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Scaling laboratory results with machine learning is no silver bullet to strengthen global (micro)plastic mitigation policy

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Zhu et al. (1) estimated "annual global losses of 4.11 to 13.52% [...] for main crops" due to microplastic (MP) and nanoplastic (NP) pollution and concluded that "These findings underscore the urgency of integrating plastic mitigation into global hunger and sustainability initiatives." These alarming results triggered substantial press echo. However, we challenge the legitimacy of such statements, given the fundamental gaps in i) process understanding of MP/NP interaction with plants in natural systems and ii) data limitations regarding global MP/NP contamination. Drawing on our expertise, we highlight three main points concerning the impact of MP/NP on terrestrial photosynthesis (Fig. 1).

Methodological Bias in Model Training and Upscaling

Most studies included in the meta-analysis investigated physiological mechanisms under controlled conditions, typically growing seedlings in hydroponic setups exposed to high concentrations of pristine MP/NP (Fig. 2). Only 11% of data points stemmed from soil-grown maize, rice, or wheat cultivated to maturity. This raises concerns about training a machine learning-based effect size model and applying it to real-world conditions. Such data neglect natural concentrations of aged NP/MP in soils and the complexity of crop yield drivers, including water and nutrient availability, plant–microbial interactions, and crop genetics.

Undisclosed Plastic Pollution Data

It remains unclear which global soil plastic pollution data were used to estimate the global MP/NP effect size on photosynthesis. The reported effect size closely matches the

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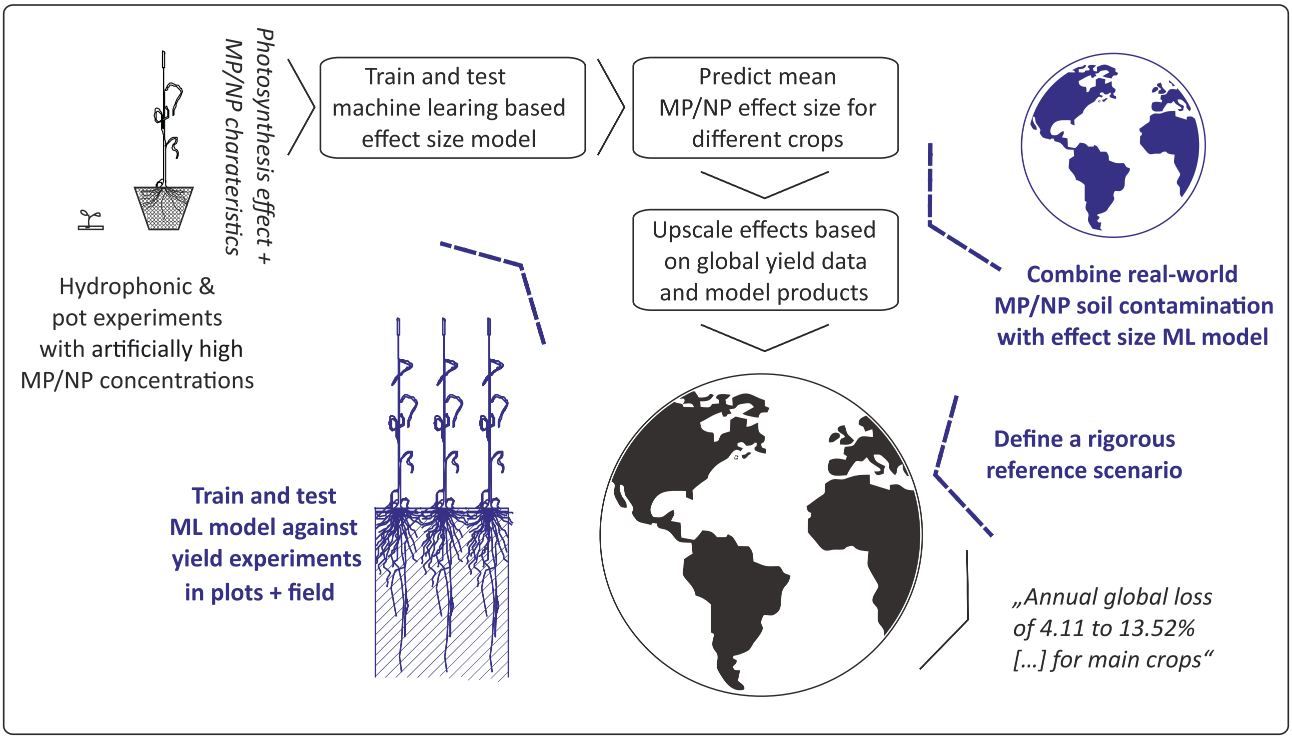

Globe graphic: https://de.vecteezy.com/gratis-vektor/globus

Fig. 1. Schematic view of our understanding of the steps performed in the study (in black). The suggested steps required to overcome the three major shortcomings are highlighted in blue, bold fonts, and dashed arrows.

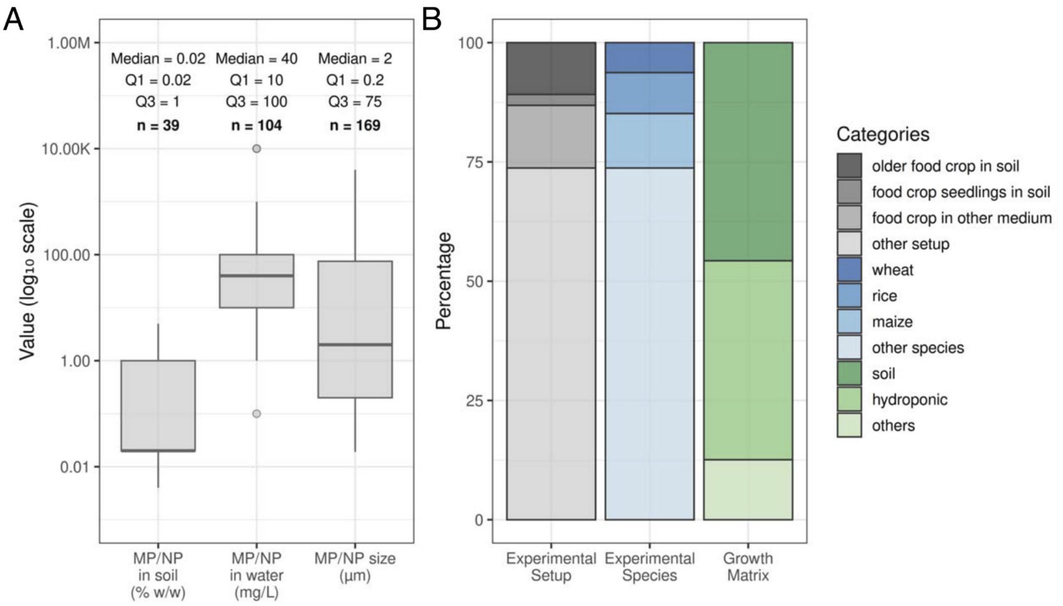

Fig. 2. *A*, statistical summaries of MP/NP concentrations and particle sizes applied in the 34 studies (n = 175 data points) on terrestrial plants of the meta-analysis. *B*, growing conditions and species used in those studies. These results are based on the supplementary information provided by Zhu et al.

result of the meta-analysis (see Point 1). Notably, the scientific understanding of global MP distribution in soils is limited (2). Moreover, Wrigley et al. (3) demonstrated that the choice of analytical methods significantly impacts reported environmental MP concentrations. There are hardly any field data on very small MP (<10 μm) or NP—the dominant particle size used in experimental setups. Only once large scale contamination datasets become available can effect sizes be realistically scaled up globally (Fig. 1).

Modeling Logic and Reference Scenario Issues

Zhu et al. quantified crop yield reductions based on current productivity. However, using present-day parameters implies a misleading reference point. To evaluate a true impact of current MP/NP pollution, a theoretical "zero-plastic" reference scenario would be needed to estimate achievable yields without MP/NP contamination (Fig. 1).

While simple models can offer insights into MP/NP contamination levels, their limitations must be transparently stated (4–6). In contrast, this study applies overly simplistic and partly opaque inferences that suggest coherence but lack scientific integrity. Connecting plastic pollution to global hunger provokes a hyperbolic narrative that prompts media outlets to report fallacies as factual. We advocate for a comprehensive research program – moving from controlled experiments to field trials—to address existing knowledge gaps (see, e.g., important gaps in Fig. 1). Crucially, we strongly encourage the continued publication of incremental findings, even with null results, to advance this emerging research field.

1. R. Zhu *et al.*, A global estimate of multiecosystem photosynthesis losses under microplastic pollution. *Proc. Natl. Acad. Sci. U.S.A.* **122**, e2423957122 (2025).
2. F. Büks, M. Kaupenjohann, Global concentrations of microplastics in soils–A review. *Soil* **6**, 649–662 (2020).
3. O. Wrigley, M. Braun, W. Amelung, Global soil microplastic assessment in different land-use systems is largely determined by the method of analysis: A meta-analysis. *Sci. Total Environ.* **957**, 177226 (2024).
4. J. Crossman, R. R. Hurley, M. Futter, L. Nizzetto, Transfer and transport of microplastics from biosolids to agricultural soils and the wider environment. *Sci. Total Environ.* **724**, 138334 (2020).
5. E. Brandes, M. Henseler, P. Kreins, Identifying hot-spots for microplastic contamination in agricultural soils–A spatial modelling approach for germany. *Environ. Res. Lett.* **16**, 104041 (2021).
6. R. Rehm, P. Fiener, Model-based analysis of erosion-induced microplastic delivery from arable land to the stream network of a mesoscale catchment. *Soil* **10**, 211–230 (2024).