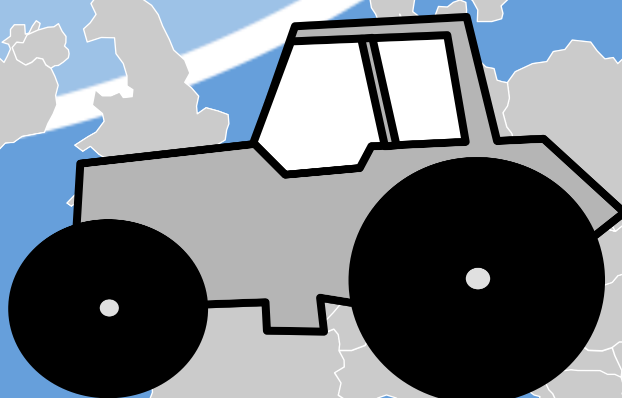
Europe's agriculture in a changing climate

Part 1: Overview global impacts in 21 sheets



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Latest update: 29 March 2019

Overview

Climate change is just one of the factors that determine agricultural production

Climate change

Changes in temperature and precipitation, but also extreme heat, flood events, pests and disease, and ozone damages, becoming increasingly important at higher levels of climate change.

Carbon dioxide

Crops respond to increasing levels of CO_2 in the atmosphere in different ways, where in general a higher concentration of CO_2 has a 'fertilizing effect' on crops.

Technical development

It has been estimated that changes in the productivity of food crops in Europe over the period 1961-1990 were strongest related to technology development; effects of climate change were relatively small. This includes progress in the development of new seeds, improvements in plant protection, new and improved sowing, cultivation and harvest techniques and enhanced fertilization.

Economics

Agricultural production is stimulated in regions that are relatively well-off, and trade flows of imports and exports change between these regions and regions with significant crop yield declines.

Climate change impacts

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Changes in temperature and precipitation, and additional impacts, including extreme heat, flood events, pests and disease, and ozone damages, becoming increasingly important at higher levels of climate change.

Crops are especially susceptible to damage when stresses from weather extremes occur during sensitive growth phases, such as leaf formation, flowering or fruit development and ripening. The consequences of spring droughts can thus be more serious than those of summer droughts. In addition, damage from more-frequent heavy rainfall and hailstorms could increase. In fruit cultivation especially, earlier flowering could increase frost risks.

Also, surface ozone, formed through the photochemistry of precursor gases mainly arising from human activities, is detrimental to crop yields. More severe ozone pollution leads to substantial crop damage on a global scale, reducing global total crop production.

Inter-annual variability of temperature and precipitation will increase in the future in Europe, particularly in the summer. Climate variations have regularly led to yield losses in the past.

Sources include Zebisch et al. (2005); Bebber et al. (2013); Tai et al. (2014); Deutsch et al. (2018)

Climate change impacts

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Climate change → The growing season for crops is changing

Two measures describe the growing conditions for crops in the summer season:

- The length of the thermal growing season is the length of the growing season for crops and trees. It starts when the daily mean temperature rises above a selected threshold in spring, and ends as the mean temperature falls below that level in autumn.
- The intensity of the thermal growing season is represented by the effective temperature sum: the accumulating sum of the daily mean temperature excesses above the threshold during this season. The commonly used base temperature for the thermal growing season is 5°C in boreal and temperate climate conditions, and 10°C in warmer climate zones.

Sources include Ruosteenoja et al. (2016)

Length and intensity of Europe's thermal growing season

Overview

Future:

- In most of Europe the thermal growing season will last 1.5 - 2 months longer in 2100 compared to 1971 - 2000 for a high-end scenario of climate change, and 20 - 40 days longer for a moderate scenario of climate change.
- The intensity of the thermal growing season with respect to the 5°C baseline (growing degree day sum) will be 60 - 100% higher in 2100 for a high-end scenario of climate change; the increase is somewhat smaller for the moderate scenario. In absolute terms, the increase of the intensity of this season is largest in the south. In relative terms, however, the increase is largest in cold areas.

Past:

In northern Europe the thermal growing season has lengthened by about 1 week between 1951 and 2000. The intensity of this season has increased all over Europe after 2000.

The growing season for crops is changing

Benefits:

A longer and more intense growing season is beneficial for especially northern Europe. It enables the introduction of new species and cultivars in agriculture, and allows a more extensive utilization of double-crop rotation. Besides, the mildness of the dark season facilitates the overwintering of fruit trees and other vulnerable perennial plants.

Downside:

Long growing seasons and mild winters favour pests and fungi, and higher temperatures in late autumn are of little use for plant photosynthesis in northern Europe due to the scantiness of the light. Also, annual cereal crops are harvested in early autumn and thus do not benefit from the autumn lengthening of the thermal growing season. In late autumn, the harvesting conditions would in any case be unfavourable owing to high moisture, even more so as precipitation is projected to increase and the low amount of solar radiation can no longer alone dry the harvest crop. In southern Europe, negative impacts dominate, particularly as a result of excessive heat and the reduced availability of water.

Sources include Ruosteenoja et al. (2016)

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Another effect of rising temperatures is the loss of organic carbon from soil due to an accelerated rate of decomposition and mineralization of organic material in agricultural soils. This loss of organic carbon decreases soil fertility and contributes to the greenhouse effect through emissions of carbon dioxide. Studies have shown that due to temperature increase by 2100, 20-30% of European soil carbon will be lost. A decrease of soil organic carbon by 40-60% is possible if climate change induced changes in crop productivity and expected land use changes are taken into account.

Sources in Zebisch et al. (2005)

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Crops respond to increasing levels of CO_2 in the atmosphere in different ways, where in general a higher concentration of CO_2 has a 'fertilizing effect' on crops.

Along with increased biomass production, a corresponding increase of root organic matter is expected as well, which may lead to permanent enrichment of soil with organic matter.

- In the short term, a rising concentration of CO_2 can stimulate photosynthesis, leading to increases in biomass production in C3 crops such as wheat, barley, rye, potato and rice. The response is much smaller in C4 crops such as maize. These benefits will be particularly pronounced in northern Europe.
- For these crops, CO_2 fertilization fully offsets negative impacts of warming up to 1-2° for the global average yield effect.
- CO_2 fertilisation effects should not be overemphasised, however, since available water supplies will be the factor on which yields primarily depend. Furthermore, increasingly frequent weather extremes could present risks for agricultural production.

The distinction between maize on the one hand, and wheat, rice, and soy on the other is particularly relevant since these crops have different photosynthetic carbon cycles. Hence, they respond differently to changes in atmospheric CO_2-concentrations.

Sources include Moore et al. (2017)

Climate change impacts

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Economics

It has been estimated that changes in the productivity of food crops in Europe over the period 1961-1990 were strongest related to technology development; effects of climate change were relatively small. This includes progress in the development of new seeds, improvements in plant protection, new and improved sowing, cultivation and harvest techniques and enhanced fertilization.

Past:

Over the period 1977-2005, winter wheat yield in France has increased due to technology by on average 1.69% per year, and similar trends were observed for winter barley and spring barley. This positive trend is stronger than the projected negative trend of yield reduction under climate change.

Global wheat production approximately doubled from 1970 to 2015, mostly due to improved management and higher yielding crop varieties.

Future:

For the period till 2080 an increase in crop productivity for Europe has been estimated of 25% - 163%, of which 20% - 143% is due to technological development and 5-20% is due to climate change and CO_2 fertilisation.

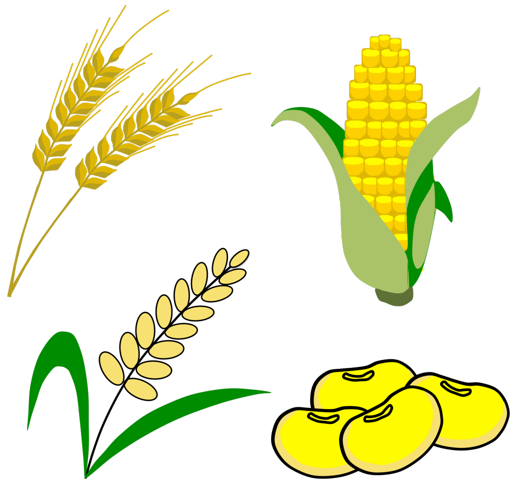
One may not conclude, however, that technological improvements will easily compensate for the impacts of climate change. After all, the effect of technological improvements on crop yields exhibits a decline in growth over the past decades. Still, if this trend of slowing yield growth due to technology is assumed to continue into the future, the projected combined effects of climate change and technical change are positive: yields are projected to increase, particularly for milder warming scenarios.

Sources include Alcamo et al. (2007); Zampieri et al. (2017); Gammans et al. (2017); Iizumi et al. (2018)

Vulnerabilities and opportunities - global yields

Observations

Maize, rice, soy and wheat are the four crops that make up a major part of the scientific literature on climate impacts on crops. These crops collectively account for approximately 20% of the value of global agricultural production, 65% of harvested crop area, and almost 50% of calories directly consumed.



IPCC (2014): Changes in temperature caused reduction in global yields of maize and wheat by 3.8 and 5.5% respectively from 1980 to 2008 relative to a counterfactual without climate change. Effects on rice and soybean yields have been small in major production regions and globally.

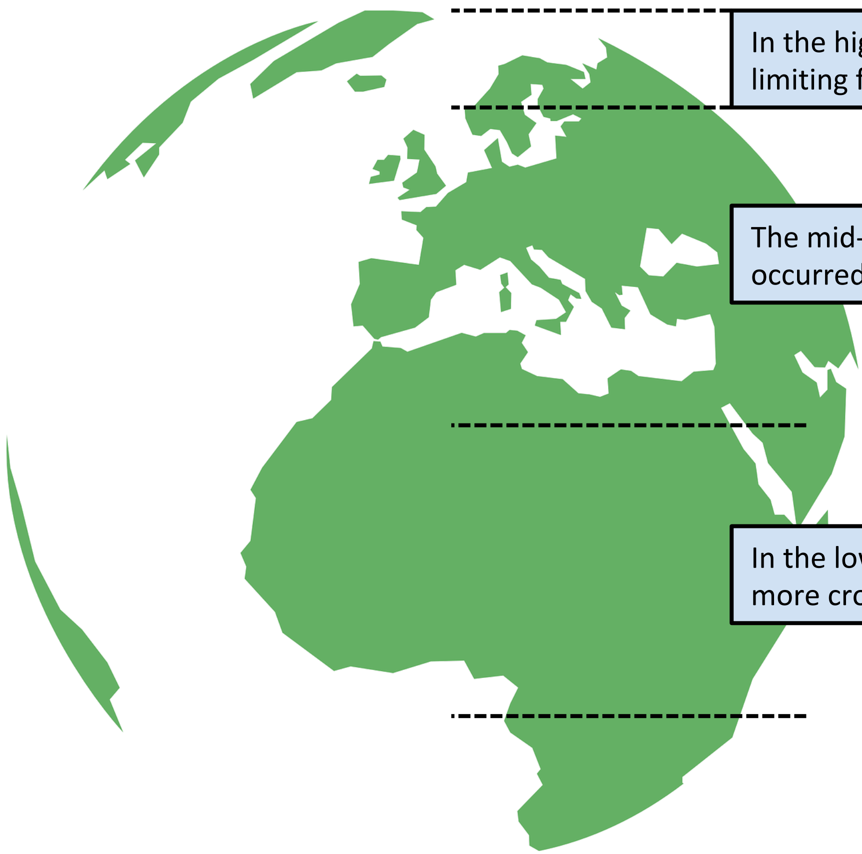
More recent study: Without climate change, current global mean yields of maize, wheat and soybeans would have been 4.1, 1.8 and 4.5% higher, respectively. For rice, no significant impacts were detected (Iizumi et al., 2018).

The uncertainties in these estimated yield impacts are large, however. For maize, the 90% probability interval is -8.5 to +0.5% (- indicating a yield loss, + an increase). For wheat and soybeans these intervals are -7.5 to +4.3%, and -8.4 to -0.5%, respectively. These estimates include the uncertainties related to the positive impact of higher concentrations of CO_2 on crop yields.

Vulnerabilities and opportunities - global yields

Observations

Geographical variation
On a global scale, global warming so far seems to have increased crop yields at the mid and high latitudes, and decreased at the low latitudes. This pattern was observed for all of the crops. The role of temperature change on yield impacts seems to dominate over that of precipitation change. Precipitation changes (more droughts) are very important in the Mediterranean, however.



In the high latitudes, where low temperatures and snow cover are the primary limiting factors for crop production, the warming has benefited crop growth.

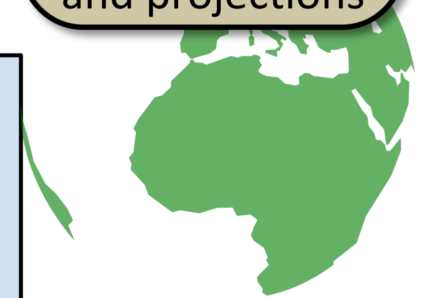
The mid-latitudes are in the transition zone between the changes that have occurred in the low and high latitudes.

In the low latitudes current temperatures are already high, and warming has led more crops to be exposed to physiologically critical temperatures.

Source: Iizumi et al. (2018)

Vulnerabilities and opportunities – Pests and diseases

Observation and projections



Observations:

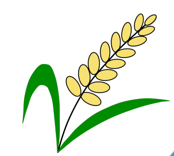
- Between 10 and 16% of global crop production is lost to pests, with similar losses postharvest.
- Overall, there has been a significant trend of increasing numbers of pest and pathogen observations at higher latitudes, globally and in both the Northern and Southern hemispheres. Although recent climate change is implicated as an important driver of these observations, other factors, such as new crop varieties and agricultural technologies, could bias the results.
- Published observations of 612 crop pests and pathogens show that the average poleward shift in recorded incidences of these pests and pathogens since 1960 is 2.2 ± 0.8 km/year for the Northern Hemisphere and 1.7 ± 1.7 km/year for the Southern Hemisphere.

Projections:

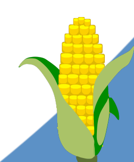
- Crop production losses to pests increase globally with rising temperatures.
- When average global surface temperatures increase by 2°C, the median increase in yield losses owing to pest pressure is 46, 19, and 31% for wheat, rice, and maize, respectively.

- The impact for wheat is relatively high: wheat is typically grown in relatively cool climates where warming will increase pest population growth and overwinter survival rates, leading to large population increases in the growing season.

- The impact for rice is relatively low: rice is grown in relatively warm tropical environments where warming reduces insect population growth rates because current temperatures there are already near optimal.



- The impact for maize is in between wheat and rice: this crop is grown in some regions where insect population rates will increase and in other regions where population rates will decline, in nearly equal measure.



Sources: Bebber et al. (2013); Deutsch et al. (2018)

Vulnerabilities and opportunities - global yields

Projections

More than 1,700 published simulations for wheat, rice and maize:

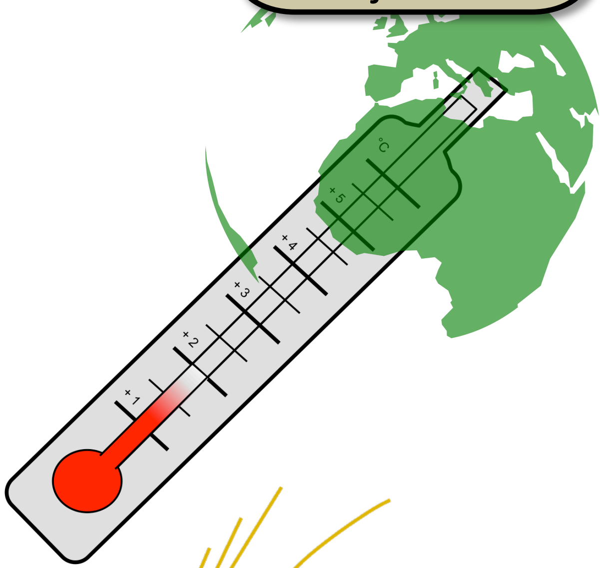
- **2030s:** A majority consensus that yield changes will be negative from the 2030s onwards;
- **2040s and 2050s:** More than 70% of projections indicate yield decreases;
- **Beyond 1950s:** more than 45% of all projections for the second half of the century indicate yield decreases greater than 10%. Yield losses are greater in magnitude for the second half of the century than for the first;
- Adaptations are more effective for wheat and rice than maize; most yield loss in wheat may be avoided, or even reversed, in tropical regions up to 2-3°C of local warming and in temperate regions across a broad range of warming;
- It looks like increases in yield variability become increasingly likely as the century progresses.

Warming reduces global yields of wheat by 6.0 ± 2.9%, rice by 3.2 ± 3.7%, maize by 7.4 ± 4.5% and soybean by 3.1% ± 5% per °C global mean temperature increase.

Sources: Challinor et al. (2014); Zhao et al. (2017) in Schleussner et al. (2018)

Paris Agreement - global yield impacts under 1.5 °C and 2 °C warming

Projections



Wheat

- Rain fed wheat yields decline (<5%) in a +1.5°C World in major wheat belts of the North American Great Plains and Europe. Larger losses are evident in the northern Murray-Darling Basin of Australia, eastern South Africa, and northern Argentina, while western Asia and the North China Plain see substantial yield increases.
- Irrigated crops respond in much the same way as rain fed crops. In both the + 1.5° and + 2°C Worlds, irrigated yields are reduced for the irrigated wheat basket of South Asia.

Sources: Lobell and Gourdji (2012); Rose et al. (2016); Zampieri et al. (2017); Schleussner et al. (2018)

Projections

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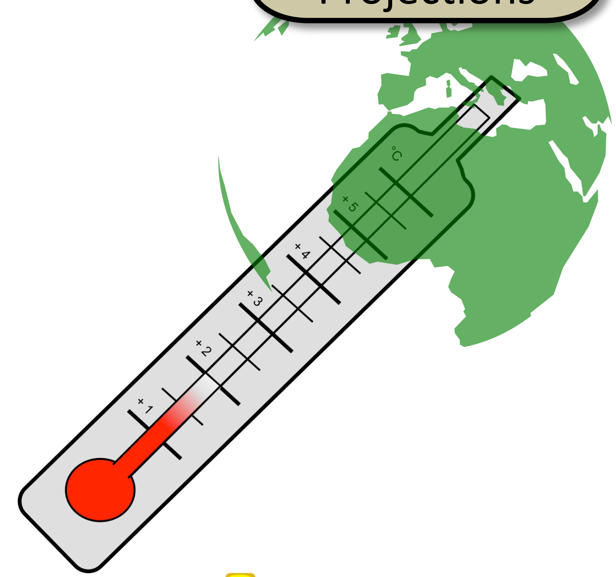
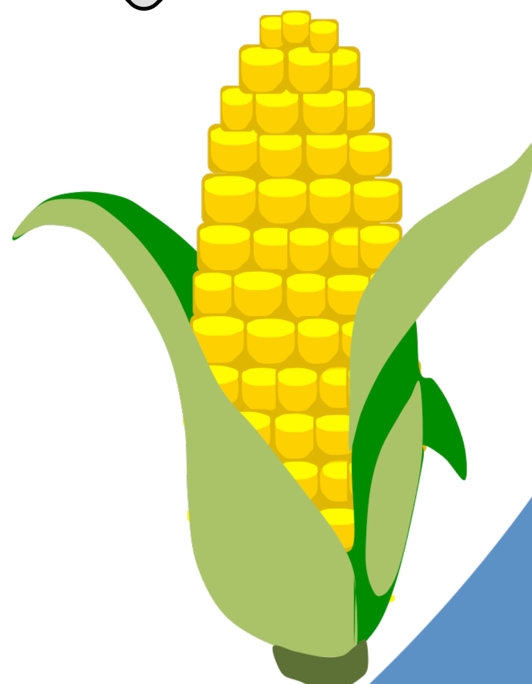
Maize

- Rain fed maize yields decline in most areas in a +1.5°C World.
- When global warming moves from +1.5° to +2°C, rain fed maize yields decline further.
- Irrigated crops respond in much the same way as rain fed crops. In both the + 1.5° and + 2°C Worlds, irrigated maize losses are large over much of North America, China, and southern Europe, while yields are reduced for the irrigated wheat basket of South Asia.
- Global maize yield is projected to reduce by 10 - 20 % for every 1 °C increase in temperature without adaptation.
- Use of farmer-instigated adaptation strategies through changing planting date and crop variety may alleviate the effects of a 0.5°C warming for maize yields; however, temperatures greater than 1 °C will negatively affect yield in most countries.





Sources: Lobell and Gourdji (2012); Rose et al. (2016); Schleussner et al. (2018)

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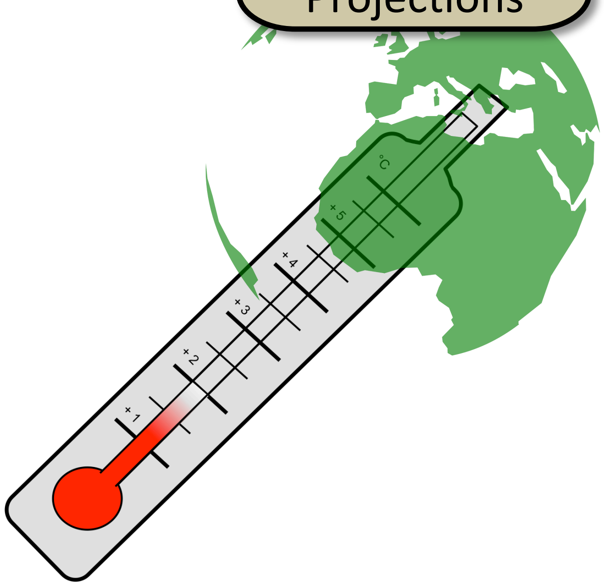
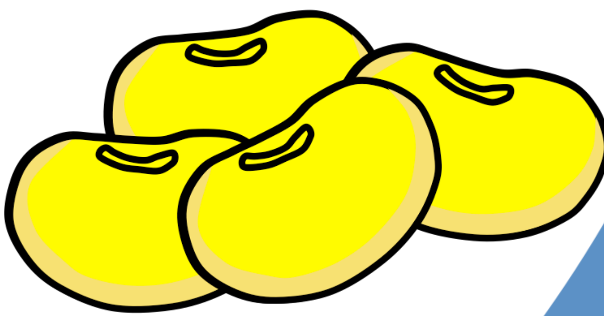


Soybean

- In a +1.5°C World, soy yields are projected to improve over much of Eastern Europe and north-western Asia, and slightly decrease over the interior of North America and equatorward portions of South America and East Asia.
- For soybean, adaptation (including planting earlier in the season and changing variety) can be effective at temperatures up to 4°C.



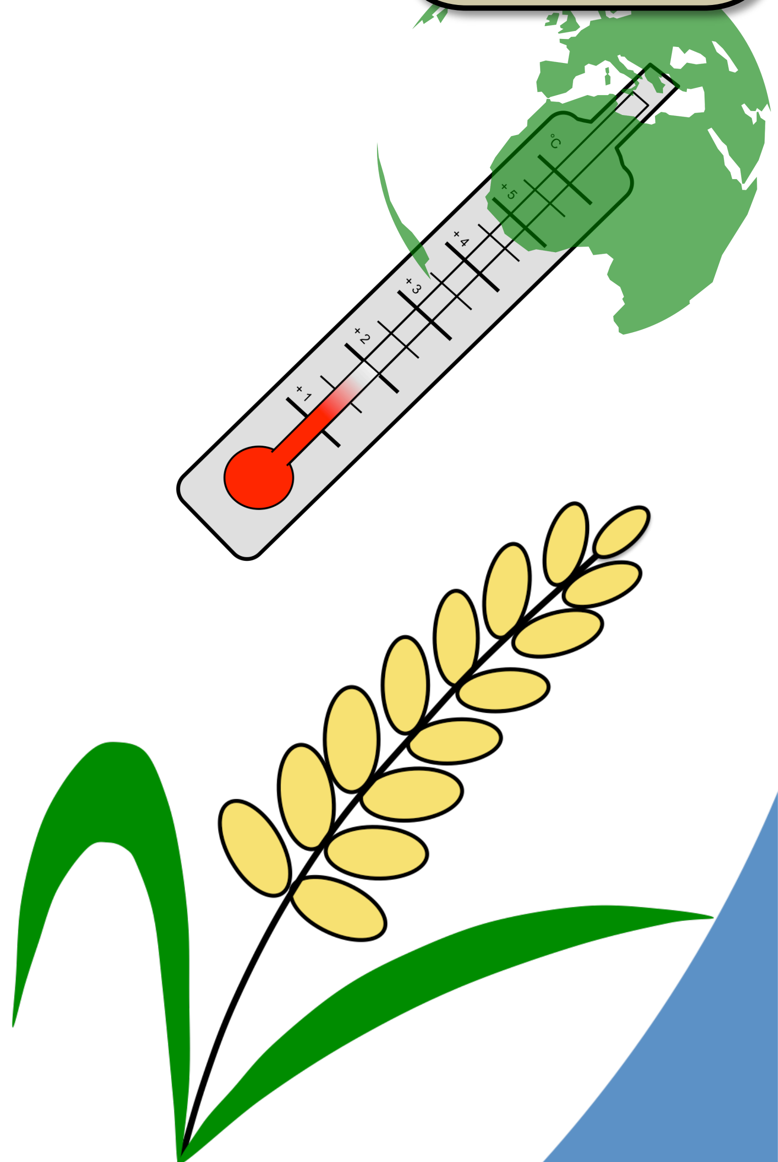
Sources: Lobell and Gourdji (2012); Rose et al. (2016); Schleussner et al. (2018)

Paris Agreement - global yield impacts under 1.5 °C and 2 °C warming

Projections

Rice

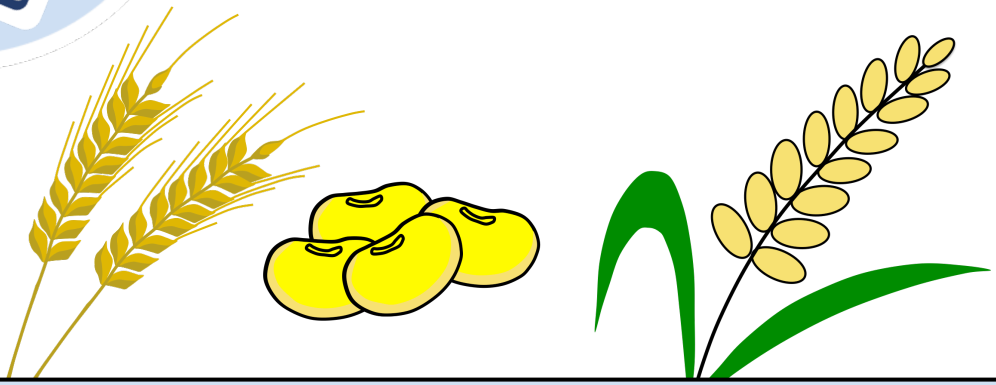
Rice yield changes in a +1.5°C World are small over the major production regions in Asia, while increases are projected over tropical Africa and South America.

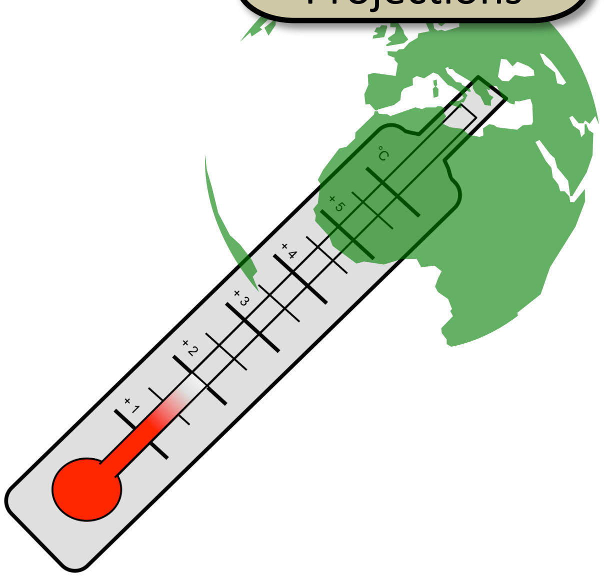


Sources: Lobell and Gourdji (2012); Rose et al. (2016); Schleussner et al. (2018)

Projections

Paris Agreement - global yield impacts under 1.5 °C and 2 °C warming





Without CO_2 effects, the production of all four crops would be lower in a + 2°C World compared with the current situation. Thanks to the CO_2 effects, however, wheat, rice, and soy yields improve in the + 2°C World: in nearly all world regions the CO_2 fertilization effect largely overcomes negative impacts of temperature and precipitation.

For maize yields, this beneficial CO_2 effect is much lower and yields decline further as temperatures rise to the +2°C World.

Source: Asseng et al. (2015) in Ruane et al. (2018)

Paris Agreement - global yield impacts under 1.5 °C and 2 °C warming

Projections

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Combined effects of higher temperatures, higher atmospheric CO_2 levels and trade effects, focused on seven crop types: temperate corn, soybean, wheat, sugarcane, cotton, tropical corn, and tropical soybean:

- Regional agricultural impacts at 1.5°C warming cannot be distinguished from those at 2°C warming. The uncertainties in the contributing impacts of climate, CO_2 and trade, and how they counteract or reinforce one another are simply too large.
- Especially the uncertainty in the effect of CO_2 fertilization on crop yield dominates the results. Without the effect of CO_2 fertilization, the agricultural sector is generally worse off in the 2°C scenario than in the 1.5°C scenario.

When all uncertainties are included, it cannot be concluded whether 1.5°C is better or worse than 2°C warming in terms of global agricultural impact.

Source: Ren et al. (2018)

Paris Agreement - Disturbing effects of mitigation policy

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The implications of stabilizing global warming at +1.5° and +2°C go beyond the direct impacts of changes in temperature and precipitations, and the response to higher CO_2-levels. Ambitious mitigation policy to achieve this climate stabilization may lead to croplands being used for bioenergy crops. This may affect food production and disturb food prices. In fact, bioenergy expansion may be more disruptive to land use and crop prices than the climate change impacts alone. This would require substantial intensification in remaining agricultural systems to meet food demands.

Source: Van Meijl et al. (2018) in: Ruane et al. (2018)

Irrigation: an additional 2.8 billion people can be fed sustainably

Projections

Closing the gap between actual and maximum crop yield

The actual yield that a farmer currently achieves is often less than the potential yield he could achieve if the circumstances for a crop cultivar were optimal, that is, a situation with non-limiting water and nutrient supplies, and with pests, weeds, and diseases effectively controlled. The difference between this potential yield and the actual yield is called the crop yield gap. Additional irrigation will be needed in many places in order to close the yield gap and to maximize food production.

Irrigation

In some regions, the development of irrigation is limited by the availability of blue water resources. In other places, more water is needed for irrigation than can be replenished on rainy days. Using this water for irrigation may not be sustainable: too little water may be left to sustain aquatic habitats and groundwater resources may be depleted.

Good news!

A recent study shows that global water consumption for irrigation could sustainably increase by 48%, enough to feed an additional 2.8 billion people.

- China has the greatest potential to sustainably increase crop production by intensifying and expanding irrigation, thereby feeding an additional 382 million people.
- Africa currently produces enough calories to feed 400 million people, making it the continent with the largest gap between crop production and demand. An increase in yields through investments in irrigation expansion could sustainably feed an additional 450 million people and substantially reduce the continent's dependence on food imports.

Several sources in Rosa et al. (2018)

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