# *Analysing pesticide use in agriculture for Green Deal policymaking – A Life Cycle Assessment perspective*

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**The European Green Deal includes a reduction target for chemical pesticides of 50% by 2030, indicating that environmental degradation from pesticide application is a major concern for EU policymakers. Here, we investigate pesticide use in Swedish agriculture from a Life Cycle Assessment perspective. In doing so, we aim at providing scientific input for designing efficient policy interventions to reduce environmental degradation from pesticide use in agriculture. We find that:**

- **Pesticide applications should be considered at the Active Substance level with a toxicity-weighted metric when evaluating their environmental impacts.**
- **Considering the environmental benefits and economic costs of measures to reduce pesticide use are essential to ensure efficient policy interventions.**
- **A discussion beyond the 50% reduction target is needed to ascertain what environmental improvements the Green Deal intends to achieve.**

## *Motivation*

As part of the Green Deal, the EU has introduced a 50% reduction target for chemical pesticides use and risk by 2030 in the Farm to Fork strategy. To monitor trends in the environmental and human health risks associated with the use of pesticides, a Harmonised Risk Indicator[1] (HRI) has been developed, which overemphasizes the influence of pesticide quantity over its relative toxicity. In this regard, a policy brief by Global 2000 (Burtscher-Schaden, 2022) demonstrates the bias of the HRI, which associates low-toxicity substances used in greater doses with higher risks. Somewhat counterintuitively this results in some relatively-harmless substances used in organic agriculture being considered worse for the environment than their conventional analogues. Bub et al. (2023) point out similar limitations of the HRI in a peer-reviewed publication focusing on the historical trend of pesticide toxicity in Germany.

Using a broader lens, a recent study examining the historical development of pesticide use in the US reveals that toxicity-weighted use has increased over the last 25 years, despite applications

[1] Simplified from HRI 1 as in the source literature. HRI 2 is not mentioned any further in this document. https://food.ec.europa.eu/plants/pesticides/sustainable-use-pesticides/harmonised-risk-indicators/trends-eu_en

having decreased substantially by weight (Schulz et al., 2021). In other words, pesticides have become more toxic but applied in smaller quantities. In addition, they observe a shift in toxicity for types of non-target organisms affected: it has decreased for vertebrates and increased for pollinators, aquatic invertebrates, and plants. In a similar context of increasing stringency in pesticide regulation, EU policymakers risk creating incentives that advance the reduction goal without achieving higher environmental protection when considering ecosystems broadly. In other words, incentives that inadvertently promote the use of more toxic pesticides in lower amounts, or pesticides that shift toxicity burdens (so called burden shifts) from some types of non-target organisms to others[2].

The aim of this report is to support EU policymakers on shaping sound instruments for the reduction of environmental damage from pesticides. We do this by analysing how pesticide usage in agriculture in Sweden affects freshwater ecosystems using Life Cycle Assessment methods.

## *Method and Data*

As a measure of the potential for pesticide application to degrade the natural environment, we quantify ecotoxicity[3] impacts of pesticides to freshwater ecosystems by combining environmental Life Cycle Assessment (LCA) impact modelling with Swedish data on pesticide use.

LCA impact modelling of pesticide ecotoxicity in this study is based on coupling USEtox and PestLCI models (Gentil et al., 2020). The European Commission actively promotes the use of LCA for decision-making support, and it has endorsed USEtox as the reference method for ecotoxicity impact modelling when applying the Environmental Footprint Method (Sala et al., 2022). Currently, USEtox is limited to ecotoxicological modelling of freshwater ecosystems, though expanding ecotoxicity evaluation under LCA principles to other relevant compartments, such as soil or marine ecosystems is an active area of research (Fantke et al., 2018).

PestLCI quantifies emissions of pesticides from the field into the natural environment. Coupled USEtox and PestLCI modelling provides ecotoxicity-weighted impact potentials for the use of pesticides at the ecosystem scale, which makes it less sensitive to burden shifts between different organism types.

Potential ecotoxicity impacts as modelled in LCA are relative expressions that focus on cause-effect relationships from emissions to damage on non-target organisms. This allows for a systematic comparison of substances based on their potential ecotoxicity damage on the natural environment. However, LCA ecotoxicity modelling does not consider detailed information about the exposed environment, and therefore should be interpreted as neither risks nor actual or predicted impacts, but potential to cause environmental damage (Rosenbaum et al., 2018).

We use pesticide application data from a 2021 survey from Statistics Sweden, together with the Swedish IACS geographical database on crop coverage across the country[4].

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[2] Burden shifts occur when the undesired collateral damage of pesticide application shifts within the natural environment, for instance from one species group to another. On its own, a burden shift does not imply an environmental improvement.

[3] Ecotoxicity refers to ability of chemical pollutants to show a harmful effect on the environment.

[4] Integrated Administration and Control System (IACS), the Swedish version is described in https://jordbruksverket.se/stod/jordbruk-tradgard-och-rennaring/sam-ansokan-och-allmant-om-jordbrukarstoden/block-och-blockareal

## *Key insights*

As a screening tool for pesticide ecotoxicity, our LCA modelling can be useful to identify the largest contributors at different levels of analysis within pesticide application in Swedish agriculture. This can then be translated into science-based input for policymakers to design effective interventions. In our case, we perform a comparative analysis at three different levels that may be relevant for designing interventions to reduce overall ecotoxicity of pesticides in Swedish agriculture, namely Active Substances, crop types, and agricultural regions.

An important limitation of our analysis is that our dataset covers one year (2021) instead of a time-series. This reduces representativity, as pest incidences due to the weather or other factors can vary substantially from one year to the next one. Larger variability is expected for fungicides and insecticides, as herbicides are more often applied as a precaution. In addition, some large shifts from one active substance to another with similar functionality may occur on a one-year basis, if a popular product is discontinued.

This section summarizes the main findings of our comparative analysis in these three levels, together with some illustrative considerations for policymakers.

*Comparing Active Substances*

Figure 1 displays the total use of each Active Substance in Swedish agriculture and their ecotoxicity impact scores for freshwater ecosystems, with a spread of 6 impact points. The highest score of 7 indicates that Alpha-Cypermethrin, an insecticide, was the Active Substance contributing the most to ecotoxicity impacts in 2021, despite being applied in 400 times lower amounts than the most common herbicides. A score difference of 2 points is considered as a significant difference in impact potential[5].

Insecticide use is already highly restricted in Sweden, which is clear from the low number of substances represented in Figure 1 and their limited contribution, on the aggregate, to total ecotoxicity. As an ecosystem-wide method, USEtox takes into account the effect of pesticides on non-target algae and plants. This can explain the comparatively high scores of some herbicides, as these types of organisms have been less in focus in past protection efforts by the regulatory authorities than e.g., vertebrates, or more recently, pollinators.

While the amount (weight) used of an Active Substance is positively correlated to its total environmental impact, differences can still amount to as much as 4 impact points between pesticides with a similar application weight:

- For instance, the herbicides Propaquizafop and Mepiquat chloride show similar application weight, but Propaquizafop has a 3 points higher ecotoxicity score than Mepiquat, considering their total application rates in Sweden for 2021.
- In contrast, the herbicides Propaquizafop and N-Methylmethanamine show similar total impact scores while the latter is applied around 100 times more in weight.

The above examples illustrate the need for considering applications at Active Substance level with a toxicity-weighted metric when evaluating the environmental impacts of pesticides. Consequently, current public reporting of pesticide application by Statistics Sweden (SCB), which is limited to aggregated weights of herbicides, insecticides, and fungicides across several crop types, is insufficient for this purpose.

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[5] Our scores represent the logarithm of USEtox freshwater ecotoxicity impact potential in base 10. This simplification allows an easier communication of the meaning of the score and its uncertainty to a reader unfamiliar to the measure. However, it is important for the reader not to aggregate our score points, as the sum of logarithms is not equal to the logarithm of the sum.

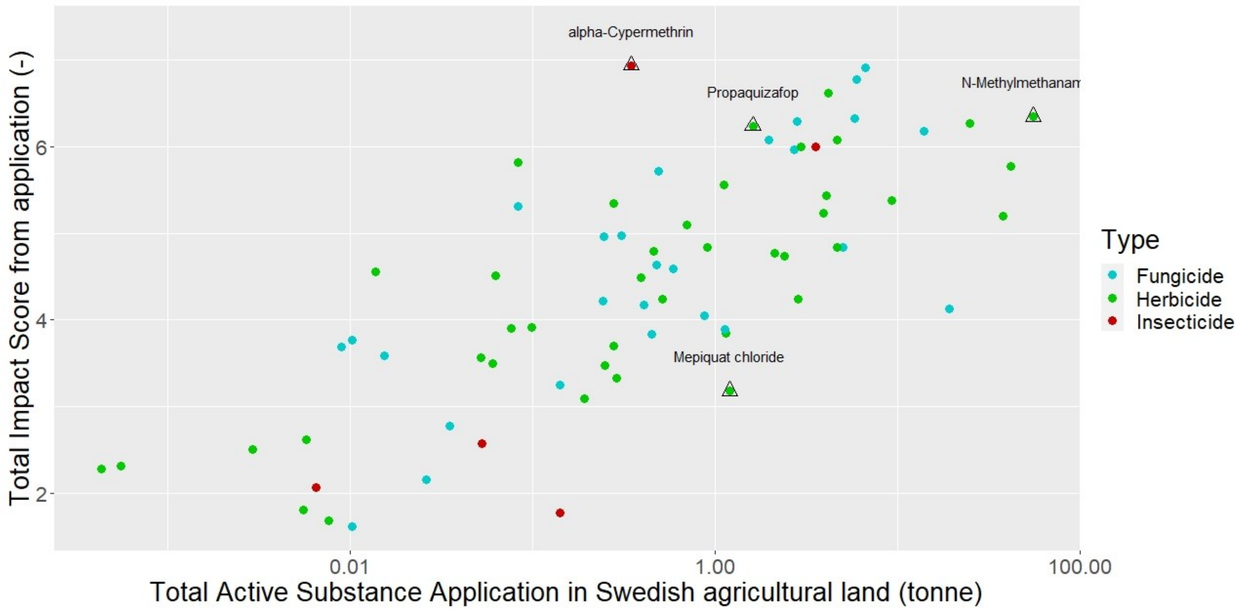


**Figure 1 – Freshwater ecotoxicity scores across active substances based on total application in Sweden.**

*Differences across crops*

Measures to replace the function of pesticides in agriculture or to mitigate their potential to damage the environment may come at considerable economic costs to farmers, for example if they require purchasing new machinery. In addition, these measures may be imperfect substitutes leading to lower yields, and they may bring about other negative environmental consequences, such as degrading soil quality from increased ploughing in replacement of herbicides. Efficient interventions to reduce the environmental impact of pesticide use in agriculture should consider their overall environmental and economic costs and benefits to society.

Figure 2 illustrates some factors that may influence the efficiency of measures, namely ecotoxicity impacts on freshwater ecosystems from six representative crops, together with their economic value at harvest (sales revenue), and their total cultivated area in Sweden. All values are expressed as contributions to the aggregated total for all six crops in Sweden. Prices at farm gate and average yield data have been obtained from the Swedish Board of Agriculture[6].

Our calculations show that:

- Winter wheat is the most common of all crops, followed by spring barley and rapeseed. Sugar beets, field beans and potatoes represent very small fractions of arable land use.
- Potatoes, rapeseed and sugar beets have a comparatively higher ecotoxicity score per hectare than other crops, as their contribution to ecotoxicity is higher than to arable land. Winter wheat still contributes the most to overall ecotoxicity impacts because of its extensive cultivation, but high value crops tend to perform worse in terms of impacts per hectare.
- The contribution of potatoes to total economic value is much higher than their land share. Potatoes give the highest economic value per hectare, but also the highest negative environmental impact.

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[6] Except for the price for beans, which is taken from Västra Götaland Länsstyrelsen, Bidragskalkyler för ekologisk produktion 2022

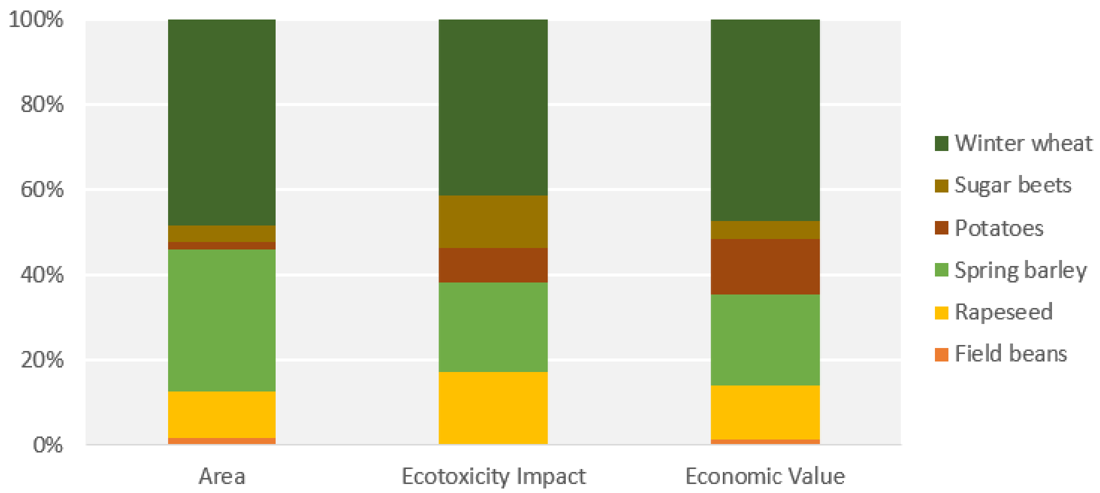


**Figure 2 – Contribution of six major crops to cultivated area, ecotoxicity impacts, and economic value of harvest. All values are expressed as a share of the aggregated total for each crop.**

There is a wide array of measures that can be deployed at the field level to mitigate pesticide impacts on the environment, such as precision application, buffer zones, genetically modified crops, and organic practices. However, factors such as economic return to farmers or crop coverage can influence the suitability of any specific measure. Considering area coverage, ecotoxicity score and economic value of harvest by crop can contribute to designing efficient policy interventions. For example:

- Precision application of pesticides (which requires specialized machinery) and buffer zones may be more cost-effective to reduce potential impacts if used in crops with lower area coverage but relatively higher environmental impact scores, such as potatoes, rapeseed, and sugar beets.
- Organic farming subsidies in Sweden go mostly to grass leys, accounting for approximately 70% of the subsidized area in 2015[7] according to the Swedish Board of Agriculture. While leys may contribute positively to environmental protection by enhancing certain ecosystem services, the ecotoxicity score of conventional leys in Sweden is very low[8]. Therefore, organic farming subsidies are not likely to be particularly cost-effective in reducing the environmental impact from pesticide application in Sweden.

In addition, it is important to acknowledge that well-functioning agricultural systems provide agricultural commodities that are essential to society, particularly food. Crop displacement to third countries and associated environmental externalities may arise if stringent environmental regulations within the EU lead to production declines within its territory. In fact, avoiding such effects from interventions striving towards the Green Deal goals has been identified as one of its main challenges (Fuchs et al., 2020).

[7] Statistics from the Swedish Board of Agriculture: https://jordbruksverket.se/om-jordbruksverket/jordbruksverkets-officiella-statistik/jordbruksverkets-statistikrapporter/statistik/2020-06-18-jordbruksstatistisk-sammanstallning-2016. Årtal korrigerat från 2016 den 6 november 2023.

[8] Data for grass leys showed almost no use of chemical pesticides across Sweden, other than for application of glyphosate (Roundup). While grass leys are not among the representative crops plotted in Figure 2, we consider their ecotoxicity score per hectare as virtually nil.

*Regional analysis*

Impact scores aggregated per yield region and normalized in area (to facilitate a comparison across different sized regions) provide an overview of source potential impacts by yield region, which is relevant to identify the main drivers of pesticide ecotoxicity potential from Swedish agriculture on freshwater ecosystems (Figure 3, right). This information can be used to adapt policy interventions to target specific yield regions, as a means to improve their cost-effectiveness.

Yield regions with higher presence of intensive arable farms, such as those in the production area Götalands Södra Slättbygder, present the highest ecotoxicity impact potential, indicating that they are significant drivers of environmental pressures from pesticides. Regions associated with higher presence of cattle and mixed crop and livestock enterprises, such as in Jönköping County, show lower impact potentials.

Analogous ecotoxicity scores aggregated by hydrological basin provide a relevant evaluation unit for ecotoxicity damage on freshwater ecosystems because physical constraints make them considerably tight compartments for waterborne pollution (Figure 3, left). In addition, the environmental quality of hydrological basins is a relevant goal from the European Water Framework Directive.

An evaluation of scores by hydrological basins shows a clear south/north divide, with basins in the south showing scores 6 to 8 points higher than in the north. This signals that reductions in northern regions could be inconsequential towards achieving a toxicity-weighted reduction target set at a national level, and measures with a strong bias towards promoting reduction in the south would be more cost-effective. However, an important limitation of our study is that it does not consider the current state of ecosystems in the basins – it may be more beneficial to reduce ecotoxicity by the same amount in the north than in the south if the north ranks comparatively higher in biodiversity values that society wants to preserve.

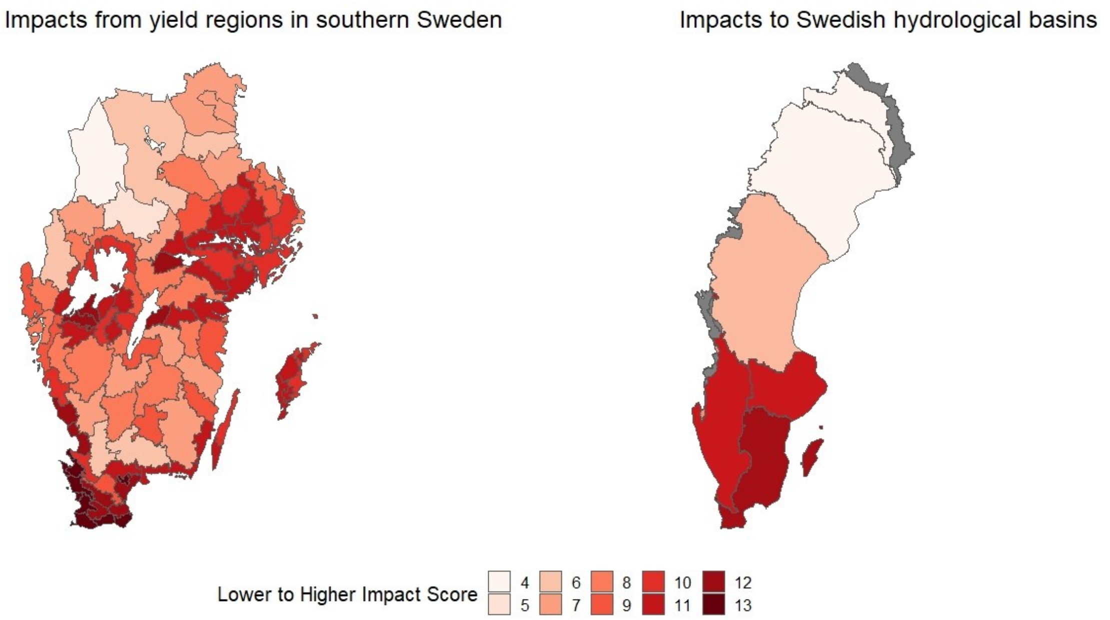


**Figure 3 – Impact scores per emitting yield region (left) and receiving hydrological basin (right).**

## *Concluding remarks*

This work aims to provide scientific input for policymakers in the task of designing interventions to reduce the environmental impacts of pesticide application in Sweden. To do so, we model pesticide ecotoxicity quantitatively according to LCA methodology, and the we perform a comparative analysis of the results for three different levels of analysis, namely Active Substances, crop types, and regions.

The following concluding remarks summarise our findings:

- **Pesticide applications should be considered at the Active Substance level with a toxicity-weighted metric when evaluating their environmental impacts.**

The EU´s HRI shows a tendency to overemphasize the role of application weight over that of substance toxicity, and thus to promote burden shifts between different types of organisms. EU policymakers therefore risk creating incentives that advance the pesticide reduction goal without achieving higher environmental protection.

In addition, there is currently no public reporting of the application of active substances by crop type and agricultural regions. This makes it difficult to evaluate the environmental impact of pesticide use. Public data would enhance the possibilities to perform risk or impact assessment alternatives to the HRI. This, in turn, would reduce the risk of creating toxicity blind-spots and moving towards improved environmental protection by means of the pesticide reduction goal, and put Sweden at the forefront of pesticide data availability.

- **Considering the environmental benefits and economic costs of measures to reduce pesticide use are essential to ensure efficient policy interventions.**

Factors such as area coverage, ecotoxicity score and economic value of the harvest of different crops can contribute to designing efficient policy interventions. Measures that are effective at mitigating the environmental damage of pesticides by reducing off-field emissions, such as buffer zones, can increase cost-effectiveness when targeting high-value crops with higher ecotoxicity scores. Economic subsidies for organic farming in Sweden are likely to be ineffective in reducing pesticide ecotoxicity impacts because they are mostly given to grass leys.

It is also important to acknowledge the environmental externalities that may arise if stringent environmental regulations within the EU lead to production declines with subsequent imports from countries with less regulated production.

- **A discussion beyond the 50% reduction target is needed to ascertain what environmental improvements the Green Deal intends to achieve.**

Sweden´s agricultural regions are very heterogeneous in agricultural conditions and structure, and pesticide application intensities, as well as landscape and biodiversity values. While national and regional targets are not mutually exclusive, regional actions and targets may bring different changes and hence effects than national ones. A discussion beyond the national 50% pesticide reduction target is needed on what environmental improvements are to be achieved and which role different regions will play in achieving them. As shown here, simply focusing on reducing the quantity of pesticides by weight is likely to be extremely cost-ineffective for improving environmental quality, which presumably, is the overriding reason for wanting to reduce pesticide use in the EU in the first place.

## *References*


Bub, S., Wolfram, J., Petschick, L. L., Stehle, S., & Schulz, R. (2023). Trends of Total Applied Pesticide Toxicity in German Agriculture. *Environmental Science & Technology*, *57*(1), 852-861. https://doi.org/10.1021/acs.est.2c07251

Burtscher-Schaden, H. (2022). *HRI 1: A RISK INDICATOR TO PROMOTE TOXIC PESTICIDES?* https://www.organicseurope.bio/content/uploads/2022/06/GLOBAL2000_HRI-1_final_28022022.pdf?dd

Fantke, P., Aurisano, N., Bare, J., Backhaus, T., Bulle, C., Chapman, P. M., De Zwart, D., Dwyer, R., Ernstoff, A., Golsteijn, L., Holmquist, H., Jolliet, O., McKone, T. E., Owsianiak, M., Peijnenburg, W., Posthuma, L., Roos, S., Saouter, E., Schowanek, D., . . . Hauschild, M. (2018). Toward harmonizing ecotoxicity characterization in life cycle impact assessment. *Environmental Toxicology and Chemistry*, *37*(12), 2955-2971. https://doi.org/10.1002/etc.4261

Fuchs, R., Brown, C., & Rounsevell, M. (2020). Europe's Green Deal offshores environmental damage to other nations. *Nature*, *586*(7831), 671-673. https://doi.org/10.1038/d41586-020-02991-1

Gentil, C., Basset-Mens, C., Manteaux, S., Mottes, C., Maillard, E., Biard, Y., & Fantke, P. (2020). Coupling pesticide emission and toxicity characterization models for LCA: Application to open-field tomato production in Martinique. *Journal of Cleaner Production*, *277*, 124099. https://doi.org/https://doi.org/10.1016/j.jclepro.2020.124099

Rosenbaum, R. K., Hauschild, M. Z., Boulay, A.-M., Fantke, P., Laurent, A., Núñez, M., & Vieira, M. (2018). Life Cycle Impact Assessment. In M. Z. Hauschild, R. K. Rosenbaum, & S. I. Olsen (Eds.), *Life Cycle Assessment: Theory and Practice* (pp. 167-270). Springer International Publishing. https://doi.org/10.1007/978-3-319-56475-3_10

Sala, S., Biganzoli, F., Mengual, E. S., & Saouter, E. (2022). Toxicity impacts in the environmental footprint method: calculation principles. *The International Journal of Life Cycle Assessment*, *27*(4), 587-602. https://doi.org/10.1007/s11367-022-02033-0

Schulz, R., Bub, S., Petschick, L. L., Stehle, S., & Wolfram, J. (2021). Applied pesticide toxicity shifts toward plants and invertebrates, even in GM crops. *Science*, *372*(6537), 81-84. https://doi.org/10.1126/science.abe1148