

# **Effects of climate change on China's crop production potential**

**CATSEI report D23**

**Günther Fischer and Tatiana Ermolieva (IIASA)**

**Draft version January 2011**

## **1 Introduction**

The fast growth of consumption in China, meat in particular, has triggered intensification and concentration of production, requiring additional irrigation and leading to increased emissions of pollutants, interacting with climate change and other environmental stresses.

China's rapidly growing demand for food and energy puts heavy pressure on its natural resources and causes degradation of the local environment at unprecedented rates. With regards to global climate change, agricultural land use and management for crop and livestock production cause significant emissions of CH<sub>4</sub> and N<sub>2</sub>O gas into the atmosphere. Excess leaching of nitrogen into ground water and rivers as well as volatilization of NH<sub>3</sub>, N<sub>2</sub> and NO<sub>x</sub> contribute to regional and local air quality problems such as acidification and eutrophication of ecosystems, and causes damage to human health. At the same time, agricultural productivity is under threat from a variety of environmental stresses including climate change, water scarcity and increasing atmospheric ozone levels.

In the CATSEI project main environmental stresses deriving from and affecting Chinese agriculture were addressed through data analysis and modelling, including: (i) climate change and water scarcity, (ii) non-point source pollution and GHG emissions, and (iii) ground-level ozone.

This report summarizes the findings with respect to the effects of climate change on China's crop production potential. It follows the presentation at the CATSEI Final Policy Forum in November 2010 in Beijing.

## **2 Climate change and water scarcity**

There is concern about the impacts of climate change and its variability on agricultural production worldwide. Research confirms that while crops would respond positively to elevated CO<sub>2</sub> in the absence of climate change, the associated impacts of high temperatures, altered patterns of precipitation, and possibly increased frequency of extreme events such as drought and floods, will likely combine to depress yields and increase production risks in many world regions.

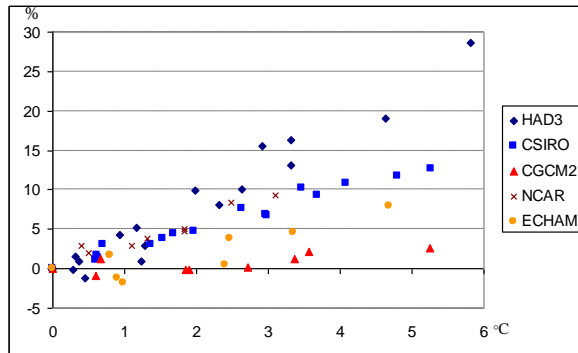
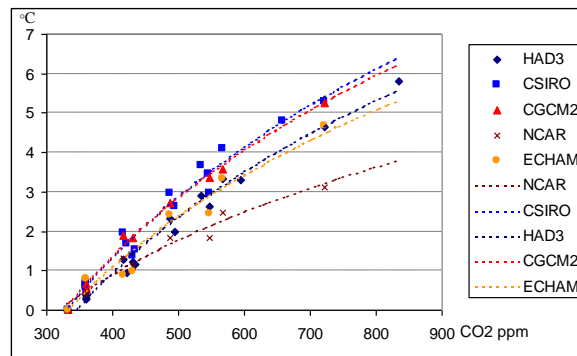
Spanning a wide range of climatic conditions, from the tropics at the southern tips of China to boreal conditions at the northern fringes, China is projected to experience significant climate change in the coming decades.

Scenarios of climate change were developed in order to estimate their effects on crop yields, extents of land with cultivation potential, and the number and type of crop combinations that can be cultivated. A climate change scenario is defined as a

physically consistent set of changes in meteorological variables, based on generally accepted projections of CO<sub>2</sub> (and other trace gases) levels.

The climate change scenarios applied in this analysis (see Figure below) project for the 2050s an average warming in the range of 2-4 °C and for the 2080s of some 3-6 °C. Precipitation changes are spatially less uniform and vary across different GCM projections. Among the used GCM outputs from different climate modeling groups, the strongest positive correlation between temperature increase and average precipitation increases was found for the Hadley Centre results.

**Temperature response to increasing CO<sub>2</sub> concentrations (China)**



**Correlations between temperature increase and precipitation change (China)**

Climate change and variability affects thermal and hydrological regimes, and in turn, this influences the structure and functionality of ecosystems. Dependent on location and current conditions, agro-ecosystems can be highly sensitive to global environmental change. Contingent on the main current limiting factors, climate change impacts on crops can be positive or negative. In higher latitudes, e.g., in Northeast China, where temperature constraints are among main limiting factors, the positive effects of climate change can be substantial.

The main global change factors affecting crop productivity include:

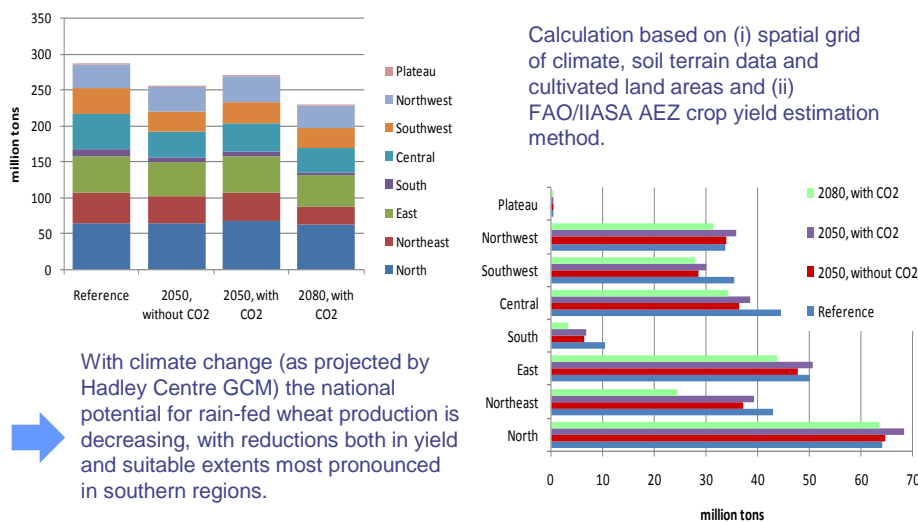
- Global warming
  - + Removal of cold temperature limitations
  - + Longer growing season
  - Faster growing period
  - Exceeding of temperature thresholds
  - Increased crop water requirements
  - Increased incidence of pests and diseases
- Changes in composition of atmosphere
  - + Yield increases due to CO<sub>2</sub> fertilization
  - + Increased water-use-efficiency

- Pollution (e.g. ground-level ozone)
- Alterations in precipitation patterns, soil moisture conditions, surface runoff
- Increased occurrence of extreme weather events

Agronomists naturally have paid much attention to the spatial diversity in China. The spatial simulation tool used in CATSEI was a national implementation of the IIASA-FAO Agro-ecological Zones model (AEZ) for the territory of China. The AEZ modeling uses detailed agronomic-based knowledge to simulate land resources availability, to assess farm-level management options and to estimate crop production potentials. It employs detailed spatial biophysical and socio-economic datasets to distribute its computations at fine gridded intervals over China's entire territory. This land-resources inventory is used to assess, for specified management conditions and levels of inputs, the suitability of crops in relation to both rain-fed and irrigated conditions, and to quantify expected attainable production of cropping activities relevant to specific agro-ecological contexts. The characterization of land resources includes components of climate, soils, landform, and present land cover (see Fischer et al. 2002; 2005; 2011).

The impact of climate change has been assessed for all major crops using for different time periods (the 2050s and 2080s), outputs of different climate models, and for different assumptions concerning the effectiveness of adaptation.

## Climate Change Impacts on Rain-fed Wheat Production Potential of Cultivated Land



The AEZ simulations for wheat indicate that climate change will likely have negative impacts on China's capacity to grow this staple food crop in the future. Large negative impacts are projected for the southern regions in China where temperature regimes will become less suitable for wheat cultivation. For instance, assuming full adaptation to best-suited available wheat types, rain-fed wheat production potential in the 2050s under climate change as projected by the Hadley Centre GCM was estimated at -6 percent, with the South region losing about one-third of its wheat potential. For irrigation conditions, losses under full agronomic adaptation at national level are less

(i.e. -2 percent). With irrigation available, losses of production capacity in southern regions would almost be compensated by increased production capacity in the Northeast and Northwest regions.

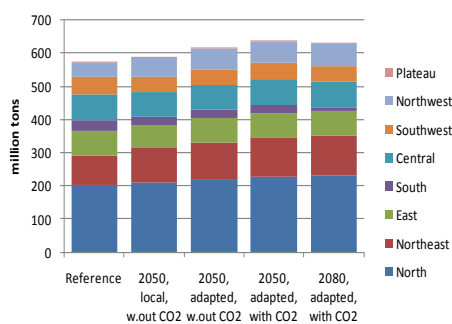
## China: Climate Change Impacts (% change) on Rain-fed Wheat Production Potential

Region	HadCM3 2050s		2050s, Irrig.	2080s
	Adapted var. without CO2	Adapted var. with CO2	Adapted var. with CO2	adapted var. with CO2
North	1	6	0	-1
Northeast	-14	-8	7	-43
East	-5	1	-3	-13
South	-37	-34	-62	-68
Central	-26	-22	-28	-30
Southwest	-20	-15	-10	-21
Northwest	1	7	32	-7
China	-11	-6	-2	-20

Assumes full adaptation to best-suited wheat type.

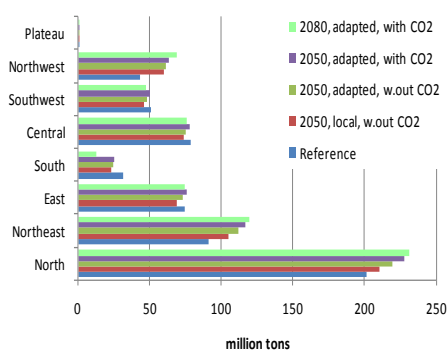
In the case of maize, for which statistics record a rapid production growth in the last decades due to fast growing feed demand, the AEZ simulations indicate a modest improvement of the production potential. Especially in the northern part of China climate change will result in a longer thermal growing period and improved heat provision which will allow higher yields when soil moisture is available naturally or through irrigation. With agronomic adaptation to best-suited maize types, our estimates for the 2050s using Hadley Centre climate projections show an increase in China's maize production capacity in the order of 10 percent.

## Climate Change Impacts on Rain-fed Maize Production Potential of Cultivated Land



➔ With climate change (as projected by Hadley Centre GCM) the national potential for rain-fed maize production is increasing, mainly due to yield increases in Northeast, North and Northwest regions.

Calculation based on (i) spatial grid of climate, soil terrain data and cultivated land areas and (ii) FAO/IIASA AEZ crop yield estimation method.

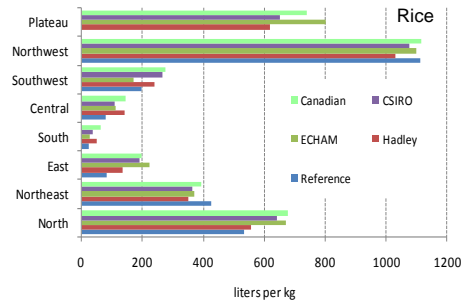
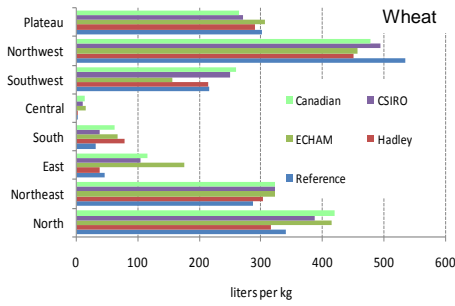


## China: Climate Change Impacts (% change) on Rain-fed Grain Maize Production Potential

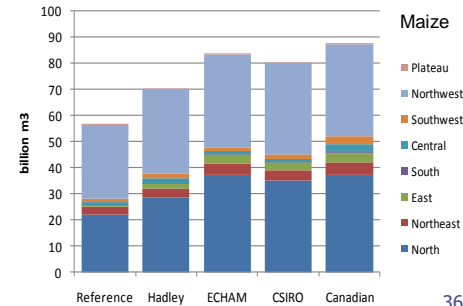
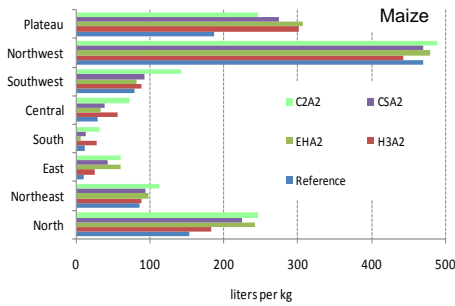
	HadCM3 2050s			2080s
	local varieties without CO2	adapted var. without CO2	adapted var. with CO2	adapted var. with CO2
North	4	9	13	15
Northeast	16	23	28	31
East	-7	-2	2	0
South	-27	-23	-20	-60
Central	-6	-4	-1	-3
Southwest	-10	-6	-2	-7
Northwest	39	42	47	60
China	3	7	11	10

*Assumes full adaptation to best-suited maize type.*

In China, with over 40 percent of cultivated land irrigated, irrigation water is a key driver of agricultural production. For this work, AEZ was used to compute water movement through the soil–plant–atmosphere continuum, to assess net crop irrigation water requirements (WRQ) (see Fischer et al., 2007b). The WRQ is defined herein as the amount of water—in addition to available soil moisture from precipitation—that crop plants on irrigated land must receive to grow without water stress. Calculations of crop irrigation water requirements were carried out on a spatial layer of current cultivated land, for different crops and time periods, as aggregated for main regions and shown below for the 2050s.



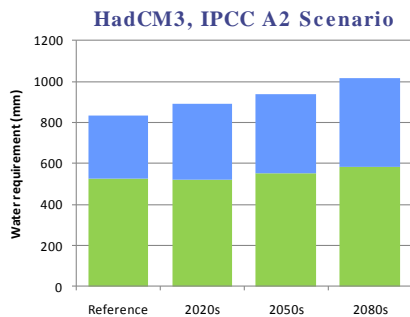
## Changes of Crop Irrigation Requirements, 2050



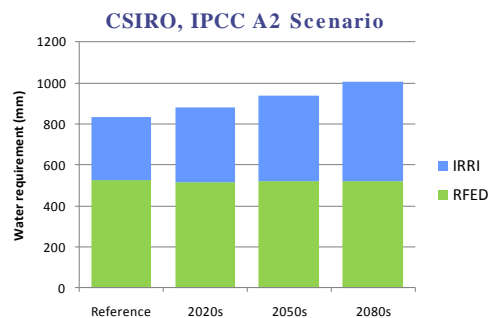
36

From the analysis we can conclude that total crop water requirements overall will increase in China's current irrigated land due to higher temperatures. The AEZ simulations indicate that precipitation will be insufficient to cater to the increased crop water requirements and that additional irrigation water per unit area will be required to fill a growing gap. Hence, a critical factor in China's exposure to future climate change will be the impacts and yet uncertain consequences for available water resources, in particular in the northern regions of China (see also Piao et al. 2010).

## China: Climate Change Impacts on average Crop Water Requirements in Irrigated Areas



Calculation based on (i) spatial grid of climate and irrigated land areas and (ii) FAO/IIASA AEZ crop soil water balance method.



➔ With climate change the share of irrigation in total water requirements as well as the total amount of water to be supplemented by irrigation increases; magnitude dependent on scenario and climate model.

### 3 Conclusions

The conclusions of the preceding analysis can be summarized as follows:

- Climate change requires substantial adaptation of cropping systems in China's regions;
- Crop production potential tends to shift northwards with climate change;
- Positive temperature effects may be limited by soil moisture deficits and more frequent extreme events;
- Crop water requirements projected to increase 10 percent or more by 2050; a growing fraction to be supplied by irrigation;
- High risk that water scarcity will increase with climate change. Magnitude of effects varies with GCM and emission scenario;
- The impacts of climate change on China's agriculture critically depend on the consequences for water resources.

## References:

- Fischer G, Van Velthuisen H, Mahendra S, Nachtergaele F O (2002). Global agro-ecological assessment for agriculture in the 21st century: methodology and results. International Institute for Applied Systems Analysis (IIASA). Research report RR-02-02, IIASA, Laxenburg, Austria.
- Fischer G, Shah M, Tubiello FN, and van Velthuisen HT (2005). Socio-Economic and Climate Change Impacts on Agriculture: an Integrated Assessment, 1990–2080, *Philosophical Transactions of the Royal Society B* 360(1463), 2067–2083 (DOI: 10.1098/rstb.2005.1744).
- Fischer G, Tubiello FN, van Velthuisen HT, Wiberg D (2007b). Climate change impacts on irrigation water requirements: Effects of mitigation, 1990-2080. *Technological Forecasting & Social Change (Special Issue: Greenhouse Gases - Integrated Assessment)*, 74(7):1083-1107 [2007].
- Fischer G, Prieler S, Teixeira E, Toth G, van Velthuisen HT, Wiberg D (2011). Global Agro-Ecological Zones (GAEZ v3.0), Model Documentation, International Institute for Applied Systems Analysis, Laxenburg, Austria (forthcoming).
- IPCC (2007). Summary for Policymakers. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (eds.), pp. 7-22, Cambridge University Press, Cambridge.
- Piao S, Ciais P, Huang Y, Shen Z, Peng Z, Li J, Zhou L, Liu H, Ma Y, Ding Y, Friedlingstein P, Liu C, Tan K, Yu Y, Zhang T, Fang J (2010). The impacts of climate change on water resources and agriculture in China, *Nature* Vol 467, Issue 7311, 43-51.