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Successful implementation of global targets to reduce nutrient and pesticide pollution requires suitable indicators

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Indicators proposed for nutrient and pesticide pollution in the current text of the Convention on Biological Diversity's post-2020 Global Biodiversity Framework (GBF) are inadequate for tracking progress and informing policy. We highlight a set of more relevant pollution indicators that would strengthen the monitoring framework of the GBF and discuss conditions for their successful implementation.

Pollution is ranked as one of the five main drivers of biodiversity loss by the Intergovernmental Science-Policy Platform On Biodiversity And Ecosystem Services (IPBES) global assessment[1]. Pollution by pesticides and nutrients, especially nitrogen and phosphorus, are of particular concern. At COP15 in 2022, the Convention on Biological Diversity (CBD)'s Global Biodiversity Framework (GBF) adopted ambitious global targets to at least halve excess nutrients lost to the environment and overall pesticide risk by 2030 (ref. 2). Previous targets set by governments at COP10 of the Convention on Biological Diversity in 2010 sought to "bring pollution down to levels that are not detrimental to ecosystem function and biodiversity". There was little progress in the ensuing decade, so ensuring that targets are met this time around will require considerably stronger commitments from all actors.

Here, we suggest a set of indicators for nutrient and pesticide pollution that would be better suited for monitoring progress and informing policy than those currently proposed in the monitoring framework of the GBF[3,4]. We also argue that there cannot be a one-size-fits-all approach to the adoption of quantitative objectives, because global targets to reduce pollution need to be explicitly adapted to national and geographical contexts. Finally, jointly addressing pesticide and nutrient pollution will require a systemic approach, tackling drivers on an agri-food system level as well as non-agricultural sources.

BOX 1

Indicator types in the GBF monitoring framework

Headline indicators are a small set of high-level indicators that capture the overall scope of the GBF's goals and targets to be used for communication, planning and tracking progress. Countries are requested to provide these indicators in their national reports to the CBD. Component indicators are a larger set of optional indicators to provide complete coverage of all facets of goals and targets. Complementary indicators are optional indicators for thematic or in-depth analysis.

Suitable indicators to define and monitor reduction targets

In a science brief provided to the 'Open-ended Working Group on the Post-2020 Global Biodiversity Framework' in June 2022, we provided scientific background to support negotiations of the GBF pollution target (target 7)[5]. In it, we argued that objectives for reducing nutrient pollution should focus on reducing nitrogen and phosphorus lost to the environment from all sources, and not solely from agriculture. This is because anthropogenic losses of nitrogen and phosphorus to the environment are known to degrade biodiversity, regardless of their source. A focus on agricultural nitrogen and phosphorus input use alone would be too narrow to capture this effect fully. We also argued that objectives for reducing pesticide pollution should focus on reducing risk rather than reducing total applied quantities. This is because certain groups of species are at high risk from very toxic pesticides, even when used in low quantities.

The wording of target 7 of the GBF on pollution reflects these recommendations and is solidly founded in science. However, the high-priority indicators in the current version of the monitoring framework for nutrient pollution (the index of coastal eutrophication potential) and pesticide pollution (pesticide environment concentration) are not well matched to capture the overall scope of the targets, track progress and inform policy[3,4] (Box 1, Fig. 1).

Nutrient pollution. For nutrient pollution, the current headline indicator is the index of coastal eutrophication potential[6]. Although this is an established indicator for marine pollution in the UN Sustainable Development Goals, its narrow focus on the ratios of riverine nitrogen, phosphorus and silicon loading greatly limits its relevance to the broader problem of the effects of nitrogen and phosphorus pollution on biodiversity and ecosystem services. It is also an indicator of nutrient sinks and impacts, rather than sources of nutrient pollution (Fig. 1). There is good evidence that indicators of nutrient sources are

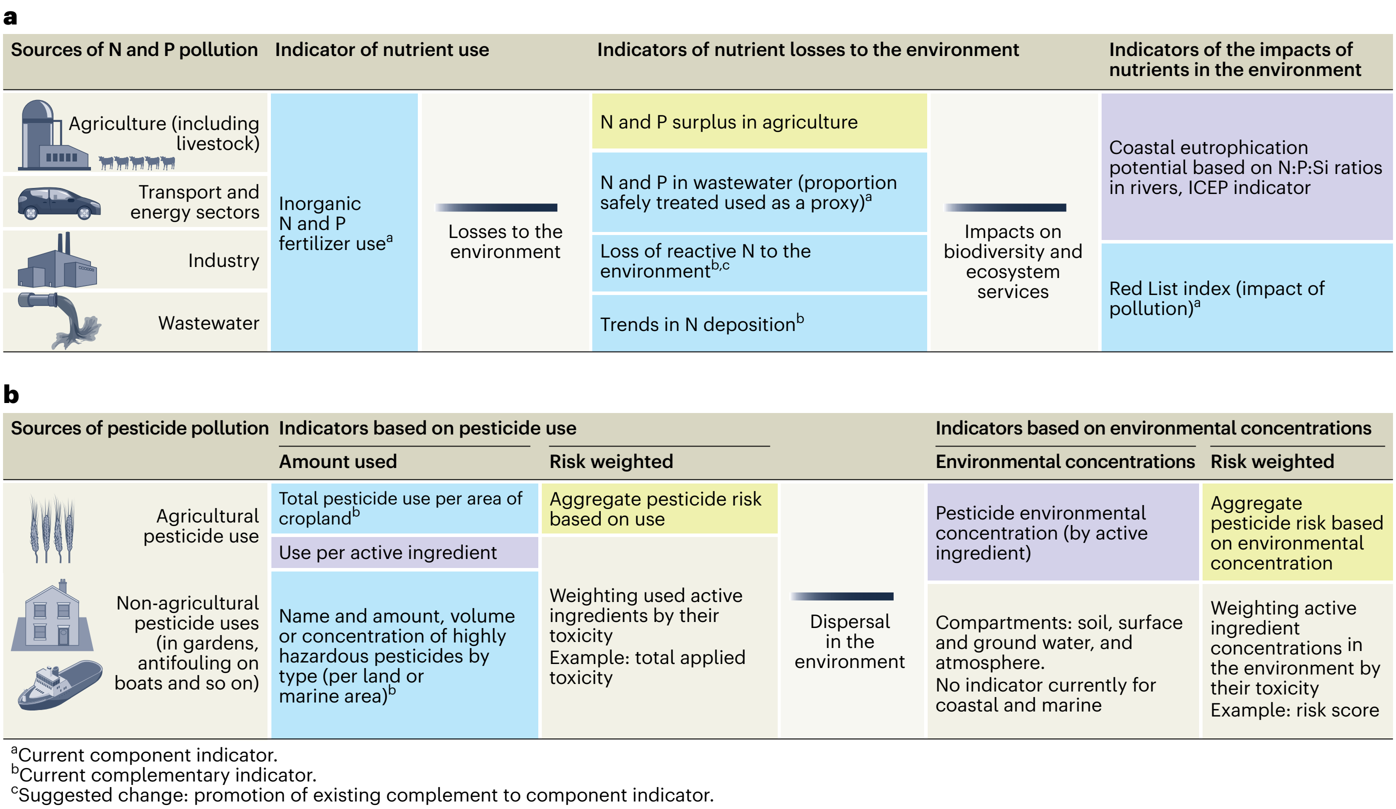

Fig. 1 | Primary sources of pollution and proposed indicators for nutrient and pesticide pollution for the monitoring framework of the GBF. a, Indicators for nutrient pollution. **b**, Indicators for pesticide pollution. Purple, current headline indicators; blue, current component and complementary indicators; yellow, new headline indicators proposed here. The current headline indicator for nutrients is the index of coastal eutrophication potential (ICEP) (Sustainable Development Goal indicator 14.1.1a); for pesticides, it is the pesticide environment concentration (note that pesticide use per active ingredient (also in purple) is necessary to calculate pesticide environment concentration). We suggest that the highest-priority indicators for the GBF should be indicators of nitrogen (N) and phosphorus (P) lost to the environment and risk-weighted pesticide use or environmental concentration. Additional complementary indicators are given in Supplementary Tables 1 and 2. Agriculture is shown topmost in both panels because it is by far the main source of nutrient and pesticide pollution. See ref. 29 for a quantitative ranking of nitrogen and phosphorus sources. Si, silicon.

much more effective in informing and implementing policy to reduce nutrient pollution[7].

We urge the ad hoc technical expert group of the CBD (the CBD AHTEG) and governments to raise the profile of indicators that focus on the sources of nutrients lost to the environment in the GBF monitoring framework. This could include:

- Promoting indicators of agricultural nitrogen and phosphorus surplus (an estimate of excess nitrogen and phosphorus agricultural fertilizer lost to the environment) to headline indicators;
- Complementing these with additional component indicators of the sources of nitrogen and phosphorus pollution, including agricultural nitrogen and phosphorus efficiency (the per cent of nitrogen and phosphorus taken up by crops), nitrogen and phosphorus footprints[8], and gaseous nitrogen emissions from agriculture, transport and industry; and
- Encouraging further development of the component indicator on wastewater treatment so that it can be used to estimate nitrogen and phosphorus pollution.

Together, these indicators would be much better aligned with the objectives of target 7 and provide reasonably comprehensive coverage of nitrogen and phosphorus pollution sources (Fig. 1). These could be completed with a broad range of complementary indicators of nutrient pollution. Agricultural indicators are currently available at national, regional and global levels. For example, agricultural nitrogen and phosphorus efficiency data are directly available from FAOSTAT, and agricultural nitrogen and phosphorus surplus can easily be derived from FAOSTAT cropland nutrient budgets[9] (see Supplementary Table 1 for an overview of available indicators, data sources and applications).

Pesticide pollution. For pesticide pollution, the current headline indicator of pesticide environment concentration does not yet have agreed-upon methodology, so it will be up to the CBD AHTEG to work with partners to guide development[3].

This indicator is intended to be based on the predicted environmental concentration of pesticides, which is one part of the methodology used by Tang et al.[10] to calculate pesticide risk. It uses a modelling approach to estimating concentrations of pesticide active ingredients in the environment, taking into account active ingredient use and physicochemical properties as well as environmental data. It is an important first step in estimating risk for biodiversity but lacks the key final step of converting environmental concentrations of active ingredients into risk (as in Tang et al.[10]). Many governments are not yet willing to report pesticide risk using the risk score as in Tang et al.[10] or total applied toxicity as in Schulz et al.[11], in spite of the recent adoption of the risk score in the environmental performance index[12].

Continued work can solidify the scientific foundations of these indicators and facilitate their wider use. These indicators should also be improved to account for risks related to pesticide mixtures, interactions with other stresses and sublethal effects, among others[13]. However, this should not be used as an argument for delaying the use of the objective and transparent indicators of pesticide risk that are currently available (Supplementary Table 2). Tang et al.[10] highlight the value of analysing pesticide risks on a global level, and countries such as Denmark have demonstrated over the past decade that the regular reporting of pesticide risk is possible without large administrative barriers[14].

Central to the use of pesticide risk indicators will be more precise reporting of pesticide use data on a product or active ingredient level, as there exist large differences in the toxicity of different pesticide active ingredients. We urge the scientific community, the CBD AHTEG and governments to work together to find a common means for reporting pesticide active ingredient- or product-level use, otherwise it will not be possible to compare and collate pesticide risk reported by countries and will leave the door open to using indicators of pesticide risk that do not have a strong scientific basis and are not sufficiently transparent. For example, the collection of active ingredient- or product-level pesticide use data could be coordinated by the Food and Agriculture Organization of the United Nations (FAO), which already collects aggregate country-level pesticide use data.

Translating global targets into national and regional contexts

During the negotiations of the GBF and in our interactions with governments both leading up to and at COP15, many governments were explicitly or implicitly working under the assumptions that (1) nutrient and pesticide pollution targets referred only to agricultural sources and that (2) quantitative objectives would need to be directly translated from global to national scales. Global targets are important communication tools and policy drivers, emphasizing the widespread nature of nutrient and pesticide pollution. However, adapting these targets to national and regional levels is a challenging but necessary task, given the heterogeneous economic, cultural, political and environmental contexts that drive pollution, reduction potentials, trade-offs and their interconnectedness (as described, for example, in refs. 10,15–17).

As one example, Zhang et al.[9] show how differences in national conditions can be taken into account when halving the global agricultural surplus of nitrogen, while simultaneously maintaining food security. Some countries, such as China and the Netherlands, have very high nitrogen surpluses that leave ample opportunity for reducing nitrogen losses from agriculture. However, other countries have insufficient agricultural nitrogen inputs, leading to a loss of soil fertility. Zhang et al.[9] estimate that China could reduce nitrogen surplus by over 70% by 2050 while increasing food production by over 20%, whereas sub-Saharan Africa will need to almost triple its nitrogen inputs (with an ensuing doubling of nitrogen surplus) to improve soil fertility and double food production by 2050. Further, in many countries, large and cost-efficient reductions in nitrogen and phosphorus lost to the environment can be made through improving wastewater treatment and reducing NO_x emissions from transport and industry[18] with important benefits for human health.

Similarly, pesticide use and risks – as well as their drivers, reduction potentials and role in agricultural production – differ markedly, so global numerical objectives should not be applied directly to national levels[10,19].

Reducing trade-offs with other policy goals requires a more holistic governance framework

Addressing nutrient pollution requires a multisector approach that accounts for agricultural and non-agricultural sources such as wastewater and fossil fuel combustion. Similarly, pesticides are not exclusively used in agriculture, but are also used in forestry, aquaculture, municipal spaces and non-professional applications. However, the dominance of agriculture as the main driver of both nutrient and pesticide pollution means that a joint and systemic approach to the governance of pollution from agri-food systems is critical.

The provision of sufficient nutrients to crops, as well as the management of agricultural pests, are vital for food security and farmers' livelihoods[9,20]. To reach reduction targets while minimizing trade-offs with other policy goals such as food security, the reduction of greenhouse gas emissions or soil conservation, policies should not aim to simply cut the provision of agricultural nutrients or pest management[21] but rather to reduce excess nutrients and substitute pesticides with other available pest management options.

Such a transformation is possible while maintaining food security, but will require the identification, provision and implementation of alternatives in close collaboration with food-value chain actors – supported by changes in dietary patterns, reductions in food waste and the optimization of nutrient recycling[9,22–24]. The efficiency–substitution–redesign framework describes such a transformation pathway[25]. In the short term, increased efficiency and substitution can already substantially reduce pollution without compromising food security. Adapted crop management practices, novel technologies and machinery can all improve the efficiency of nutrient and pesticide applications[26]. For example, over the past decade, Denmark has substantially reduced pesticide risks by introducing risk-weighted pesticide taxes, which has led to the use of pesticides with lower risk[14]. In the medium to long term, a more fundamental transformation of farming systems will be required to reach more ambitious reduction targets. This may include organic agriculture[27] or emergent approaches, such as new pesticide-free production systems on large scales[28].

Finally, pesticide and nutrient pollution have for too long been dealt with as separate challenges with separate regulations and policies. Their shared drivers, loss pathways and leverage points for policies in the transformation of agricultural systems create a need for a common, systemic and collaborative approach for their management. Such a collaborative approach could deliver more meaningful and long-lasting pollution reductions, while fostering synergies and reducing potential trade-offs from separate policies[7,28]. This requires collective thinking and bridging between research and stakeholder communities that currently do not sufficiently communicate. There is an urgent need for scientific assessments to help to meet the biodiversity objectives of the GBF, considering heterogenous national conditions and identifying joint pathways for the reduction of nutrient and pesticide pollution. Over the longer term, global assessments such as the upcoming international nitrogen assessment and a pollution assessment by IPBES, which was requested by the CBD at COP15, could provide much of the scientific basis for future policy in this area.

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References

1. IPBES. *Summary For Policymakers Of The Global Assessment Report On Biodiversity And Ecosystem Services* (IPBES, 2019).
2. CBD. *Kunming-Montreal Global Biodiversity Framework* (CBD/COP/15/L.25) (CBD, 2022).
3. CBD. *Monitoring Framework For The Kunming-Montreal Global Biodiversity Framework* (CBD/COP/15/L.26) (CBD, 2022).
4. CBD. *Mechanisms For Planning, Monitoring, Reporting And Review* (CBD/COP/15/L.27) (CBD, 2022).
5. CBD. *Science Briefs On Targets, Goals, And Monitoring In Support Of The Post-2020 Global Biodiversity Framework Negotiations* (CBD/WG2020/4/INF/2/Rev.2) (CBD, 2022).
6. United Nations Environment Program (UNEP). *Understanding The State Of The Ocean: A Global Manual On Measuring SDG 14.1.1, SDG 14.2.1 And SDG 14.5.1* (UNEP, 2021).
7. Kanter, D. R., Chodos, O., Nordland, O., Rutigliano, M. & Winiwarter, W. *Nat. Sustain.* **3**, 956–963 (2020).
8. Dukes, E. et al. *Sustain. Clim. Change* **14**, 415–423 (2021).
9. Zhang, X. et al. *Nature* **528**, 51–59 (2015).
10. Tang, F. H. M., Lenzen, M., McBratney, A. & Maggi, F. *Nat. Geosci.* **14**, 206–210 (2021).
11. Schulz, R., Bub, S., Petschick, L. L., Stehle, S. & Wolfram, J. *Science* **372**, 81–84 (2021).
12. Wolf, M. J. et al. *2022 Environmental Performance Index* (Yale Center for Environmental Law & Policy, 2022).
13. Dietrich, C., Wang, M., Ebeling, M. & Gladbach, A. *Environ. Sci. Eur.* **34**, 16 (2022).
14. Kudsk, P., Jørgensen, L. N. & Ørum, J. E. *Land Use Policy* **70**, 384–393 (2018).
15. de Vries, W., Schulte-Uebbing, L., Kros, H., Voogd, J. C. & Louwagie, G. *Sci. Total Environ.* **786**, 147283 (2021).
16. Schulte-Uebbing, L. F., Beusen, A. H. W., Bouwman, A. F. & de Vries, W. *Nature* **610**, 507–512 (2022).
17. Tang, F. H., Malik, A., Li, M., Lenzen, M. & Maggi, F. *Commun. Earth Environ.* **3**, 272 (2022).
18. Winiwarter, W., Höglund-Isaksson, L., Klimont, Z., Schöpp, W. & Amann, M. *Environ. Res. Lett.* **13**, 014011 (2018).
19. Maggi, F., Tang, F. H. M., la Cecilia, D. & McBratney, A. *Sci. Data* **6**, 170 (2019).
20. Savary, S. et al. *Nat. Ecol. Evol.* **3**, 430–439 (2019).
21. Feuerbacher, A., Luckmann, J., Boysen, O., Zikeli, S. & Grethe, H. *PLoS ONE* **13**, e0199025 (2018).
22. Muller, A. et al. *Nat. Commun.* **8**, 1290 (2017).
23. Möhring, N. et al. *Nat. Food* **1**, 535–540 (2020).
24. Barbieri, P. et al. *Nat. Food* **2**, 363–372 (2021).
25. Pretty, J. *Science* **362**, eaav0294 (2018).
26. Finger, R., Swinton, S. M., El Benni, N. & Walter, A. *Annu. Rev. Resour. Econ.* **11**, 313–335 (2019).
27. Seufert, V. & Ramankutty, N. *Sci. Adv.* **3**, e1602638 (2017).
28. Möhring, N. & Finger, R. *Food Policy* **106**, 102188 (2022).
29. Kanter, D. R. & Brownlie, W. J. *Environ. Sci. Policy* **92**, 1–8 (2019).

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