainties into consideration?

- Step 1
  - Calculation of multi-impacts by using multi-climate projections

- Step 2
  - Assuming that each impact is equally possible, we calculate statistical metrics.

**Ex. -5%, 5%, -15%, -10%, 9%**

1. Average
   \[ \text{Ave.} = \frac{-5 + 5 + (-15) + (-10) + 9}{5} = -3.2 \% \]
2. Standard deviation
   \[ \text{Stdev.} = 10 \% \]
3. Probabilities
   \[ \text{Pr. of yield decrease} = 60 \% \]
## Climate projections (from PCMDI)

<table>
<thead>
<tr>
<th>Country</th>
<th>Model name</th>
<th>A1B (18 GCMs)</th>
<th>A2 (14 GCMs)</th>
<th>B1 (17 GCMs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norway</td>
<td>BCCR-BCM2.0</td>
<td></td>
<td>○</td>
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<td>CGCM3.1(T47)</td>
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<td>Germany</td>
<td>ECHAM5/MPI-OM</td>
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<td>○</td>
<td>○</td>
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<tr>
<td>Germany / Korea</td>
<td>ECHO-G</td>
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<td>○</td>
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<tr>
<td>China</td>
<td>FGOALS-g1.0</td>
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<tr>
<td>USA</td>
<td>GFDL-CM2.0</td>
<td>○</td>
<td>○</td>
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<tr>
<td>USA</td>
<td>GFDL-CM2.1</td>
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<tr>
<td>USA</td>
<td>GISS-AOM</td>
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<td>USA</td>
<td>GISS-EH</td>
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<td>Japan</td>
<td>MIROC3.2(hires)</td>
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<tr>
<td>Japan</td>
<td>MIROC3.2(medres)</td>
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<td>Japan</td>
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<td>UK</td>
<td>UKMO-HadGEM1</td>
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</table>
Crop model

- **M-GAEZ model**
  - Based on **Global Agro-Ecological Zone model** (GAEZ-model)
  - **GAEZ-model** was Developed by IIASA and FAO (Fischer et al., 2002)
    - was used for the assessment of global food security in IPCC AR4.
    - is one of main tools used by FAO for analyses of land resources

Number of hunger (IPCC AR4)

<table>
<thead>
<tr>
<th>Reference</th>
<th>2020</th>
<th>2050</th>
<th>2080</th>
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<tbody>
<tr>
<td></td>
<td>Millions at risk</td>
<td></td>
<td></td>
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<tr>
<td>A1</td>
<td>663</td>
<td>208</td>
<td>108</td>
</tr>
<tr>
<td>A2</td>
<td>782</td>
<td>271</td>
<td>768</td>
</tr>
<tr>
<td>B1</td>
<td>749</td>
<td>239</td>
<td>91</td>
</tr>
<tr>
<td>B2</td>
<td>630</td>
<td>348</td>
<td>233</td>
</tr>
</tbody>
</table>
Actual Yield = Potential Yield × Water stress × Agro-climatic stress × Soil stress

- **Potential Yield**: Yield limited by Temperature and Radiation Photosynthesis (T,R) – Respiration (T)
- **Water stress**: Multiplier determined by soil water stress
- **Agro-climatic stress**: Multiplier related to constraints by insect, pest, weed, etc.
  - Example: Yearly warm region has high agro-climatic stress.
- **Soil stress**: Crop can not grow in rock and sandy region
Advantages and Disadvantages of M-GAEZ model

• **Advantages**
  – Multi-crops: 26 crops (154 sub-species)
  – Soil water balance (FAO56 methodology)
    • crop water demand can be calculated.
  – Constraints by pest, insect, weed are considered
    • But poor!

• **Disadvantages**
  – Old type process model (or semi-process model)
    • Based on 1970s’ knowledge
  – No soil nutrient dynamics (no fertilizer effect)
Validation of M-GAEZ

Comparison of yields between simulation and observation

Average yields for 1980s by Asian countries

Yearly variability in yields in 1980s in Asia
Result I - without CO2 fertilization effect -
Result II - with CO2 fertilization effect -

1990s – 2020s
Average change in yields (ACY) [%]
- 60 ≤ ACY < 50
- 50 ≤ ACY < 40
- 40 ≤ ACY < 30
- 30 ≤ ACY < 20
- 20 ≤ ACY < 10
- 10 ≤ ACY < 5
- 5 ≤ ACY < 1
- 1 ≤ ACY < 0
- 0 ≤ ACY < 5
- 5 ≤ ACY < 10
- 10 ≤ ACY < 15
- 15 ≤ ACY < 20
- 20 ≤ ACY < 25
- 25 ≤ ACY < 30
- 30 ≤ ACY < 35
- 35 ≤ ACY < 40
- 40 ≤ ACY < 45
- 45 ≤ ACY < 50
- ACY ≤ -50

1990s – 2050s
Average change in yields (ACY) [%]
- 60 ≤ ACY < 50
- 50 ≤ ACY < 40
- 40 ≤ ACY < 30
- 30 ≤ ACY < 20
- 20 ≤ ACY < 10
- 10 ≤ ACY < 5
- 5 ≤ ACY < 1
- 1 ≤ ACY < 0
- 0 ≤ ACY < 5
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- 10 ≤ ACY < 15
- 15 ≤ ACY < 20
- 20 ≤ ACY < 25
- 25 ≤ ACY < 30
- 30 ≤ ACY < 35
- 35 ≤ ACY < 40
- 40 ≤ ACY < 45
- 45 ≤ ACY < 50
- ACY ≤ -50

1990s – 2080s
Average change in yields (ACY) [%]
- 60 ≤ ACY < 50
- 50 ≤ ACY < 40
- 40 ≤ ACY < 30
- 30 ≤ ACY < 20
- 20 ≤ ACY < 10
- 10 ≤ ACY < 5
- 5 ≤ ACY < 1
- 1 ≤ ACY < 0
- 0 ≤ ACY < 5
- 5 ≤ ACY < 10
- 10 ≤ ACY < 15
- 15 ≤ ACY < 20
- 20 ≤ ACY < 25
- 25 ≤ ACY < 30
- 30 ≤ ACY < 35
- 35 ≤ ACY < 40
- 40 ≤ ACY < 45
- 45 ≤ ACY < 50
- ACY ≤ -50
Result III

- **In the 2020s**
  - Little difference in average changes in production (ACP) among SRES scenarios
  - The probabilities of production decrease (Pr(\(CP<0\))) are high for all SRES scenarios

- **In the 2050s**
  - Positive and negative effects are in equilibrium

- **In the 2080s**
  - Large difference in ACPs and Pr(\(CP<0\))s among SRES scenarios.
    - A2 has largest adverse effect although A2 has the largest CO2 fertilization effect

![Bar graph showing changes in production](chart1)

### Without CO2 fertilization effect

<table>
<thead>
<tr>
<th>Year</th>
<th>A1B</th>
<th>A2</th>
<th>B1</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACP without CO(_2) effect</td>
<td>-5.2</td>
<td>-6.3</td>
<td>-4.2</td>
</tr>
<tr>
<td>ACP</td>
<td>-3.3</td>
<td>-4.5</td>
<td>-2.5</td>
</tr>
<tr>
<td>SDCP</td>
<td>3.2</td>
<td>3.2</td>
<td>3.1</td>
</tr>
<tr>
<td>Pr((CP&lt;0))</td>
<td>83.3</td>
<td>100.0</td>
<td>76.5</td>
</tr>
</tbody>
</table>

### With CO2 fertilization effect

<table>
<thead>
<tr>
<th>Year</th>
<th>A1B</th>
<th>A2</th>
<th>B1</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACP without CO(_2) effect</td>
<td>-8.6</td>
<td>-9.4</td>
<td>-5.4</td>
</tr>
<tr>
<td>ACP</td>
<td>-0.3</td>
<td>-0.9</td>
<td>0.2</td>
</tr>
<tr>
<td>SDCP</td>
<td>3.9</td>
<td>3.7</td>
<td>3.3</td>
</tr>
<tr>
<td>Pr((CP&lt;0))</td>
<td>72.2</td>
<td>85.7</td>
<td>47.1</td>
</tr>
</tbody>
</table>
Summary of the Part I

• **Key questions**
  – How much impact does climate change have in comprehensive consideration of future climate projections?
  – Is net effect of elevated CO2 concentration positive or negative?

• **Our answer**
  – Net effect of elevated CO2 concentration in comprehensive consideration of future climate projections is negative in the 2020s and 2080s, and nearly zero in the 2050s.

• **Suggestions**
  – **It is necessary to take immediate adaptive actions in the near future, regardless of socio-economic development.**
    • Because the probabilities of production decrease are high for all SRES scenarios in the 2020s
  – **The reduction of CO2 emission in the long term has a large potential to mitigate negative changes.**
    • Large difference in change in production among SRES scenarios in the 2080s
    • High CO2 concentration scenario, A2, has largest adverse effect in the 2080s, while low CO2 concentration scenario, B1, has smallest adverse effect in the 2080s.
Part II

Adaptation policy assessment
Introduction

- Mitigation and adaptation policy

<table>
<thead>
<tr>
<th>Characteristics of mitigation and adaptation</th>
<th>Mitigation of climate change</th>
<th>Adaptation to climate change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefited systems</td>
<td>All systems</td>
<td>Selected systems</td>
</tr>
<tr>
<td>Scale of effect</td>
<td>Global</td>
<td>Local to regional</td>
</tr>
<tr>
<td>Life time</td>
<td>Centuries</td>
<td>Years to centuries</td>
</tr>
<tr>
<td>Lead time</td>
<td>Decades</td>
<td>Immediate to decades</td>
</tr>
<tr>
<td>Effectiveness</td>
<td>Certain</td>
<td>Generally less certain</td>
</tr>
<tr>
<td>Ancillary benefits</td>
<td>Sometimes</td>
<td>Mostly</td>
</tr>
<tr>
<td>Polluter pays</td>
<td>Typically yes</td>
<td>Not necessarily</td>
</tr>
<tr>
<td>Payer benefits</td>
<td>Only little</td>
<td>Almost fully</td>
</tr>
<tr>
<td>Monitoring</td>
<td>Relatively easy</td>
<td>More difficult</td>
</tr>
</tbody>
</table>

Fussel and Klein (2006)

Adaptation policies are only actions against the near future impacts
3rd Key Question

- How much can adaptation policies reduce the impacts of climate change in the near future?

or

- Which adaptation policies are effective?
Method
- Quantification of effectiveness of adaptive actions-

• Risk of decrease in yields: $R$

\[ R = \Sigma \text{impact} \times \text{Probability} \]

※only negative impacts are summed

• Effect of adaptive action A: $E_A$

\[ E_A = (R_A/R_0) \times 100 \]

$R_A$: $R$ with adaptive action A

$R_0$: $R$ with no adaptive action
Adaptive actions

1. Changes in crop variety and planting date
   - Changes to suitable crop variety and planting date for future climate condition
   - Autonomous adaptation

2. Expanding irrigated area
   - Changes from rain-fed to irrigated area
   - Stable water enough for crop growing are supplied in irrigated area
   - Planed adaptation

3. Expanding crop area
   - Changes to rice fields from other land uses.
   - Planed adaptation
Result I

- There is large difference in effects of adaptive actions among countries.
- Changes in varieties and planting date have high effect for most countries.
- Irrigated area expansion has high effect in India and Pakistan.
Summary in Part II

• **Key questions**
  – How much do adaptation policies reduce the impacts of climate change in the near future?
  – Which adaptation policies are effective?

• **Our answer**
  – There is large difference in effects of adaptive actions among countries.
  – Changes in varieties and planting date have high effect for most countries.

• **Suggestions**
  – Adaptive actions suitable for each countries should be taken
Thank you for your attention!!