AGRICULTURE

Running AMOC in the farming economy

Climate tipping points, such as the collapse of the Atlantic Meridional Overturning Circulation (AMOC), could drive significant structural changes in agriculture, with profound consequences for global food security.

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Climate change can be broadly characterised into three types of change. First, there is the change in climate — the expectation of weather based on several decades of data. The average temperature and precipitation throughout a year determine, among other things, the performance of crops and livestock, and thus farm economics. Second, there is the changing variability of weather, particularly the incidence of extreme events. For farming, whether it is wetter or drier than normal affects yields, and heat and drought — or extreme rainfall — can affect livelihoods catastrophically. Thirdly, the climate arises from a dynamic, non-linear system which, under continuous, incremental forcing, has the potential to rapidly change to new states[1]. Such tipping points can radically reshape global and local conditions, as Paul Ritchie and colleagues[2] show in this issue of *Nature Food*.

Of the three types of change outlined above, the third is least explored and most unresolved[1], partly because of model uncertainty. One iconic potential tipping point is the weakening and collapse of the Atlantic Meridional Overturning Circulation (AMOC). This is the Atlantic branch of the global thermohaline circulation that transports a large flux of heat (6–10 °C)[3] from the tropics towards Europe. Climate observations already show a 'cold spot' in the north Atlantic — the only place globally that is not warming — linked to an observed weakening of the AMOC[4]. Models project further weakening of the AMOC as climate change continues and the melting Greenland ice-sheet 'hoses' freshwater, with lower salinity and density, into the north Atlantic[5]. This cap of fresh water stops deep convection in the Labrador Sea, and collapse of the overturning circulation could follow. In current projections, the occurrence of collapse requires sustained levels of greenhouse gas emissions, but there are indications that the climate models used might be biased towards being too stable.

Uncertainties in models and emissions trajectories related to technological, economic, institutional and climate-related variables preclude consensus about the probability and timing of any tipping point. But it is certainly plausible, even if unlikely, that the AMOC could weaken to the point of collapse in the coming decades. AMOC collapse would strongly increase seasonality in Europe with harsher, stormier winters (even in a globally warmer world), together with hotter, drier and less windy summers. There would be widespread cooling across the northern hemisphere, with less precipitation in the northern mid-latitudes and large changes in precipitation in the tropics[6]. These effects would translate into a significant loss of crop yields across the world, which would clearly affect agricultural economies and drive global food prices up.

As they report in this issue[2], Ritchie et al. have undertaken the most detailed study to date of what might happen to agriculture in Great Britain (GB) if a climate tipping point occurred. Historically, there are clear associations between climate, land prices and farm viabilities in GB. It is currently more profitable to grow arable crops than to farm pasture-based livestock systems, but the extent of arable land is limited by temperature and rainfall. The authors explore the relationships between growing-season climate, yields and farm incomes, with and without irrigation, projecting forwards to 2080. Uniquely, in addition to 'smooth' climate change, they simulate collapse of the AMOC over the period 2030 to 2050 — a 'rapid-onset, low probability' scenario, but one within the bounds of plausibility.

Ritchie et al. find that without AMOC collapse, temperature would increase by 1.9 °C in 2080 relative to today, with small declines in rainfall. This would lead to a small net increase in arable area (despite some decreases in south-east England) and a projected net gain of £40 million in GB's agricultural economy. With significant investment in irrigation, there could be a larger net gain in arable area (rising from 32% to 42% of GB's agricultural land) and a net benefit of £125 million. However, investment in irrigation to achieve these gains far exceeds the gains themselves.

Simulating AMOC collapse leads to significant changes in growing-season conditions: a cooling of 3.4 °C by 2080, and a decrease in average summer rainfall of 123 mm. This vastly diminishes the profitability of arable land, resulting in its reduction to about 22% of the current area, and an overall decline in the agricultural economy by about a third (£346 million). Again, although the decline in arable land due to rainfall limitation could be offset by irrigation, this would cost more than £800 million, making it infeasible. Changing agricultural landscapes so substantially would lead to indirect effects; for example, expanding livestock areas could lead to the degradation of water courses due to manure enrichment.

This study is important in that it starts to unpick what might happen if the AMOC collapsed, and draws attention to the potential impacts of hard-to-reverse climate disturbances more broadly. However, although significant, the numbers presented might be underestimated. The land-use model is based on a statistical model derived from farm yields averaged over the past 30 years, while projections are based on future growing season climates. As weather changes, extremes become more common. A run of bad weather over several years can make farm businesses fail. Likewise, harsher winters, unconsidered here, will present their own challenges for agriculture — whether in accessing land or securing the welfare of livestock in the cold.

Further research on the global impacts of climate tipping points is needed. The collapse of the AMOC would significantly reduce global agricultural productivity[6,7], thus driving food prices up[7,8]. Although rising global prices might seem to improve farm profitability in GB, they would seriously undermine food security in other parts of the world. The transient yield shortfalls that led to food price spikes from 2007 to 2008, and from 2010 to 2011, are perhaps a tiny fraction of the loss that AMOC collapse would cause; yet, these price spikes destabilised economies in food-insecure countries[8] and sparked the Arab Spring. An AMOC collapse might, therefore, significantly reshape the global economy — to the extent that the equilibrium assumptions of this study would simply not apply. But, under those circumstances, collapse of the GB's agricultural economy might be a minor consideration compared to the material threats to our way of life as AMOC-induced risks start to cascade through global systems. ❐

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References

1. Lenton, T. M. et al. *Nature* **575**, 592–595 (2019).
2. Ritchie, P. et al. *Nat. Food* https://doi.org/10.1038/s43016-019-0011-3 (2020).
3. Drijfhout, S. *Sci. Rep.* **5**, 14877 (2015).
4. Caesar, L., Rahmstorf, S., Robinson, A., Feulner, G. & Saba, V. *Nature* **556**, 191–196 (2018).
5. Haskins, R. K., Oliver, K. I. C., Jackson, L. C., Wood, R. A. & Drijfhout, S. S. *Clim. Dyn.* https://doi.org/10.1007/s00382-019-04998-5 (2019).
6. Jackson, L. et al. *Clim. Dyn.* **45**, 3299–3316 (2015).
7. *Extreme weather and resilience of the global food system* (Global Food Security Programme, 2015).
8. Challinor, A. J. et al. *Phil. Trans. Roy. Soc. A* **376**, 20170301 (2018).

Competing interests

The author declares no competing interests.