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Quantifying the effects of climate extremes on the future yield gap

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Background

Actual crop yields worldwide are lower than expected yield potentials. Global food security depends on closing this "yield gap".

Future yield is expected to be affected by climate change via changes in climatic variable means (notably changes in temperature and precipitation), but more importantly, via changes in frequencies and amplitudes of extremes on various spatiotemporal scales (like frosts, droughts, heat waves). Quantification of effects of extremes and future changes therein is very relevant to estimate effects on the current and future yield gap.

Objective

The goal of the research is to quantify the effects of current and future climate extremes on actual and potential crop yields.

Introduction

Climate extremes can seriously affect crop yields by crossing crop-specific thresholds (Supit et al, 2010). Effects can for instance be increased development, loss of fertility, leaf senescence, and lethal temperature effects.

These crop-specific extremes occur on different spatiotemporal scales. Also, there are significant sources of uncertainty. E.g., when and where will extremes occur, and how (much) will they affect crops?

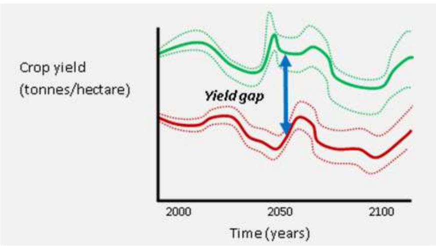

Figure 1. Illustrative scenario for climate change aggregated effects on the yield gap, the difference between yield potential (green) and actual yield (red) at some site. It is expected that the yield gap is affected by climate change, not only via trends but also via extremes.

Uncertainties about inputs and extremes create uncertainty margins (dashed) that should be included in yield gap predictions.

Currently neither extremes nor uncertainties are adequately handled by impact assessment techniques. Methodologies have to be developed to deal with these important aspects.

Approach

We propose an approach consisting of 2 phases.

1/ Analysis of factors

Various types of uncertainties exist ('unknown unknowns', 'known unknowns', noise, ...). An inventory of possible sources of uncertainties is composed by experts. E.g., temperature effects on wheat development are known much better than lethal temperatures for wheat.

This inventory is used as input for phase 2.

Approach (cont.)

2/ Quantification

We use output of several GCMs consisting of time series (2010-2100) of six climate variables driven by different high and low end scenarios. This represents uncertainty w.r.t climate processes and CO_2 emissions.

GCM output drives crop growth model WOFOST (De Wit et al., 2012), adapted to adequately handle crop threshold values and estimate current and future yield potentials.

Climate and crop time series are analysed w.r.t. correlations, trends, and properties of extreme values. Actual yields are estimated from data and derived statistical relationships.

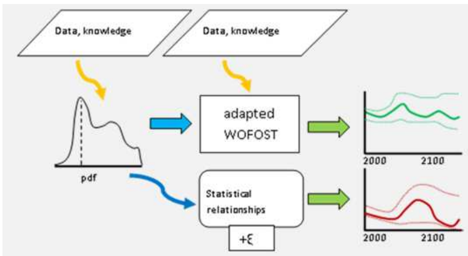

Figure 2. Quantification of climate extremes to crop yields. Data/GCM output and knowledge are used to adapt WOFOST to handle extremes, and generate input to estimate actual and potential yields. Input uncertainties are propagated and translated to yield gap uncertainties.

Results

Some preliminary analyses reveal large uncertainty in the distribution and frequencies of extreme events.

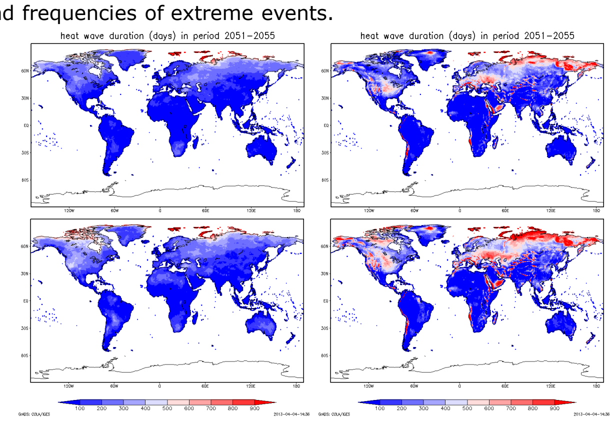

Figure 3. Expected **heat waves** for the period 2051-2055 for two different GCMs under a low (upper panels) and a high (lower panels) end emission scenario. Output of all runs are nearly identical for e.g. middle Africa, but deviate strongly for e.g. the US and the Ukraine region.

The above figure gives an example of the importance of quantifying uncertainties in climate extremes and their effects on crop yields.

References

Supit et al. (2010). Agr. Sus. 103: 683-694.
De Wit et al. (2012). Agr. For. Met. 164: 39-52.

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