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Science for Environment Policy

Shifts in cropland and trade patterns could feed the world in 2050 — but no easy solution to future food and water security

How can we grow more crops without taking too much water away from freshwater ecosystems for irrigation? A new study indicates that it is possible to double crop production by 2050[1] without exceeding set limits for water extraction if more crops are grown in regions with higher rainfall and with corresponding shifts in international trade and agricultural management. However, without appropriate safeguards, and if we follow the current business-as-usual scenario, this could come at the ecological cost of converting natural land and forest into cropland. This research provides a 'first-step' in analysing potential trade-offs in the global food-trade-water nexus.

About 40% of the world's food is produced on land that needs irrigating due to insufficient rainwater. Extracting too much water for irrigation comes at an environmental cost, leading to the loss of biodiversity in riverine ecosystems and to less healthy soil that does not receive adequate sediment and nutrients. To curb this loss, environmental flow requirements (EFRs) have been defined for many river systems around the world. These place limits on how much water can be taken from the environment.

The major challenge of balancing food production with water conservation is intensified by the rapidly growing demand for food around the world. Climate change, which is expected to increase water scarcity in the coming decades, complicates matters further.

There are numerous potential ways to reduce the environmental impacts when feeding a growing population such as drastically reducing food waste, changing to sustainable diet[2] and increasing agriculture efficiencies[3], but this study considers how demand for food could be met if crop production was doubled whilst respecting EFRs under a changing climate, and the potential effects of this on land use and global trade. The research is conducted in the context of the UN's Sustainable Development Goals (SDGs); these goals are complex and intertwined, and so require an integrated policy approach[4].

The researchers used an integrated assessment model, GLOBIOM, to analyse the effects of different water policies on global food production, land use and trade, up to the year 2050, focusing on 18 key crops. They assumed: a climate-change scenario of high greenhouse gas emissions (RCP 8.5); an intermediate shared socio-economic pathway[5] (SSP2), which assumes that social, economic and technological trends do not change significantly; that the world's population grows to nine billion; and that dietary intake will rise and converge towards high levels of 3 000 calories per person per day, based on FAO projections (this is an average world level, and would vary by region[6]).

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The total area of cropland would need to expand globally by 17–20% to accommodate this demand, but the share of irrigated versus rain-fed land, as well as its location, would vary depending on water policy.

There are large uncertainties associated with integrated assessment models[7] and the researchers describe their study as a 'first step' in analysing the links between future food security, freshwater use and associated trade-offs, while also recommending further research to test the robustness of their results with other models. It is also important to test different socio-economic pathways.

However, on the basis of this study's results, the researchers conclude that EFRs may lead to the growth of more crops on rain-fed land. If no EFRs are in place, irrigated cropland may [need to] expand by about 80 million hectares (compared with the year 2000), mainly in east and south Asia, the model suggests. As a consequence, water resources could deplete at a high rate in most arid regions. However, if EFRs are introduced, irrigated cropland could shrink by 59 million hectares. The study assumes EFRs are set at 60% of the mean monthly flow during the dry season and 30% during the wet season. The researchers also consider a high EFR threshold with 90% of flow during dry season and 60% during wet season.

To meet EFRs in the future, rain-fed land must expand in place of irrigated land, the study's researchers say. Suitable locations in terms of rainfall are primarily in Latin America and the Pacific Islands. This reallocation of crop farming could lead to a drop in water extraction for irrigation of 38% — or 52% if the high-threshold EFRs are introduced.

However, this could lead to another major ecological cost: the conversion of natural land and forest into cropland, with associated impacts on biodiversity and climate change. The combination of increased food demand and EFRs could see 300 million hectares of natural grassland and forest converted to cropland, with EFRs responsible for 9–21% of this conversion (depending on the land type).

The study also calculates that a doubling of agricultural production could be achieved with a 20% increase in total cropland. This is provided that new agricultural technologies are rapidly taken up (especially in Africa, Asia and Latin America), and agriculture is intensified with effects on biodiversity and climate.

These predicted shifts and expansion in cropland would naturally lead to changes in trading patterns; the model used in this study suggests there would be more exports from water-abundant regions (e.g. Latin America and south-east Asia) to water-scarce regions (such as China and the Middle East)[8]. EFRs alone could lead to increases in bilateral trade of 10–13%. Another 5% increase is needed to compensate for the effects of climate change.

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2. Willett et al., (2019). Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. Lancet 393: 447–492.

3. Springmann, M., et al. (2018). Options for keeping the food system within environmental limits. Nature 562: 519.

4. See, for example, the water-food-energy nexus: www.unwater.org/water-facts/water-food-and-energy/

5. International committee on new integrated climate change (ICONICS): The Shared Socio-Economic Pathways (SSPs): An Overview https://unfccc.int/files/science/workstreams/research/application/pdf/part1_iiasa_rogelj_ssp_poster.pdf

6. See Figure 9.1a, Per capita calorie intake by source, 1961–2050, Trend 9, Nutrition and health: Food and Agriculture Organization of the United Nations (FAO) (2017). The future of food and agriculture – Trends and challenges: http://www.fao.org/3/a-i6583e.pdf

7. Pastor, A. V, et al. (2020). How uncertainties are tackled in multi-disciplinary science? A review of integrated assessments under global change. CATENA 186: 104305.

8. Models used for the FAO Agricultural trade, climate change and food security 2018 report yielded different conclusions on where increased trade would come from.

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Despite the uncertainties associated with integrated assessment models, the research does highlight the inherent challenges in meeting different SDGs. EFRs are not a win-win for the world, it states, as they may lead to the loss of natural areas as well as agricultural production for some regions. However, restoring and/or maintaining EFRs has the likely benefit of replenishing groundwater, increasing freshwater fish stocks, maintaining/restoring wetlands, diluting polluted waters and increasing the biodiversity of fish and riverbank vegetation. EFRs help also to provide the required water to downstream users (i.e. nature and people).

The study also highlights that converting natural areas into cropland releases stored carbon, destroys habitat and alters the hydrological cycle. Further, it argues that agricultural intensification should not come at the expense of water quality (by using extra fertiliser or pesticides, for example).

While EFRs bring many environmental benefits, the researchers say that, other solutions must also be explored to avoid undue compromises on ecosystems. These include crop-diversification in semi-arid areas and growing more drought-resistant crops.

Furthermore, it is important to consider a range of ways to curb the environmental impacts of rising food demand. Separate research[3] highlighted by this study concludes that the biggest contributions to reductions in these impacts are technological improvements in food production and water management (50%), followed by reductions in food waste (20%), shifting diets (20%) and moving to the SSP1 scenario, in which the world takes a more sustainable path (10%).

Overall, the modelling approach used by this study indicates that increased global trade could, in theory, help meet food security and water preservation SDGs. The researchers acknowledge concerns about negative environmental impacts of trade. They also add that trade liberalisation must be used cautiously to stop exporting nations with weaker environmental protection laws from suffering greater environmental impacts.