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# Rainfall is changing: when and where we need to be ready to adapt?

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ABSTRACT
*Climate model projections for the 21st century, suggest varied rainfall changes around the world with associated impacts on wheat, soybean, rice, and maize crops. Arid and wet regions of the world will become (and are already) dryer and wetter, respectively. Since large crop-producing areas are located within these regions, this is of major concern for the global food supply.*

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Climate change will affect rainfall patterns around the world. Because rainfall is such a variable quantity, and models still have hard time in providing reliable projections, few studies have to date ventured to evaluate if these future patterns will move the climate outside the range of "natural variability". A variation in positive or in negative outside such "natural variability" will have enormous impact for populations and crops likewise. In the case of positive variation, this will potentially lead to a flooded environment, whereas a negative variation will potentially lead to an arid environment – both conditions will impact populations and the food resources on which they rely upon. Therefore, it is of crucial importance to assess when such excesses of natural variation will happen and where.

With our study, we wanted to determine when, in the 21st century, climate change will prompt average rainfall regimes that are outside the short-term natural variability. To do this, we used all climate change model simulations available from the 5th Coupled Modelling Intercomparison Project (CMIP5). According to these simulations, the climate models are driven by four different emission scenarios. These emission scenarios (there are four of them) are plausible future trajectories of socio-economic development that result in different greenhouse house gas emissions. There is one low, two medium and one high emission scenario. Only the low emission scenario is compatible with limiting global warming to 2 °C, as the goal of the Paris

Agreement. Doing so, we were able to calculate the time at which the average rainfall will be statistically significant, compared to the 20st century climate. This is called the *Time of Emergence* (TOE) and it represents the moment when the magnitude of the mean rainfall change becomes greater than the natural variability.

Since wheat, soybean, rice and maize constitute around 40% of the global calorie intake, we calculated the TOE individually for each of their growing seasons. Currently, rainfall changes in most crop-growing regions have not ventured outside the natural variability. This does not mean that there are no major rainfall events (or series of events), but rather that these trends are not (yet) distinguishable from natural variability. However, a rainfall change TOE has been attributed in the near to mid future to a big part of the current crop producing regions. In particular, many of the major wheat producing areas are expected to face drier conditions.

In many subtropical regions with Mediterranean-like climates, drying trends will be below their current natural variability by mid-century. The whole Mediterranean region will experience substantial drying. In the worst-case scenario, up to 100% of the wheat and maize producing area will be affected in southwestern Turkey, Italy, southern France, the Iberian Peninsula, and Morocco. In the Southern Hemisphere, the principal TOE feature is the drying occurring after 2030 in South Africa, central Chile, and southwestern Australia, and will affect mainly wheat and maize producing areas.

On the other hand, many temperate regions in the Northern Hemisphere, such as China, the eastern United States, and India, will experience precipitation increases. Although more rain is generally good news for agriculture, oversaturation of soil moisture may increase flood risk and, therefore, make year-to-year food production more uncertain. These changes will occur very early during this century or are already emerging. Additionally, rainfall will also increase in Ecuador, Uruguay, Argentina, and Papua New Guinea by around 2060.

In terms of crop producing land, 14% of land dedicated today to the four aforementioned crops could have less rainfall, while up to 20–30% may see increases in rainfall. This would start early this century and would increase rapidly after 2040.

In the past, rainfall patterns have been difficult to predict. Climate models were, until recently, unable to produce consistent rainfall projections. It was therefore hard to give policy-advice about growing conditions. The study included all four future emissions scenarios used for climate change projections. Among the four different scenarios of emissions rate, the regions that will be affected follow the same pattern. This indicates that we have now a clear view of which regions need to undertake measures to cope with the variations. However,if we consider the scenario with the lowest emissions rate, the regions that will be affected are less and with a TOE emerging later in the 21$^{st}$ century. This could give more time to react to the variations.

In conclusion, even under the most optimistic emission scenario, rainfall patterns are expected to change significantly during the 21$^{st}$ century. However, if the missions are reduced to a level compatible with the Paris Agreement, this could significantly delay the climate variations. This could give countries more time for adopting measures such as flood resistant infrastructure development, and a reconfiguration of the agricultural systems toward more drought-tolerant crops.