Tracing the environmental footprints of pesticide use by linking mechanistic environmental modelling to multi-region input-output analysis

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Abstract: Pesticide use has been associated with several detrimental environmental impacts, including loss of biodiversity and disruption of ecosystem functioning and services, such as pollution and natural pest control. As a result, reducing the potential environmental risks of pesticide use has become an essential objective of global agricultural and environmental policies, largely as part of the Sustainable Development Goals 2 (specifically SDG 2.4.1 https://www.fao.org/3/cb1820en/cb1820en.pdf). To achieve this objective, pesticide reduction strategies need to be developed within a comprehensive framework that considers all actors in the food and agricultural supply chain. However, many global-scale footprint studies have missed to account for the environmental pressures exerted by pesticide use.

To fill in this gap, we recently developed a modelling framework to quantify the environmental footprint of pesticide use, starting from the primary producer to final consumer (Tang et al., 2022). We defined the pesticide footprint as the hazard load, which is calculated as the ratio of pesticide mass accumulated in the environment against a toxicity threshold. The degradation efficiency of pesticides can vary spatially depending on hydroclimatic conditions, soil properties, and agricultural practices. Hence, we used a mechanistic and spatially explicit environmental model to estimate the residues of 80 most used pesticides across various cropping systems at the global scale. The environmental model solved for water, gas, and heat flow along a one-dimensional variably-saturated soil column, the diffusion and advection of dissolved chemicals, volatilisation, adsorption, and degradation of pesticides. The model was solved using a general-purpose simulator (BRTSim, https://sites.google.com/site/thebrtsimproject/home), and it was deployed on a three-dimensional grid at a resolution of 0.5˚×0.5˚ with a bounding box of 180˚E – 180˚W and 90˚S – 90˚N. From the model outputs, we calculated the corresponding pesticide hazard loads in each cropping system for each of the crop producing countries. We next linked the pesticide hazard loads estimated by the mechanistic environmental model to a customised multi-region input-output (MRIO) table constructed on the Global Industrial Ecology Virtual Laboratory Platform (Global IELab, https://ielab.info/). The MRIO table traced more than a billion supply chain connections from primary production to the transformation of goods into secondary products and ultimately to end consumption. It captures the complex interactions between sectors across multiple countries.

Using this coupled framework, we unravelled the role of international trading in governing pesticide contamination, and we identified the leakage of pesticide footprint. Our findings showed that about 32% of pesticide hazard loads were traded internationally, and the consumption in developed countries drives the pesticide contamination occurring outside of their own countries. These results highlight the importance of implementing policies to reduce pesticide use while preventing adverse impacts from being transferred to other nations.

REFERENCES

Tang, F.H., Malik, A., Li, M., Lenzen, M., Maggi, F. 2022. International demand for food and services drives environmental footprints of pesticide use. Communications Earth & Environment, 3(1), 272.

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