11th Workshop on the Modeling Intercomparison Study for Asia (Laxenburg, Feb 2009)

Crop losses from ground-level ozone in Asia

Applications of
APD-IIASA/GAINS-Asia model
FAO/IIASA GAEZ model

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Two research projects

Common Aim:

- Assessment of spatial distribution of crop damage due to O_3

Complementary research questions:

- Can farmers adapt agronomic practices to reduce O_3 damage?
- What is the expected reduction in O_3 damage by possible reductions in emissions?

Crop losses due to O_3 and adaptation

GAEZ model

Methodology:

- crops: maize, rice, soybean, wheat
- crop production: modeled and statistics for 2000
- Emission scenario from GAINS (‘current legislation’ in place 2000 and 2030 CLE ‘fully implemented’)
- AOT40 exposure index: hourly O_3 from TM5 (CTM at JRC)
- Adaptation: Shift in sowing date and crop types

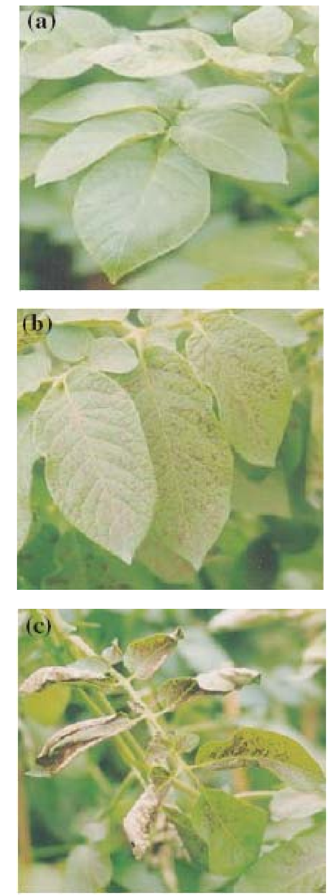
Modeling ozone damage on crops

Magnitude of damage depends on:

- Cropping calendars and O_3 concentrations

Necessary steps for the assessment:

1) Is the crop present?
2) When is the crop growing?
3) How much O_3 during crop growth?
4) What is the 'potential' yield?
5) What is the O_3 damage?



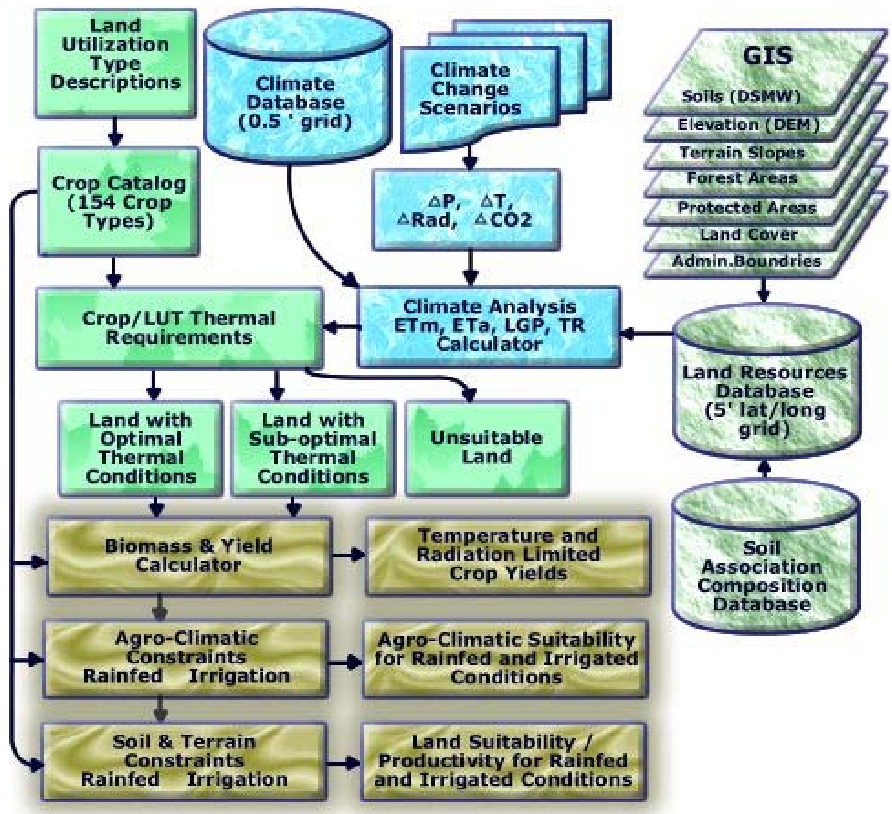
FAO/IIASA
Global Agro-Ecological Zones model

Model parameterization
- ~30 species (154 types)
- Crop responses to environment

Main model inputs
- Climate
- Soil, elevation, terrain
- Land cover

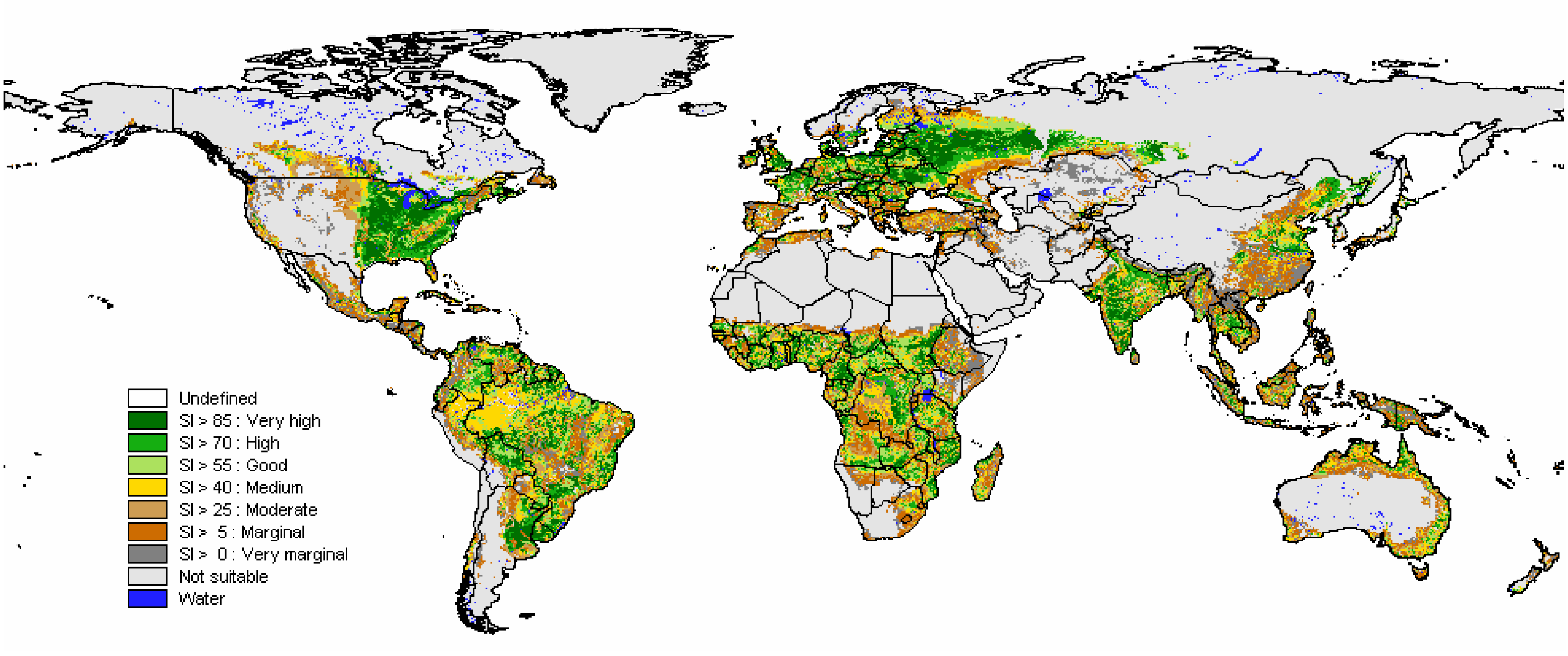
Main model outputs
- Land suitability
- Crop sowing calendars
- Crop Yields

GAEZ Structure



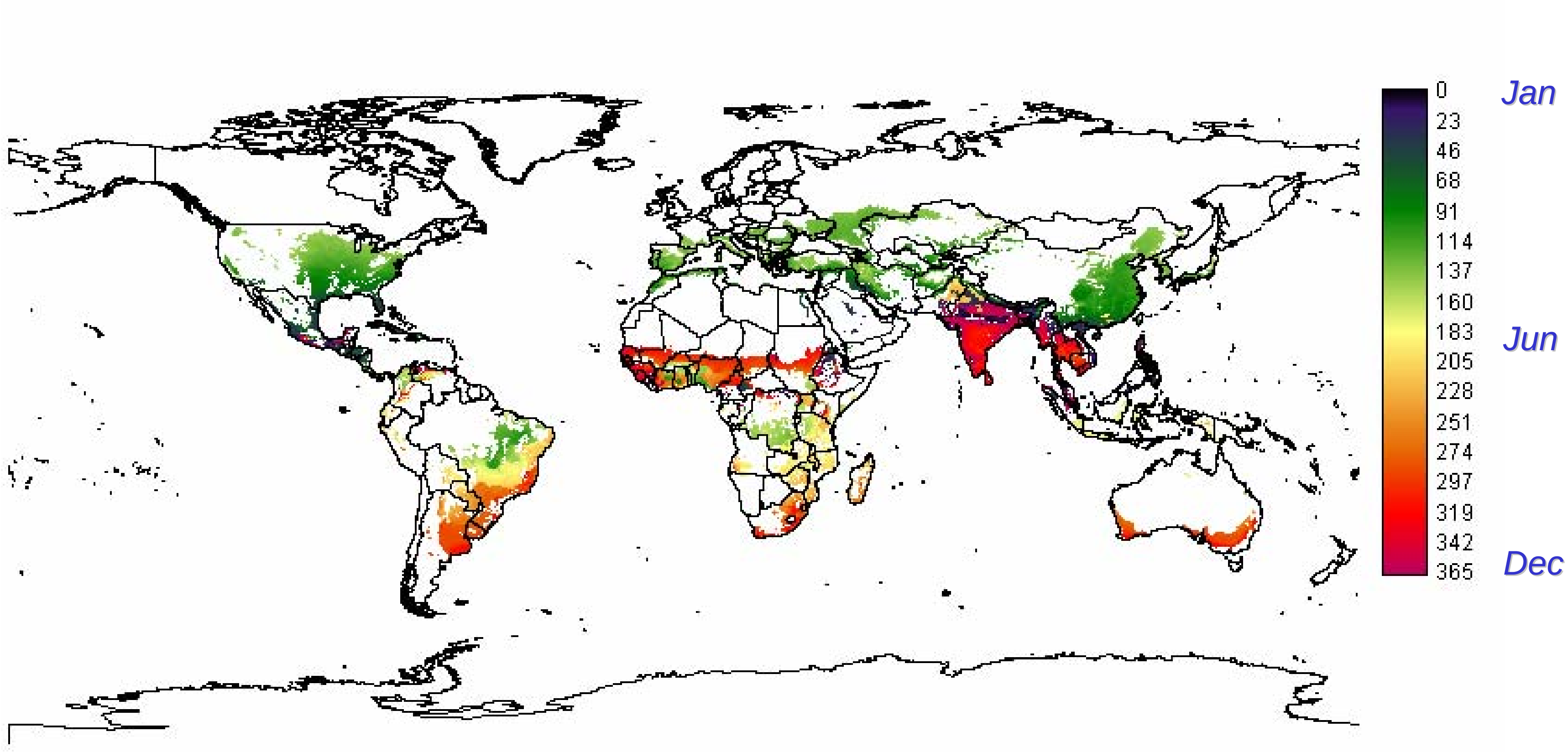
Where can crops 'potentially' grow?

Land Suitability and Yield

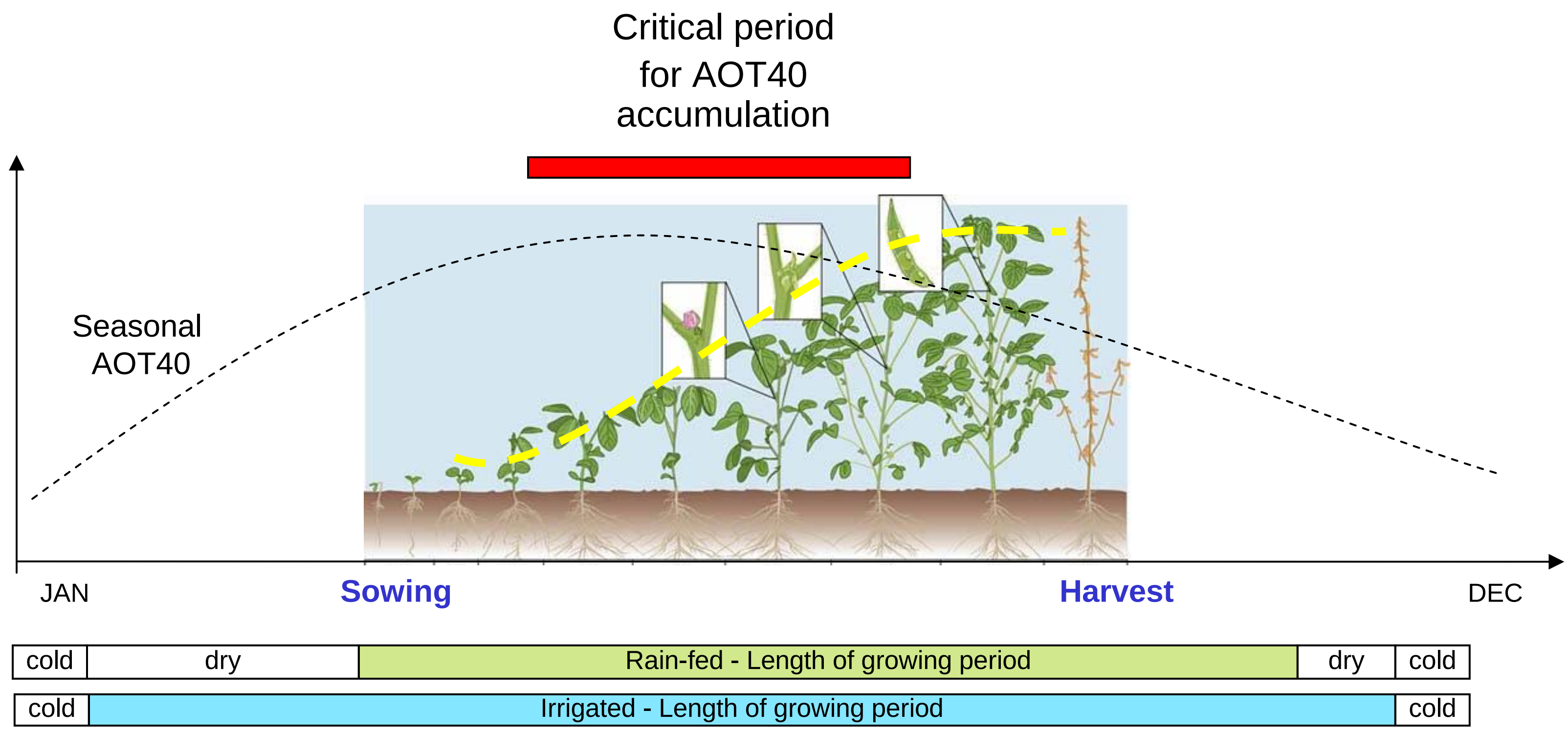


When is the crop growing?

Sowing date (day of the year)

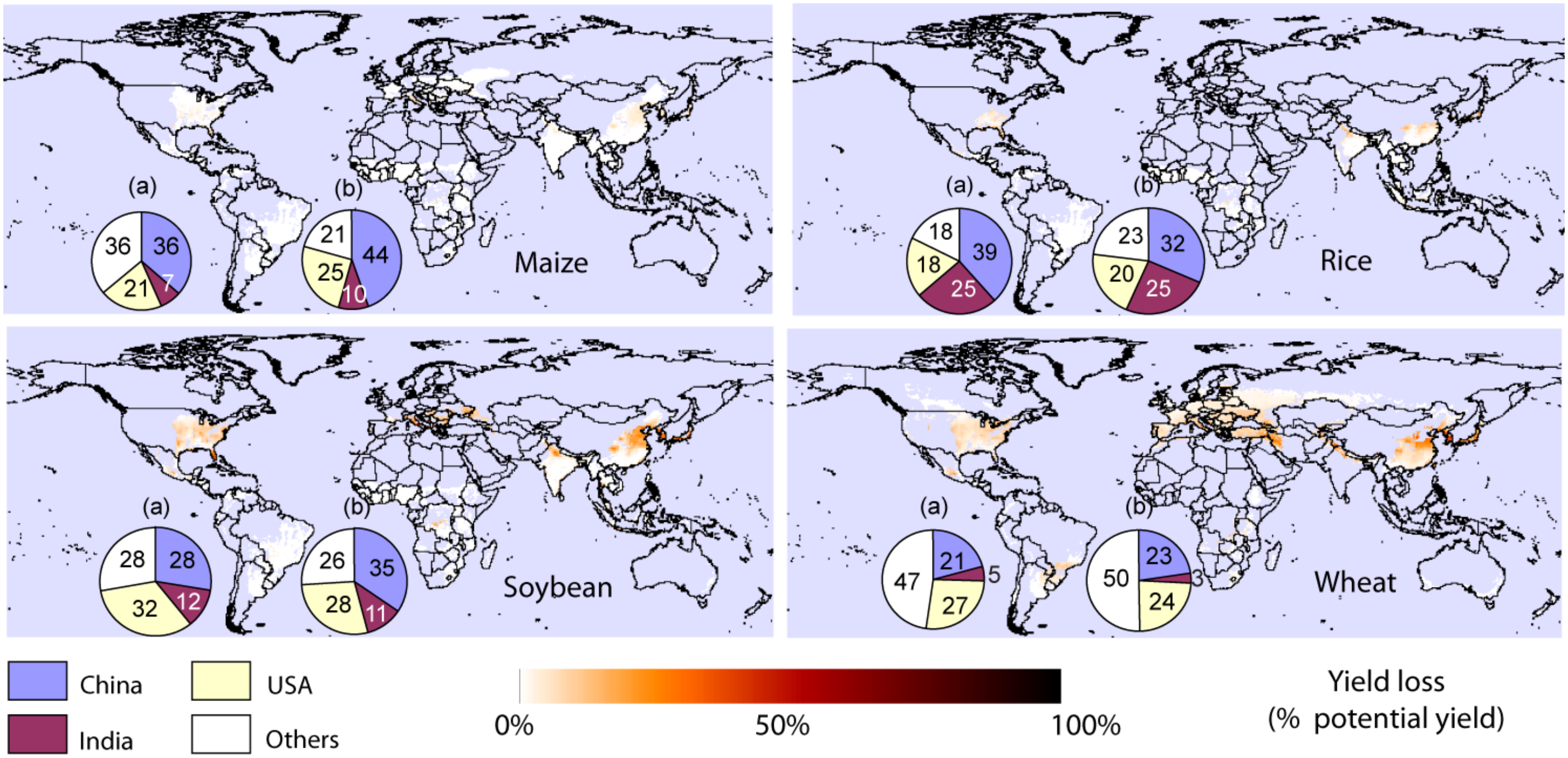


How does GAEZ estimate O_3 damage?



O_3 damage to ‘potential’ production

(rain-fed, 2000-CLE emissions)



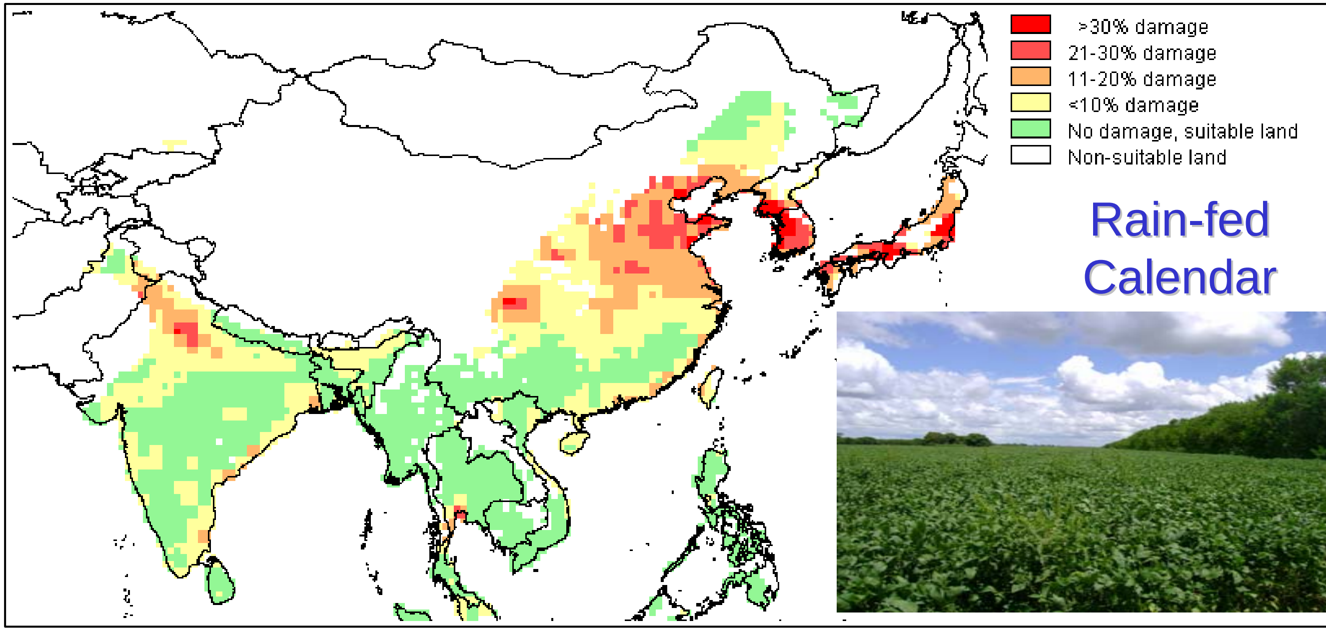
Inset graphs:

(a) Share of global threatened areas

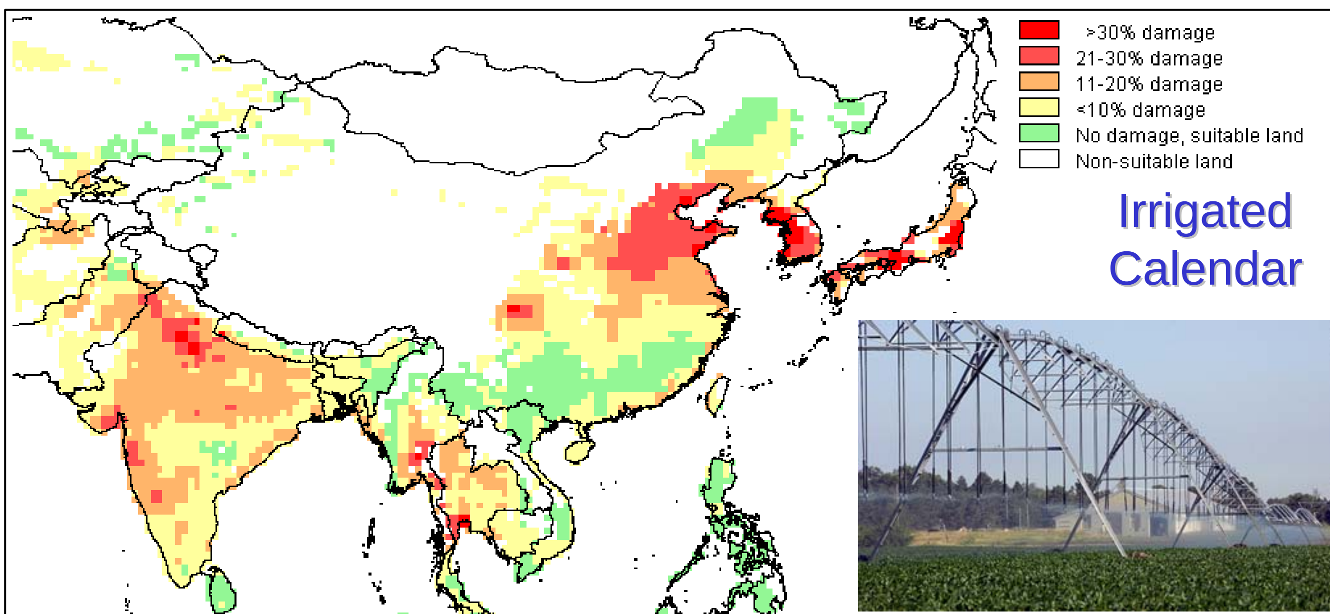
(b) Share of global losses

China, India and the US bear nearly 75% of all global losses

- Rain-fed Soybean
- 2000-CLE emission
- Highly-suitable land

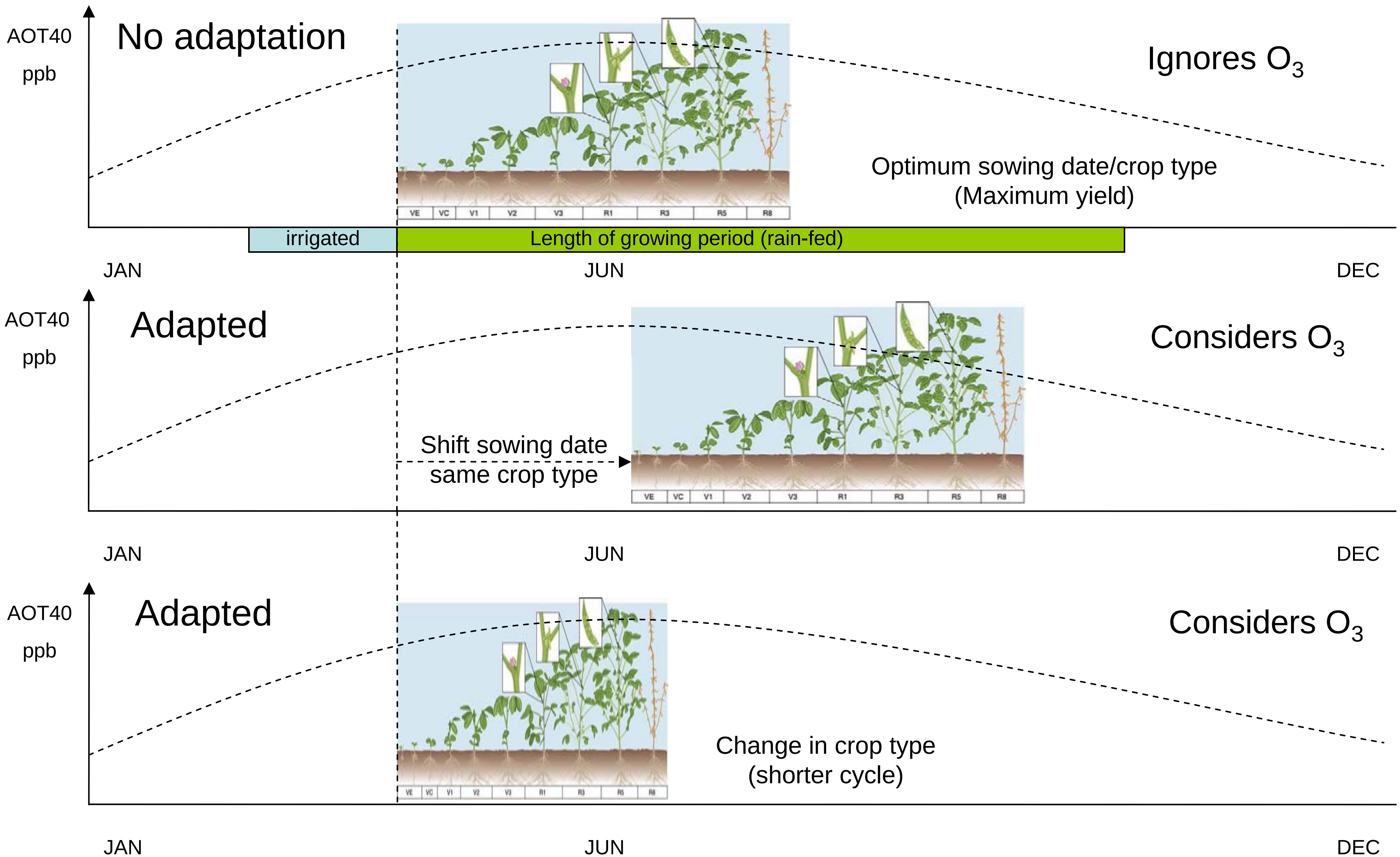


- Irrigated Soybean
- 2000-CLE emission
- Highly-suitable land

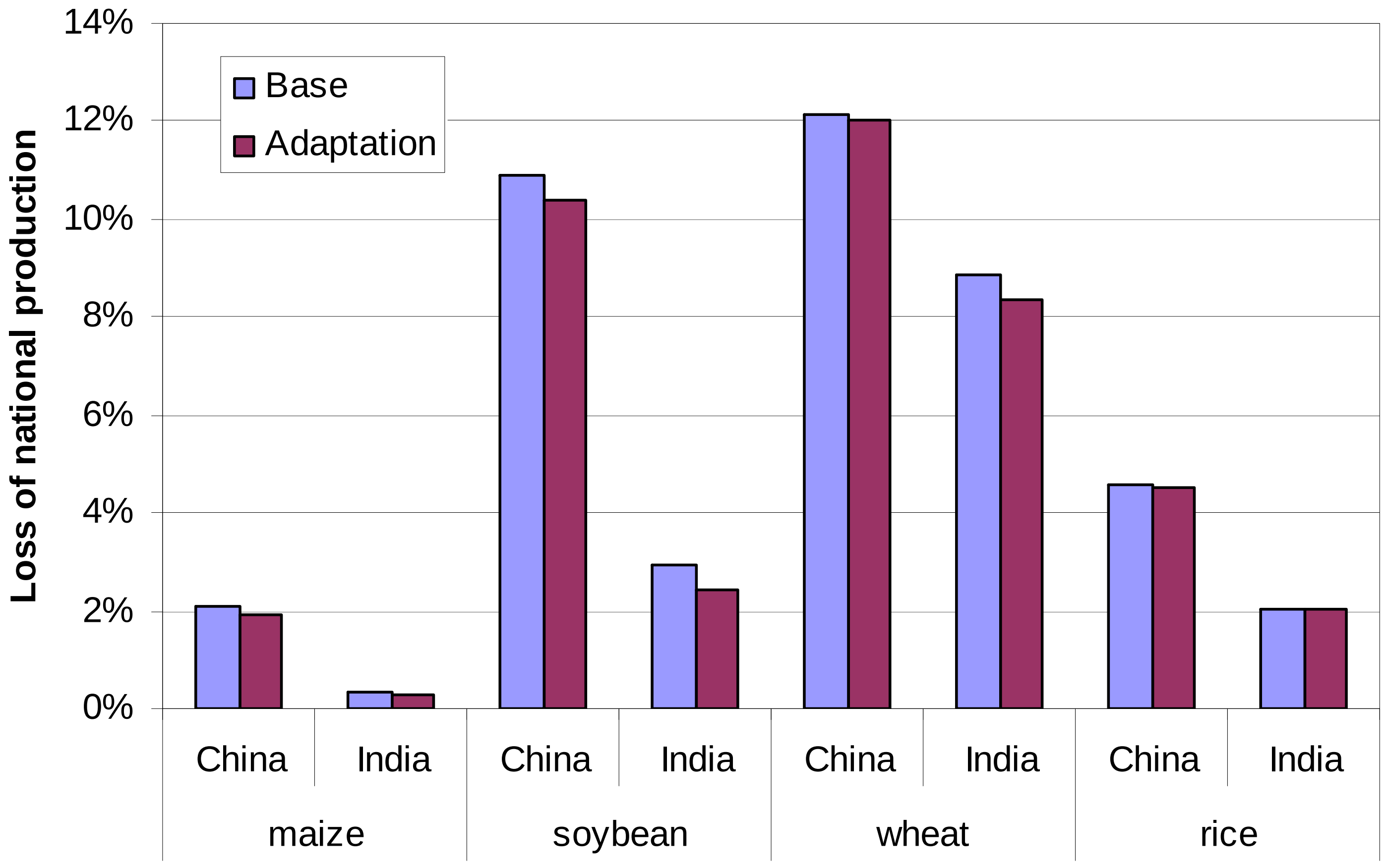


Can we escape from O_3?

Adaptation: Shifting sowing date and crop type



Rain-fed crops (2000-CLE) for GAEZ 'potential' production



0 to 16% reduction in crop losses

Percentage change in national production with 'adaptation'

(change in sowing date and crop type)

	Maize		Rice		Soybean		Wheat	
	Rain-fed	Irrigated	Rain-fed	Irrigated	Rain-fed	Irrigated	Rain-fed	Irrigated
Air quality legislation (current, 2000)								
China	0.1	0.2	-	0.2	1.0	0.7	0.2	0.3
India	-	0.9	-	4.3	0.4	11.1	0.6	0.8
USA	-	0.1	-	0.5	0.2	-	-	0.1
Air quality legislation (fully implemented, 2030)								
China	0.1	0.3	0.1	0.2	0.6	0.2	-	-
India	0.1	1.6	0.3	9.0	1.8	26.0	5.5	1.8
USA	-	0.1	-	0.3	0.2	0.1	-	-

≤1% (China, India, USA, current 2000)

Percentage change in national production with 'adaptation'

(change in sowing date and crop type)

	Maize		Rice		Soybean		Wheat	
	Rain-fed	Irrigated	Rain-fed	Irrigated	Rain-fed	Irrigated	Rain-fed	Irrigated
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USA	-	0.1	-	0.5	0.2	-	-	0.1
Air quality legislation (fully implemented, 2030)								
China	0.1	0.3	0.1	0.2	0.6	0.2	-	-
India	0.1	1.6	0.3	9.0	1.8	26.0	5.5	1.8
USA	-	0.1	-	0.3	0.2	0.1	-	-

Impact of emission reduction on crop losses

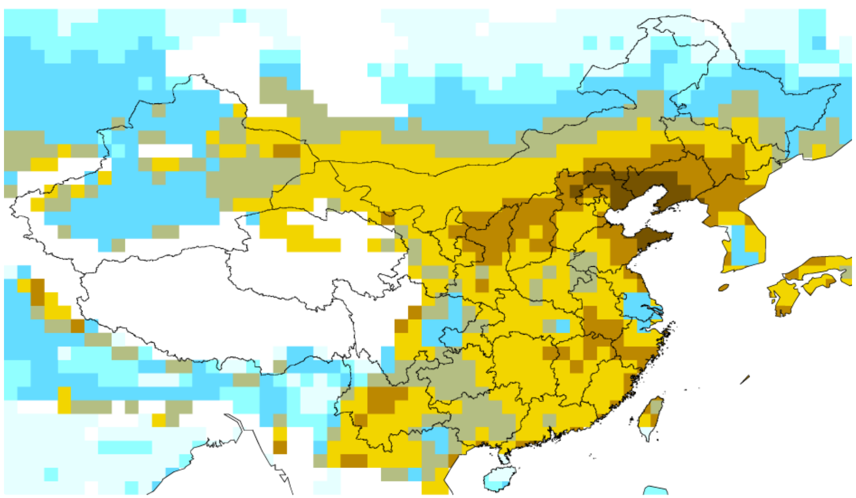
GAINS-Asia

Methodology:

- crops: maize, rice, soybean, wheat
- crop production statistics for 2000
- AOT40 exposure index
- source-receptor relationships from TM5

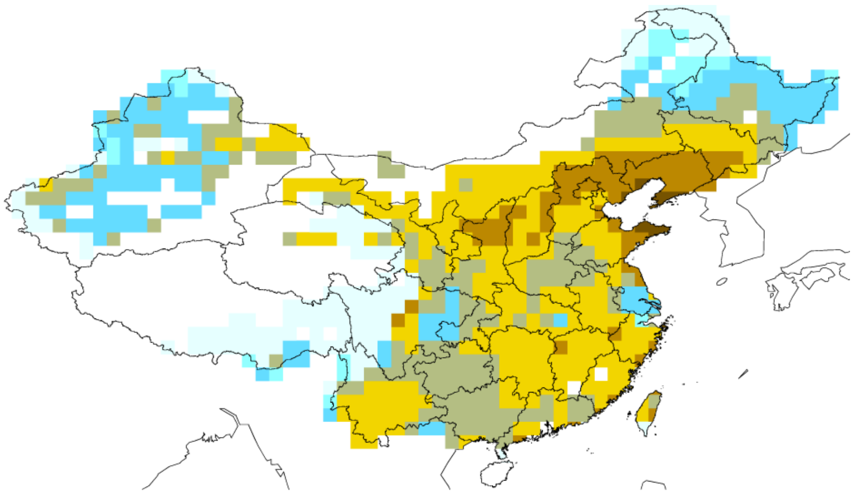
GAINS-Asia crop losses due to ozone
AOT40 and relative yield loss of wheat in 2005

AOT40 wheat



0 .. 500 ppb.h
500 .. 1000
1000 .. 3000 ← EU 'critical level'
3000 .. 5000
5000 .. 10000
10000 .. 20000
20000 ..

% yield loss - wheat



0 .. 1 %
1 .. 2
2 .. 5
5 .. 10
10 .. 20
20 .. 50
50 ..

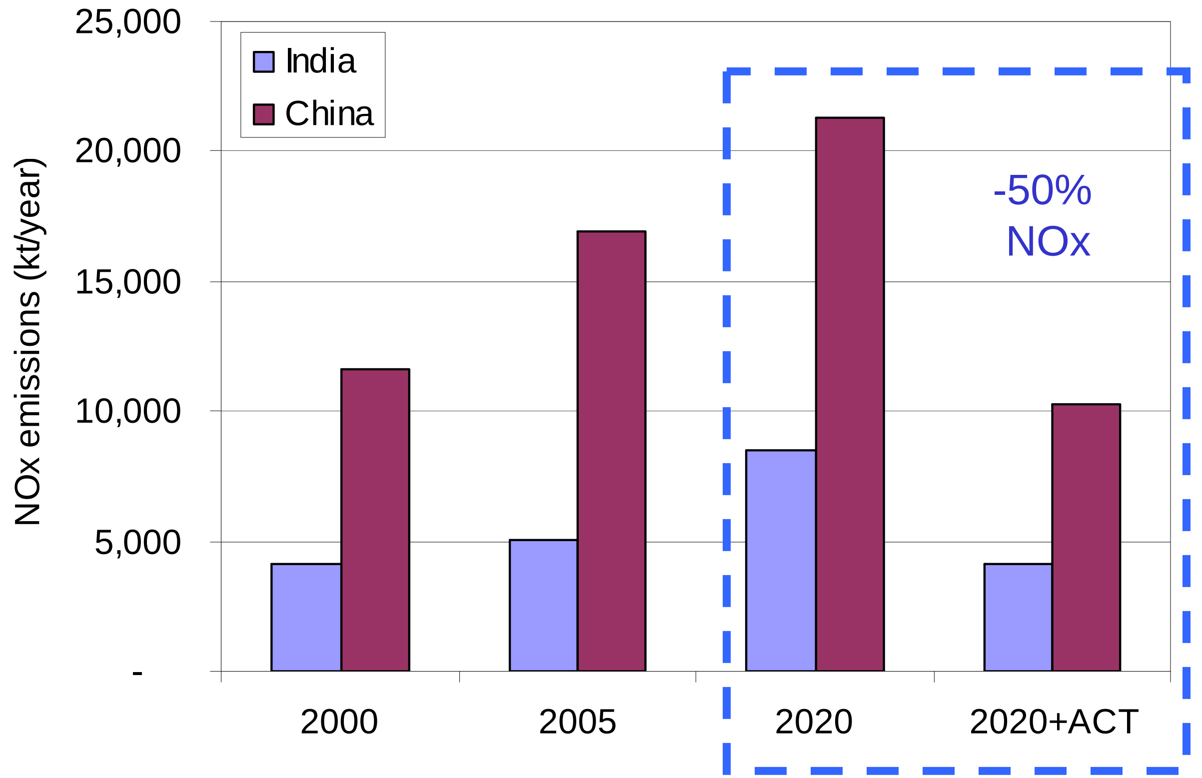
GAINS-Asia crop losses due to ozone Scenario analysis

- **Baseline08**
  - Baseline scenario developed on the basis of the EU funded GAINS-Asia project
  - Activity data sets from various sources
    - China – ERI / Tsinghua University / CATSEI project
    - India – TERI
  - Current legislation but no improvements beyond 2005 technology

- **Baseline08 + ACT**
  - Based on the final baseline ‘Baseline08’ but includes application of stringent 'Advanced Combustion Technology' legislation in industry and transport.
  - Strict interpretation of European legislation, e.g.
    - National Emission Ceiling Directive
    - EURO standards for mobile sources
    - IPPC Directive, etc.

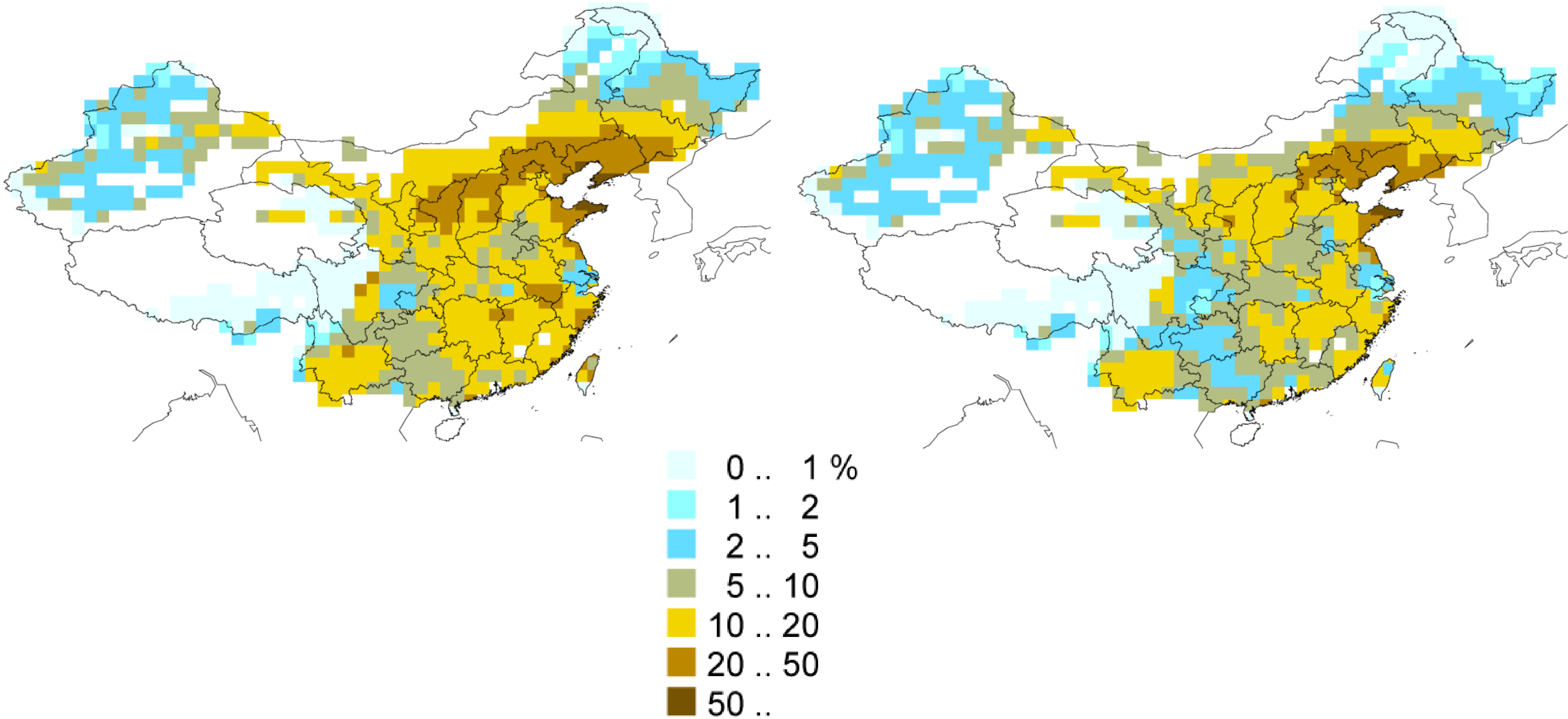
GAINS-Asia crop losses due to ozone Scenario analysis

Baseline08 + ACT

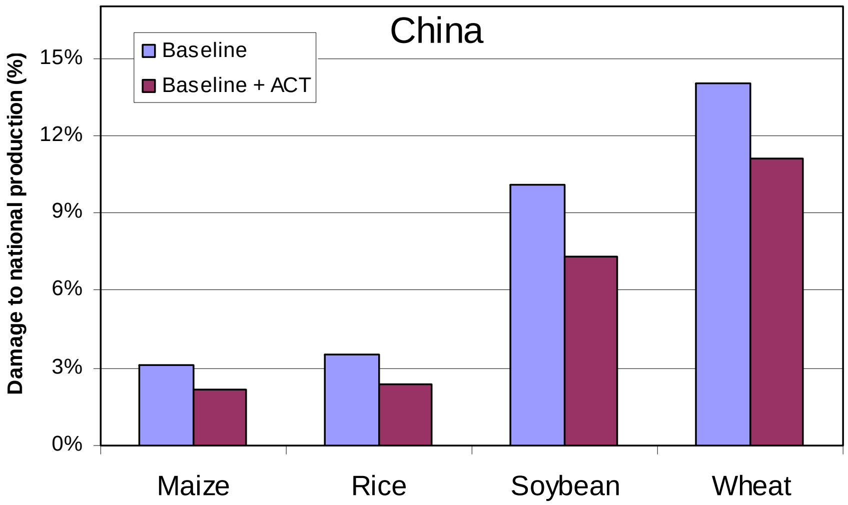


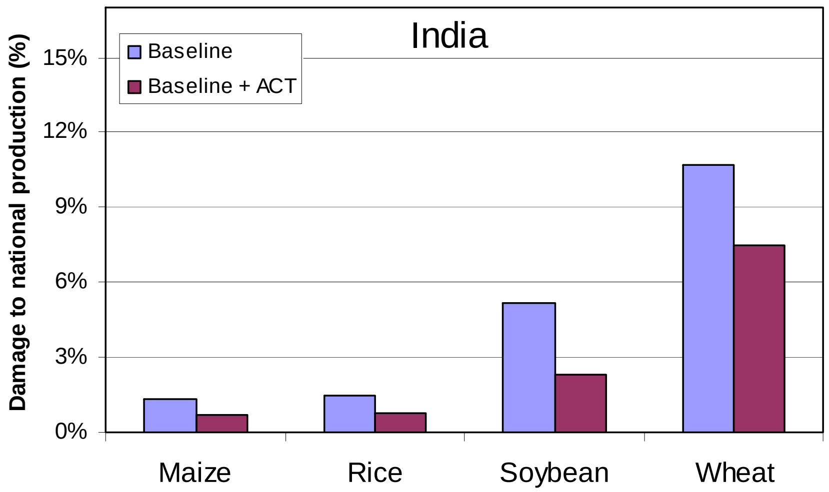
GAINS-Asia crop losses due to ozone
Relative yield loss of wheat in 2020

Baseline | Baseline + ACT



GAINS-Asia crop losses due to ozone
Relative yield loss of wheat in 2020





21 to 56% reduction in crop loss

Conclusions and remarks

- China and India bear a large share of global crop losses
- Effectiveness of adaptation is limited at national level but with possible benefits at local level
- GAINS-Asia is able to estimate O_3 related crop losses
- Emission reduction can reduce crop losses
- Next steps:
  - Develop scenarios targeted to reduce crop losses
  - Combine emission reduction and adaptation?

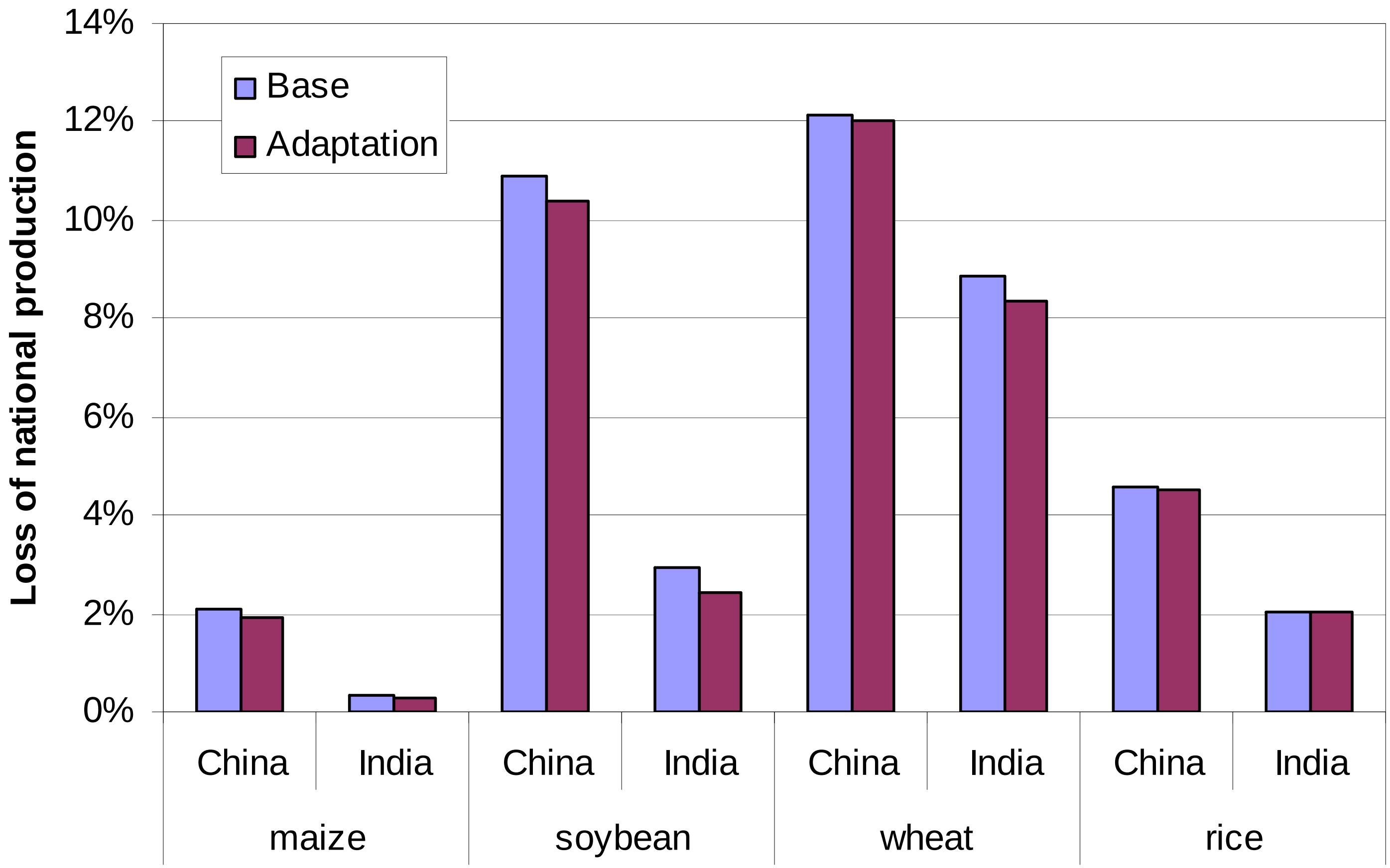
THANKS!

Atmospheric Pollution and Economic Development (APD-IIASA)
&
Land Use Change and Agriculture (LUC-IIASA)

http://www.iiasa.ac.at/rains

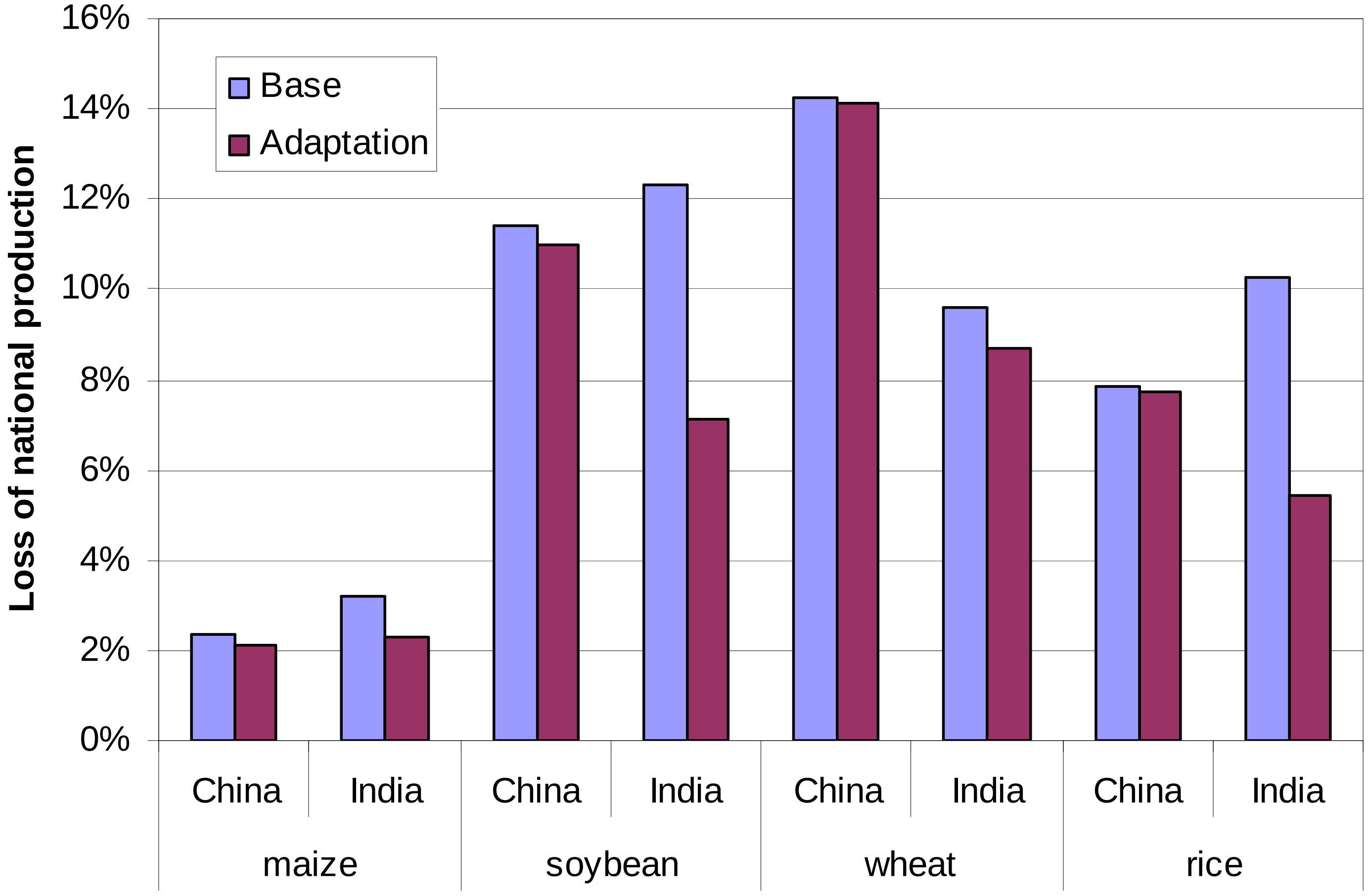
http://www.iiasa.ac.at/Research/LUC

Rain-fed crops (2000-CLE) for GAEZ 'potential' production



Only 6 to 16% reduction in crop losses

Irrigated crops (2000-CLE) for GAEZ 'potential' production



1 to 9% reduction in crop losses (exception: India 25-45%)

GAINS-Asia crop losses due to ozone

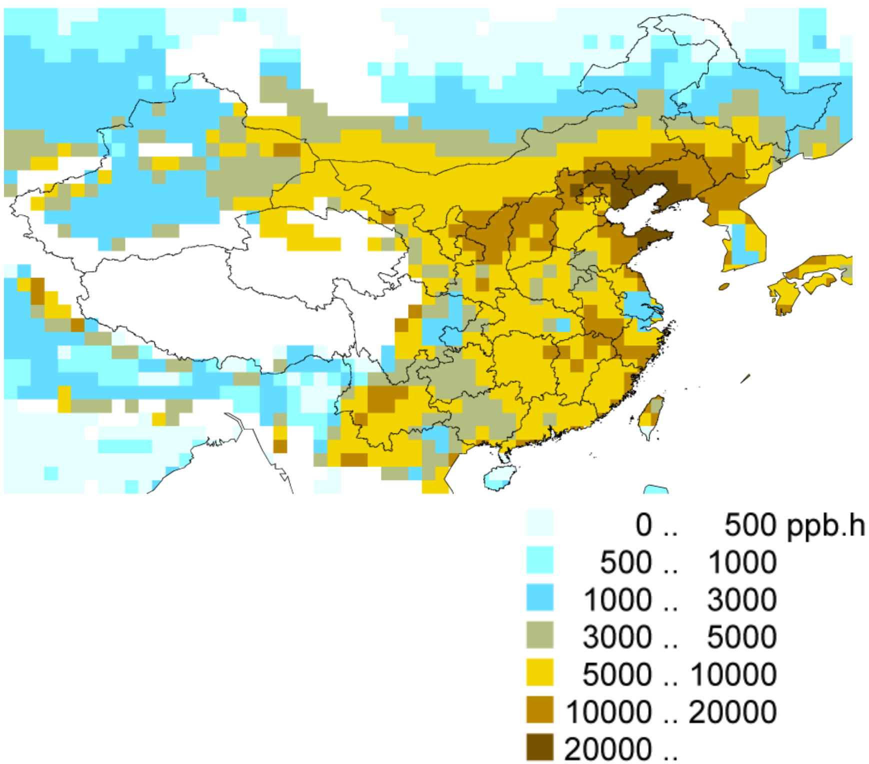
- source-receptor relationships from TM5
- crops: maize, rice, soybean, wheat
- AOT40 exposure index
- yield – response functions from Mills et al., (Atmos. Environ., 2007) – European/N.American conditions
- crop production statistics for 2000

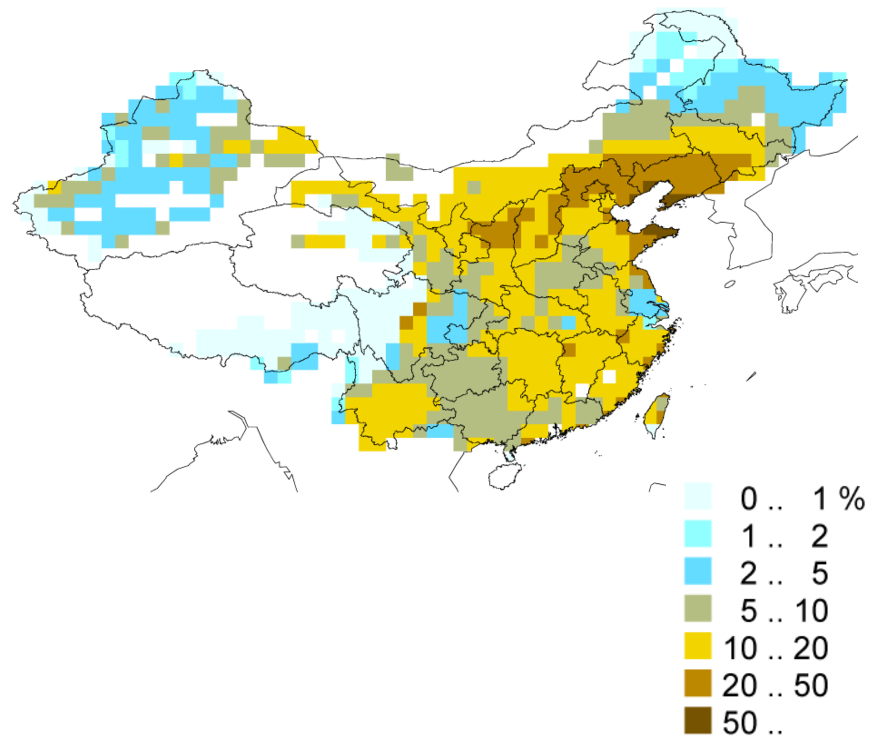
GAINS-Asia crop losses due to ozone

AOT40 and relative yield loss of wheat in 2005

AOT40 wheat

% yield loss - wheat

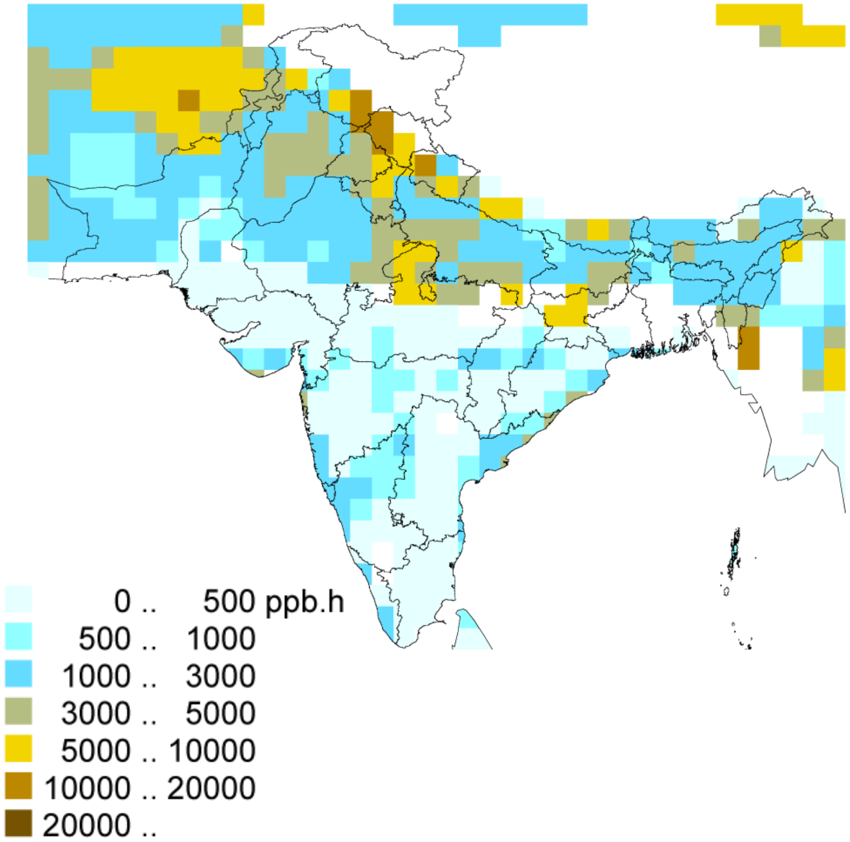




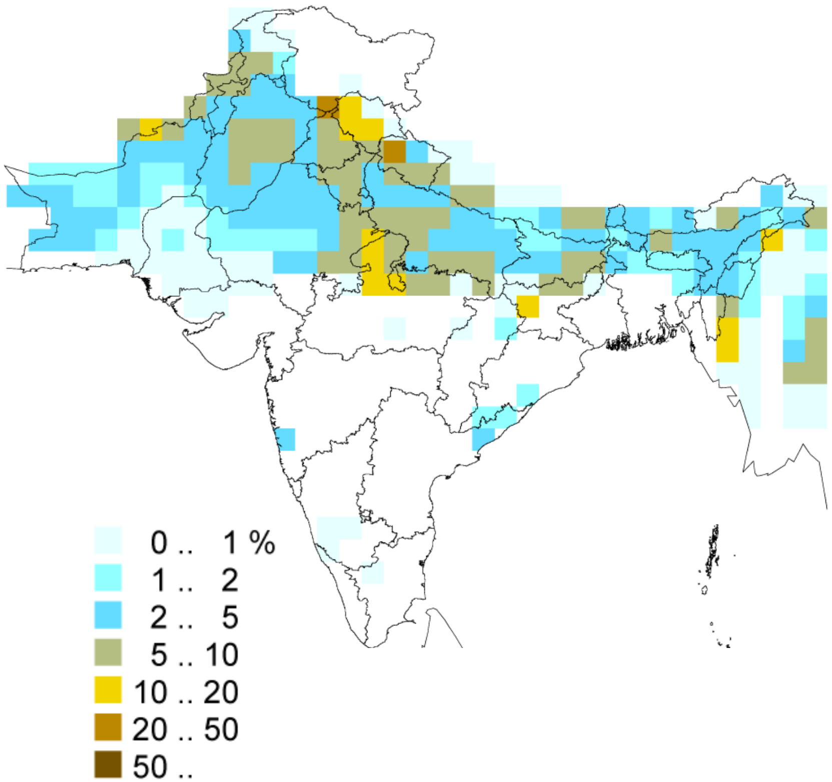
GAINS-Asia crop losses due to ozone

AOT40 and relative yield loss of wheat in 2005

AOT40 wheat



% yield loss - wheat



GAINS-Asia crop losses due to ozone
Scenario analysis

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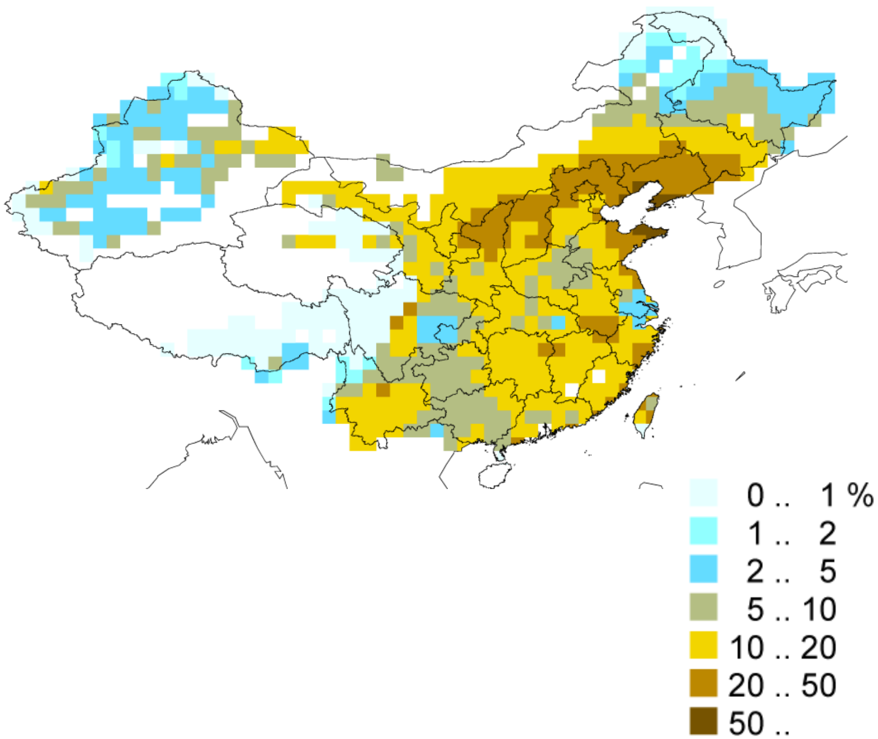
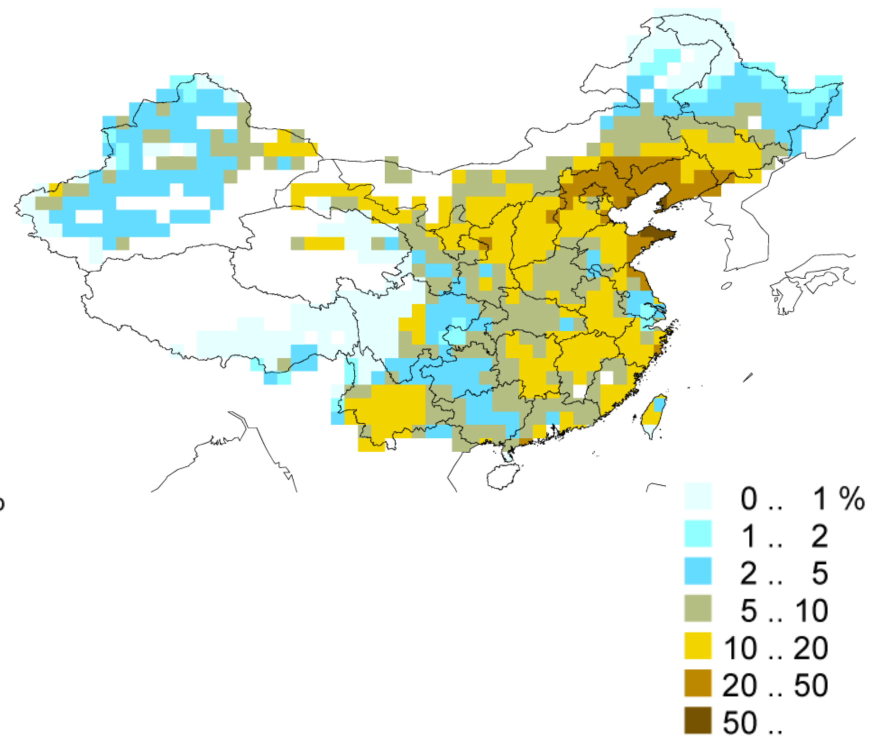
GAINS-Asia crop losses due to ozone

Relative yield loss of wheat in 2020

Baseline



Baseline - ACT

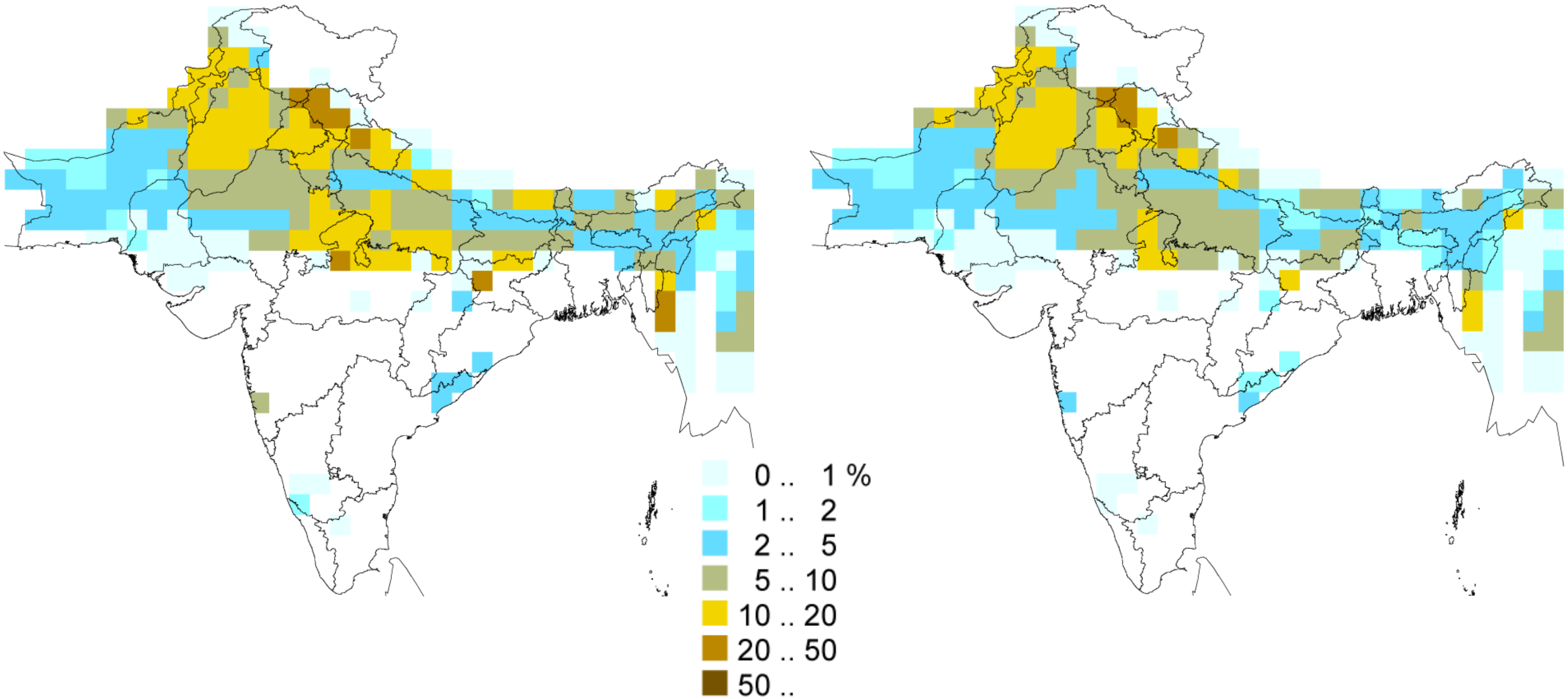


GAINS-Asia crop losses due to ozone

Relative yield loss of wheat in 2020

Baseline

Baseline - ACT



GAINS-Asia crop losses due to ozone

Relative yield loss of wheat in 2020

		Maize	Rice	Soybean	Wheat
China	Baseline	3.1%	3.5%	10.1%	14.0%
	Baseline + ACT	2.2%	2.4%	7.3%	11.1%
India	Baseline	1.3%	1.5%	5.2%	10.7%
	Baseline + ACT	0.7%	0.8%	2.3%	7.5%

GAINS-Asia crop losses due to ozone Scenario analysis

project results.

- <u>Activity data</u>

  1990-1995

  Combination of the data from the GAINS-*Asia* project, statistical updates, and the Energy Research Institute (ERI) submissions within the GAINS-*Asia* project.

- *2000-2005*

  Combination of data from Tsinghua University, specifically biofuels, and ERI submissions within the GAINS-*Asia* project, and for agriculture suplemented with data from CATSEI project (collaboration with the Land Use Change project of IIASA).

- *2010-2030*

  Mostly relying on the data from the ERI submission within the GAINS-*Asia* project. However, some modifications introduced to biofuel data in industry. Also trend in biofuel use in the domestic sector has been compared to the World Energy Outlook 2007 (IEA) and slightly modified. For agriculture data from CATSEI project are used.

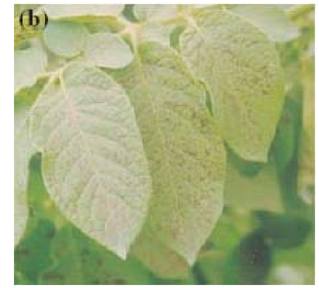
- <u>Control strategies</u>

  The control strategies are based on the sets developed within the GAINS-*Asia* project but further developed and updated, also distinguishing between urban and rural strategies. The flue gas desulphurization (FGD) penetration rates in existing and new power plants were reviewed on the basis of the IEA Coal Power Plant data from 2008.

- This set of strategies assumes no further improvements beyond existing control technology in 2005.

Crop Modeling

Modeling ozone damage on crops



Ozone damage depends on:

- Cropping Calendars and O_3 concentrations

Things we need to know:

1) Is the crop present?
2) When is it growing?
3) How much O_3 during crop growth?
4) What is the ‘potential’ yield?
5) What is the O_3 damage?

Rice, irrigated, 2000-CLE