Climate change and global water resources: Adaptation strategies for the agricultural sector

Over the last 50 years, the global irrigated area roughly doubled and the amount of water used by the agricultural sector increased substantially. Around the year 2000, a third of the global crop production was harvested from irrigated areas. In the same period, the construction of large reservoirs, with dams or other means, increased the volume of usable water. It was estimated that reservoirs supply water to 30-40% of the irrigated areas worldwide, contributing to 12-16% of the global food production (World Commision on Dams 2000). Both the expansion of irrigated areas and the construction of reservoirs have, therefore, been critical to the increase in global food production in the 20th century.

But there is reason for concern. There is a limit to the amount of freshwater that can be exploited sustainably. About one third of the world's population is already living in countries suffering from water stress. And global agricultural production will have to more than double in this century in order to meet the growing demand for food under more difficult climatic conditions. Increasing scarcity of irrigation water calls for adaptation strategies for the agricultural sector.

Irrigation water can constrain food production needed for a growing population

Researchers at Wageningen UR, in collaboration with international partners, investigated whether enough water resources are available to sustain a higher level of agricultural production and in which regions water scarcity is expected to be most severe. They also tried to find out which water sources were available to support irrigated agriculture. Tracking down water is, however, not an easy task as water moves around the Earth and atmosphere in a complicated cycle involving weather, climate, plants and trees, animals, and people. To understand how the complex interplay between climate change, land use change, population growth and economic development can influence water availability and demand, the researchers used a global hydrology and crop model called LPJmL (Biemans et al., 2011; Rost et al., 2008).

The researchers found that almost a fifth of total irrigation water worldwide is currently supplied

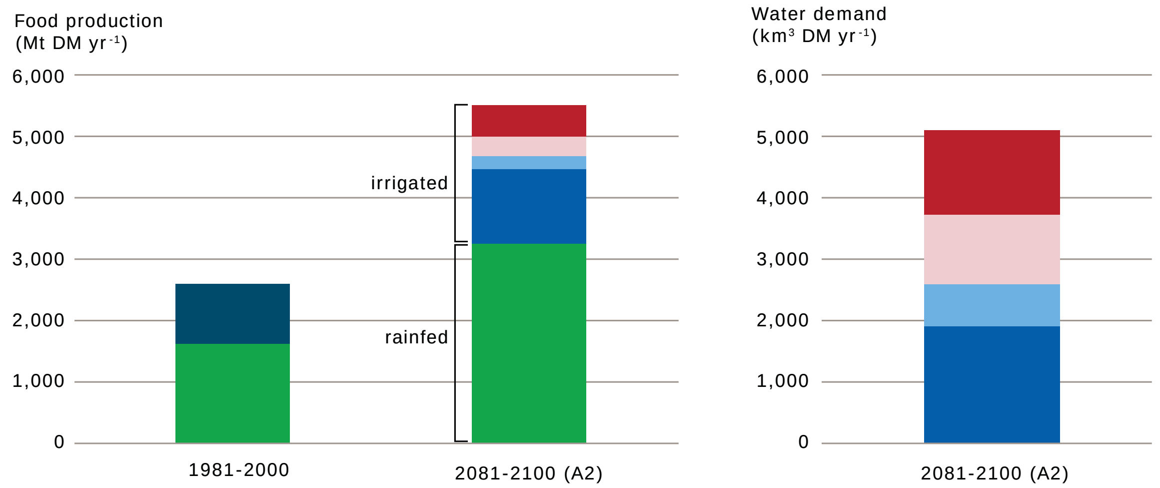


Figure 1 Left: Recent and future rainfed and irrigated food crop production (Biemans 2012). Right: The increase in irrigated agriculture will result in higher irrigation water demand. The colours show the potential fulfilment of this irrigation water demand from different water sources: dark blue from rivers and lakes, light blue from surface water reservoirs, pink from groundwater if supply can be sustained at current volumes, and red represents volumes that will be unavailable. The water shortage could lead to a shortfall in irrigated crop production (left)

directly from reservoirs (Biemans et al., 2011), substantiating that reservoirs play a very important role in global food production.

Global agricultural scenarios project that an increase in irrigated area between 30% and 45% is needed to increase food production (e.g., Fischer et al., 2005). Inevitably, this will lead to higher irrigation water demands. However, integrated analysis using the LPJmL model showed that with current reservoir capacity and inefficient irrigation in large parts of the world, not enough water can be supplied to sustain the required increase in food production in the future. Worldwide, these limitations could reduce irrigated food production to as much as 20% (Figure 1) (Biemans 2012).

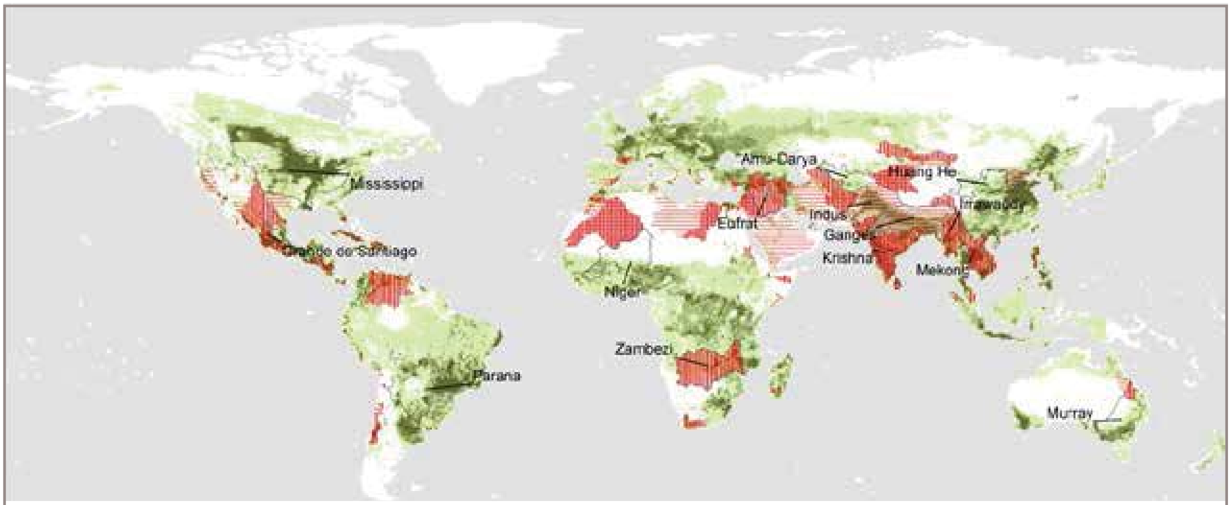
In some basins of Southern Africa and South Asia, irrigated crop production could be reduced by as much as 50% due to water shortages (Figure 2). At the same time, the effects of climate change are likely to have a major impact on water supply and demand at the local level as some regions will experience more rain than usual and in some regions it will be drier.

Adapting to limited water resources

The researchers also looked at potential solutions to future water shortages. If the yield on irrigated lands becomes lower as a result of the water shortages, either much more land will be required to achieve the production needed, or water use efficiency and water storage will have to increase. Potential solutions could include, for example, improved irrigation systems, drought-tolerant crops, brackish irrigation and other practices or technologies to help improve the management of water resources. Focusing on five rivers in Asia, it was determined that adaptation measures like improving irrigation efficiency and increasing reservoir size could help make up the shortfall (Biemans et al., 2013). However, the study also showed that the best solution may be different in each basin, emphasising the need for region-specific adaptation strategies.

Future action

LPJmL is a suitable tool to study the linkages between water availability and crop production. It was used to show that the current projections of the future food system are not 'waterproof', and that the agricultural system represented in those projections might overstate projected output on irrigated land by around 20%, which leads to an overestimate of the total crop production by around 8% due to irrigation water shortage. To meet future water demands, there is a clear need to factor adaptations into the way in which water systems are managed as part of sustainable agricultural practices. Improved irrigation efficiency and increased storage capacity in large reservoirs can clearly help to reduce water scarcity and improve food production.



Crop production areas (A2)
Basins with a reduction in irrigated crop production more than 20% due to water shortage
Basins where irregated crop production is more than 20% depending on groundwater
(only basins shown where irrigated production is more than 50% of total crop production

Figure 2 Vulnerable river basins where irrigated crop production could become at risk. In the red dashed areas, a loss of irrigated crop production of more than 20% is projected. In the pink dashed area irrigated, production depends, to a large extent, on groundwater and is potentially at risk if groundwater tables drop

Contributors
Hester Biemans *hester.biemans@wur.nl*
Ronald Hutjes