Agricultural productivity under future climate scenarios

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Estimates of the possible impacts of climate change on agricultural productivity range widely, depending on the crop, location, and estimation method used. For wheat in temperate regions, the recent Intergovernmental Panel on Climate Change (IPCC) assessment shows a wide range of estimates (without adaptation), ranging from a 50% decrease in productivity to a 40% increase, with the average being slightly negative (about a 5% decrease) and decreasing with increased temperature.

IMPACT

Using relative yield to study agricultural productivity improves our knowledge of assessing the impact of climate change on agriculture. This methodology bridges the division between process-based models and statistical models that assess climate change impacts.

An important limitation of many studies of climate impacts is that they simulate the impacts on yield at a small number of "representative" sites. However, data show that conditions vary substantially across most landscapes in terms of soils, climate, and other factors affecting yields. Here we report results from a method based on crop simulation models that is designed to represent this high degree of heterogeneity in conditions while controlling for possible systematic biases in simulated yields.

Methods. We developed a new methodology built on relative yield to better assess climate change impacts and predict actual crop productivity under future climates. We defined relative yield for a spatial unit such as a field, farm, or map pixel as the ratio of future yield over historical yield. We obtained these yields from a crop simulation model for future and current climates, using representative management data. Under the assumption that the systematic bias in simulated yields is similar for both current and future climates, the bias effect should be reduced by using the ratio of future over current simulated yield. Note that a relative yield with a value of 1 indicates no difference between future and current yield, while a value greater than 1 means future yields are higher and a value less than 1 means future yields are lower than current yields.

Results. We used the relative yield methodology to study the REACCH region based on projected yields from a crop simulation model called CropSyst. For this analysis, we used the projections from 14 global climate models (GCMs) under two emissions scenarios (known as representative concentration pathways): RCP 4.5 and RCP 8.5.

1. We find that climate change will likely benefit winter wheat productivity on average by increasing average relative yields in the REACCH region under most projections of future climate, but will likely lower spring pea productivity by reducing average relative yields in the annual system (Figure 1).
2. The effects of climate change on crop productivity are not uniformly distributed among farms, and due to this heterogeneity, the simulations indicate that while a majority of farms would tend to have higher yields with climate change, a substantial proportion could have lower yields (that is, would be vulnerable to yield losses) (Figures 2 and 3).

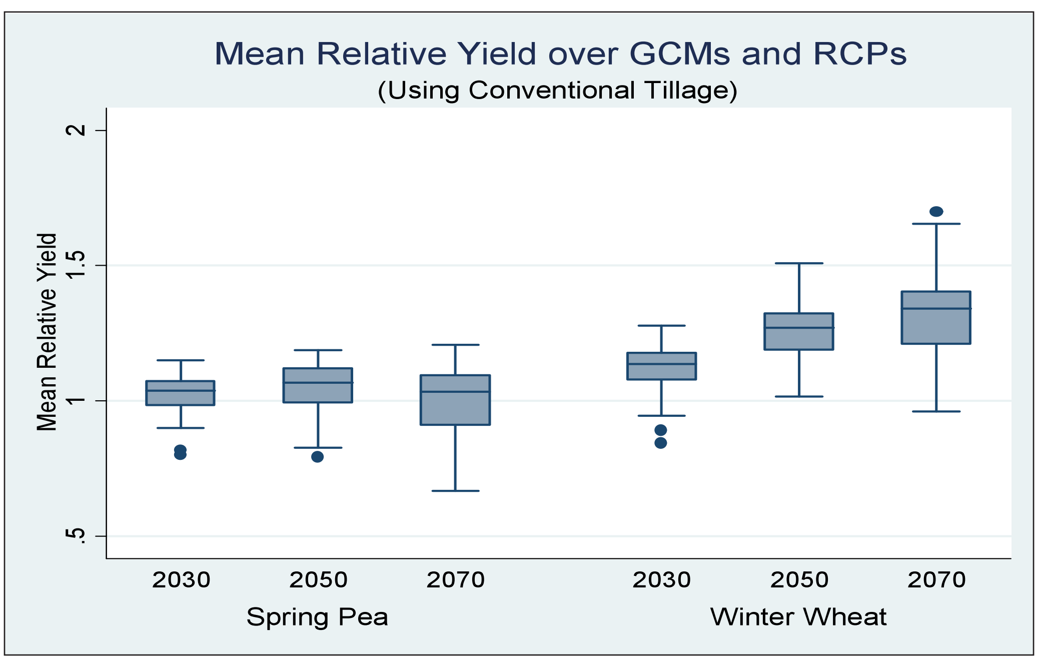

Figure 1. *Mean relative yield of spring peas and winter wheat over 14 global climate models (GCMs) and two emissions scenarios (known as representative concentration pathways, or RCPs).*

3. There is substantial uncertainty in projections of future climates, and thus there are also large uncertainties in the impacts on crop productivity. Figures 1, 2, and 3 all show that the projected distributions of relative yield in the REACCH region are substantially different for different GCMs.

Conclusions. The results from the REACCH region study show that on average, wheat producers in the region are likely to experience higher yields with future climates. However, there is substantial variation in the size of these yield gains, and at some locations losses are possible. There is also much uncertainty in the projections of future climate, which in turn means that there is substantial uncertainty about the future yield impacts.

These relative yield estimates provide growers and policy makers with information about the likely effects of climate change on productivity in the region. In related research, these yield estimates have been combined with economic data to study the likely economic impacts of these changes (see the companion article "Economic impacts of climate change on winter wheat").

In interpreting these findings, it is important to keep in mind that they do not account for important factors such as pests and disease effects of climate. Current research is addressing this limitation. Also, it is important to recognize that the results presented here do not incorporate possible adaptations to climate change. Current research is investigating adaptations and will be reported in the next REACCH annual report.

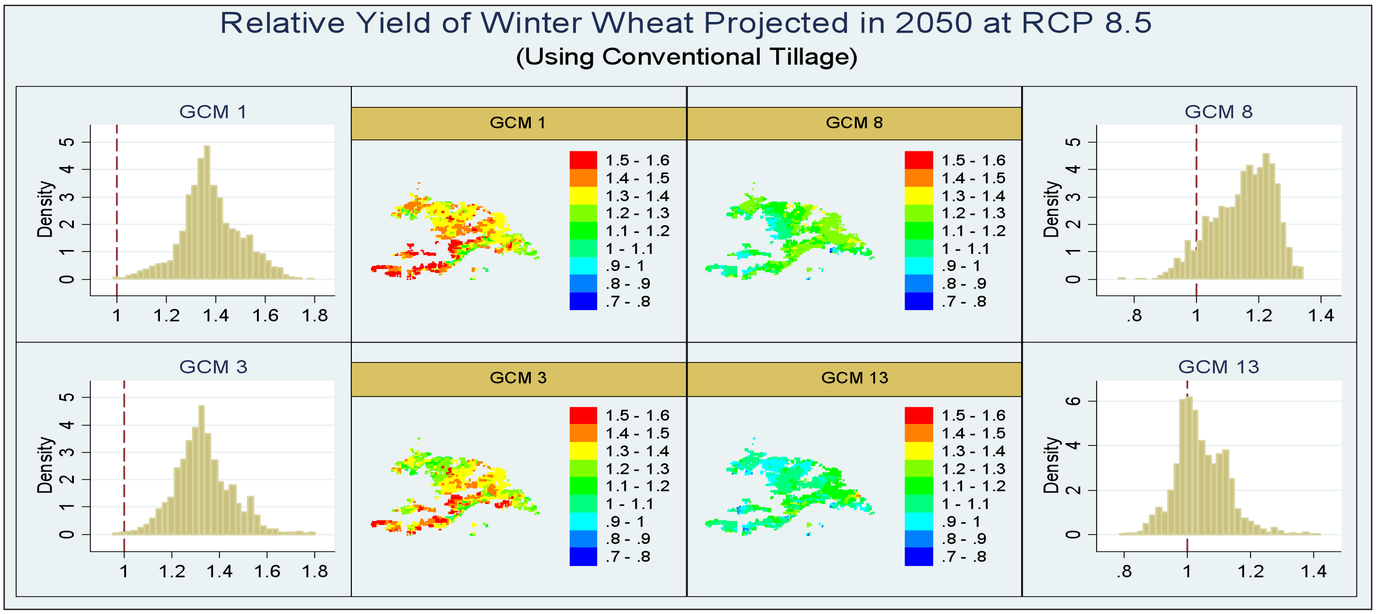

Figure 2. *Relative yield distributions of winter wheat for four global climate model (GCM) projections at representative concentration pathway (RCP) 8.5.*

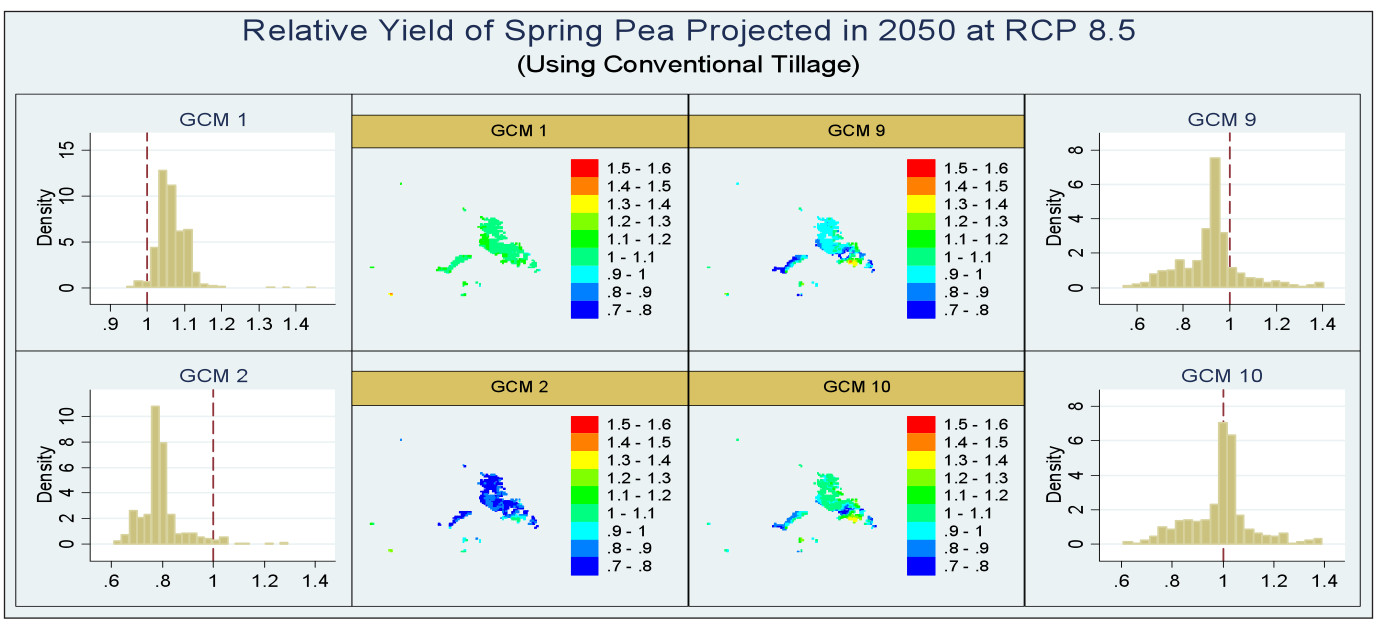

Figure 3. *Relative yield distributions of spring pea for four global climate model (GCM) projections at representative concentration pathway (RCP) 8.5.*