impacts of climate change on
chinese agriculture

Summary

Modelling the interaction of climate change

water availability and socio-economic scenarios on cereal production

The project, *Impacts of Climate Change on Chinese Agriculture*, sought to understand how climate change will affect rural China.

Phase I (2001–2004) of this joint UK/China collaboration examined the impact of climate change on crop yields. Phase II (2005–2008) built on this work to investigate the impacts of climate change on national cereal production and the cereal quantities available to each person in China to 2100. This pamphlet gives an overview of the main findings of Phase II relating to the modelling of the interaction of the separate effects of climate change, population growth, technological progress, water availability and the effects of carbon dioxide on cereal production.

Competing pressures on agricultural production in China

China is undergoing rapid changes in economic structure and development, lifestyle, demand on land and water resources, and pressures on the environment. Agriculture faces significant challenges in sustaining and increasing output to meet growing demand for food.

The availability of water is critical for agricultural production and is already a major stress factor for China's grain production (particularly in northern areas). The pressure of increasing population and per capita consumption on land and water use are major factors in determining the characteristics of future scenarios of food security and are likely to be key factors in increasing the risk of famine in the future.

Climate models predict an acceleration of recent warming in China, with associated changes in rainfall and the frequency of extreme events.

However, studies of climate change impacts on crops in China show conflicting results and uncertainties, mainly relating to the methods used and the effect of carbon dioxide (CO_2) on plant growth (referred to as CO_2 fertilisation) which tends to increase yields.

There is little previous work on the interactions between climate change, crop production, land use, water availability and socio-economic change. This pamphlet summarises our work in combining crop and water simulation models with climate and socio-economic scenarios to explore how changes in cereal production and water availability due to climate change will interact with other socio-economic pressures in China.

OUR APPROACH

We considered the effects and interactions of multiple drivers of change (climate, CO_2 fertilisation, water availability and land use change) in relation to their impacts on staple cereal production in China in the 2020s (2011-2040) and 2050s (2041-2070). We addressed the following key questions:

- What are the likely impacts of climate change on China's cereal production?
- How do climate impacts compare to socio-economic pressures over this century?
- Where and how do significant interactions arise?
- What are the effects of broad level adaptation policies on future impacts?

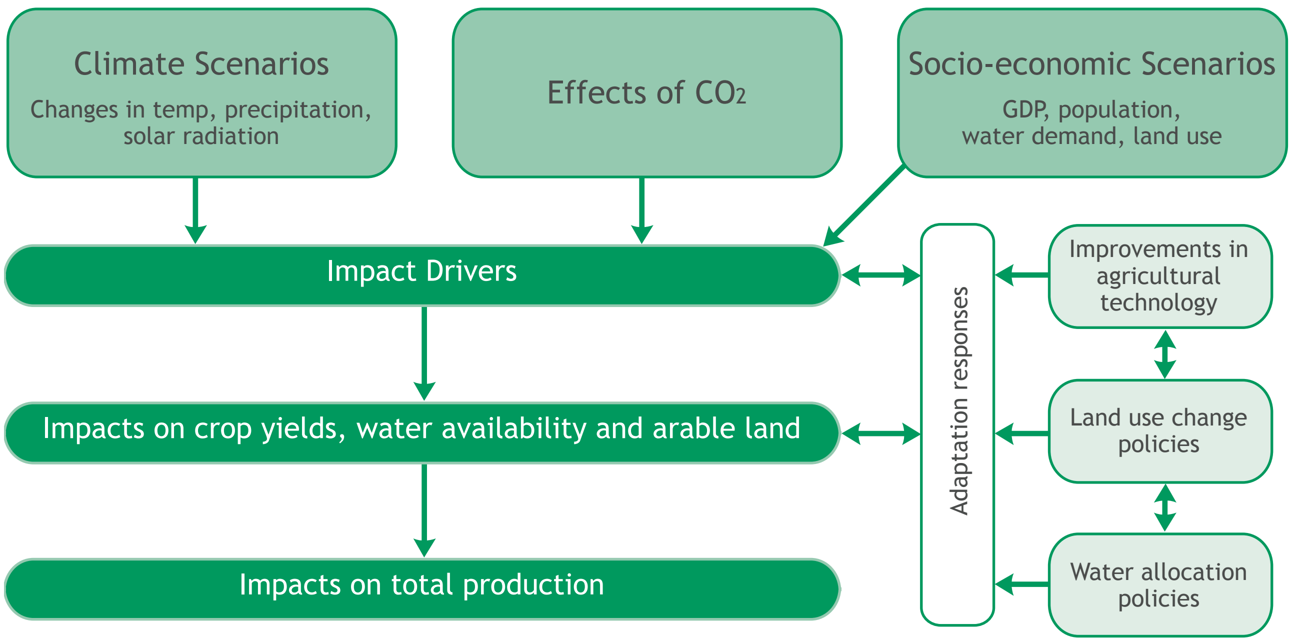


Figure 1: Main steps and interactions between different components in the analysis

To do this we combined socio-economic storylines for China with the results obtained with a high-resolution regional climate model, PRECIS, and the CERES suite of crop models (as described in two of the other pamphlets in this series). As before we limited our analysis to two of the emission scenarios for greenhouse gases developed by the Intergovernmental Panel on Climate Change (IPPC), (for full definitions see *Special Report on Emissions Scenarios, IPPC, 2000*):

- **A2 scenario**: medium–high emissions from a continuously increasing global population
- **B2 scenario**: medium–low emissions and lower population growth

We used the step-wise approach summarised in Figure 1 to assess the direct effects of climate change on yields of cereal crops (rice, maize and wheat) and the indirect effects of changes in water availability (as it affects the supply of irrigation water). Within this framework we also considered factors such as the effects of CO_2 fertilisation, changes in arable land and demand for water due to population increase and economic development based on socio-economic scenarios for China (see Figure 2).

SOCIO-ECONOMIC SCENARIOS FOR CHINA

Socio-economic scenarios are projections of a possible future based on a clear storyline interpreted in quantified terms. They generally incorporate key variables that are likely to change significantly over the period of study. Such scenarios provide the context for future climate change impacts and guide the development of plausible adaptation strategies. To be consistent with our climate scenarios, we developed socio-economic storylines for the A2 and B2 emissions scenarios up to 2050 using methods based on those used by IPCC. The following variables were generated:

- National annual population
- Rate of growth of gross domestic product (GDP)
- Water demand from four sectors – agriculture, industry, domestic and environment
- Agricultural land use

Overall the socio-economic scenarios forecast that there will be a decrease in arable land and an increase in water demand accompanied by a shift in the proportional use of water by sector – primarily away from agriculture in response to greater demand from other sectors such as industry.

INTEGRATED RESULTS OF CEREAL PRODUCTION

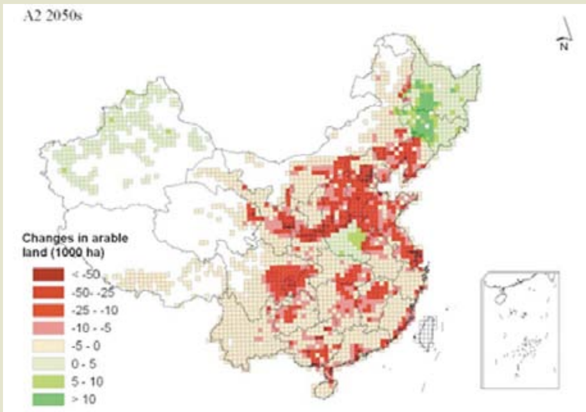
We used our modelling framework to generate changes in crop yields and water availability. From the areas of the crops sown across China, we converted these changes into estimates of cereal production expressed as a national total or per capita based on population growth from the two emissions scenarios. We calculated the changes in arable land based on the socio-economic projections for each province and extrapolated them to a grid scale. Figure 2 shows the geographical distribution of accumulated changes in arable land for the 2050s under the two climate scenarios A2 and B2.

Three adaptation strategies, which reflected national agricultural policy objectives, were simulated to assess their effectiveness in offsetting climate change impacts on cereal production. The adaptations consider:

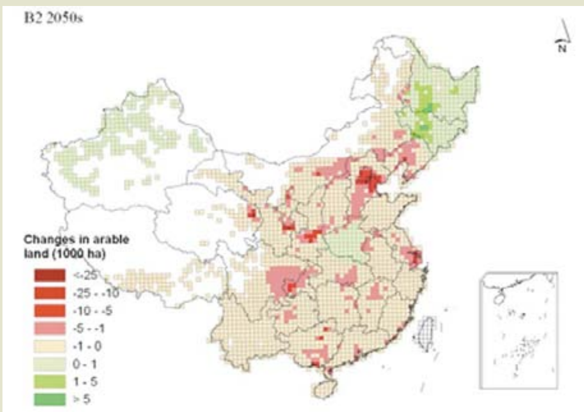
- Prioritisation of water allocation for cereal production
- Successful implementation of controls on agricultural land conversion
- An optimistic scenario of improvements in agricultural technology in the future

Without adaptation, per capita cereal production will fall due to the combined effects of climate change, population increase, water scarcity and loss of arable land. By simulating adaptation responses up to 2050, China could maintain per capita cereal production given reasonable assumptions about land and water management policies and the uptake of improvements in agricultural technology.

Figure 2: Accumulated changes in arable land due to socio-economic development for 2050s under two climate scenarios



(a) A2 (medium-high emissions)



(b) B2 (medium-low emissions)

KEY FINDINGS

Our results demonstrate the importance of integrating climate change with other socio-economic drivers of change and the significant benefits of implementing successful adaptation policies. We judge these results to be near the upper limits of response (i.e. fairly optimistic) because PRECIS gives much wetter conditions than other climate models, the carbon dioxide fertilisation may not be sustained and the crop models are likely to underestimate the negative impacts of extreme events on crop growth and water availability

Without adaptation:

- Climate change alone has small to moderate negative effects on China's potential cereal production. The most serious impacts are with the B2 scenario (medium–low emissions) in the 2050s. With the effects of CO_2 included, climate change produces increases in cereal production under both climate scenarios. The increases are larger with the A2 scenario (medium-high emissions).
- The combined impacts of climate change and changes in water availability (which falls due to demand from other sectors) produce a significant decrease in the area of rice that can be irrigated with the A2 climate scenario and a moderate decrease with B2. Changes in the area of irrigation for wheat and maize are generally small because demand for irrigation water falls due to increased efficiency of water use (caused by higher CO_2 levels). The differences between crops are due to their different geographical distribution.
- Including land use change leads to lower total cereal production with the A2 climate scenario (≤10%) and higher production with B2 (≥10%).
- Population growth means that per capita cereal production declines for all drivers combined in 2020 and 2050 with both the A2 and B2 climate scenarios.

With adaption:

- Water allocation policies have modest benefits on total cereal production though much more could be done (e.g. efficiency gains and technology improvements).
- A combination of water adaptation and arable land conservation policies offsets the negative impacts on production and shows increases in total cereal production in the 2020s and 2050s with both climate scenarios.
- Adaptation based on optimistic and sustained improvements in agricultural technology results in significant increases in national total cereal production.
- In terms of cereal production per capita, improvements in agricultural technology are the only way in which production can keep pace with population growth (and the effects of other drivers) to maintain/improve existing levels of production.

CONCLUSIONS

Water availability plays a significant limiting role on potential cereal production due to the combined effects of higher crop water requirements and increasing demand for non-agricultural use of water. Combining crop and water simulation models with scenarios of climate and socio-economic change has demonstrated that the absolute effects of climate change alone are modest and that the interactive effects of other drivers tend to counterbalance them, leading to small overall changes in total production by 2050. The interactions are complex and the outcomes are highly dependent on socio-economic development pathways and assumptions about the effects of CO_2 on plant growth.

FURTHER INFORMATION

The full report, *Future Cereal Production in China: Modelling the Interaction of Climate Change, Water Availability and Socio-economic Scenarios*, together with all the other reports and six summary pamphlets from the project, are available from the project website (**www.china-climate-adapt.org**).

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