US$ 219 billion risk from pesticides for US food retailers

Financial and environmental risks related to pesticide use on four key crops

Gerard Rijk, Barbara Kuepper

10 December 2024

About this report

This report has been commissioned by Friends of the Earth U.S.

About Profundo

With profound research and advice, Profundo aims to make a practical contribution to a sustainable world and social justice. Quality comes first, aiming at the needs of our clients. Thematically we focus on commodity chains, the financial sector and corporate social responsibility. More information on Profundo can be found at www.profundo.nl.

Authorship

This report was researched and written by Gerard Rijk and Barbara Kuepper. Correct citation of this document: Rijk, G., B. Kuepper and J. Arnould (2024, December), *US$ 219 billion risk from pesticides for US food retailers,* Amsterdam, The Netherlands: Profundo.

Front page cover photograph by Ankith Choudhary – Unsplash.

Acknowledgements

The authors thank Kendra Klein, Pierre Mineau and Charles Benbrook for their valuable contributions. Pierre Mineau, PhD, is Principal Senior Scientist at Pierre Mineau Consulting and Adjunct Professor at the Department of Biology, Carleton University. Charles Benbrook, PhD, is the director of Benbrook Consulting Services. Kendra Klein, PhD, is Deputy Director of Science at Friends of the Earth.

Disclaimer

Contents

List of figures

List of tables

Abbreviations & Definitions

CO_2e	Carbon Dioxide Equivalent = Greenhouse Gas (GHG)
Costs versus Value	The word 'costs' is often used for annual numbers and risks, and the word 'value' is often used for DCF calculation or a multiple-year period of damages and risks
CRR	Chain Reaction Research
DCF	Discounted Cash Flow. The methodology recalculates values realized in the future to the present through the use of a discount factor
Enterprise value	Market capitalisation plus debt minus cash
Equity value	Market capitalisation (see below) - it represents what the owners of a company would receive if they sold the business and paid off all debts
ETS	Emission Trading System
GDP	Gross Domestic Product
GE	Genetically Engineered
Gross profit	Revenues minus costs of goods sold
HHP	Highly Hazardous Pesticide
Market capitalisation	Number of shares x share price
Market value	Market capitalisation (see above)
mt	Metric ton
Net(-)debt	Gross debt minus cash
PAN	Pesticide Action Network
$SCCO_2$	Societal Costs of Carbon Dioxide
Stranded assets	Assets that have become redundant due to a change in regulation, or structural change in market demand
Turnover	Sales, or proceeds of all the products sold
VAT	Value Added Tax
Value	Often meaning a sum of damages over multiple years or DCF value
Value-at-risk	The value that might be lost - it quantifies the extent of possible financial losses over a specific time frame

Key Findings

This report focuses on the whole US food retail sector, not on specific companies. This means that risks and impacts will vary from company to company. Note that the numbers reported in the key findings represent the high-end scenario, for the low-end scenario, see Table 1.

- The US food retail sector faces up to US$ 219 billion in financial, climate, and biodiversity costs and risks for the period 2024-2050 stemming from the use of pesticides in the domestic production of just four crops — soy, corn, apples, and almonds.
- This represents 32% of US food retailers' current equity value. In the high-end scenario, a value equal to nearly one-third of the total stock available to shareholders would be lost if food retailers were held fully accountable for all risks associated with pesticide use in the domestic production of soy, corn, apples, and almonds.
- The use of pollinator-harming pesticides on the four target commodities is associated with biodiversity risk valued at a staggering US$ 34.3 billion for the US food retail sector between now and 2050. This is a conservative estimate, as it is impossible to account fully for the damage done to ecosystem services and nature's intrinsic value by toxic pesticides.
- Climate damage costs for US food retailer sales of products containing soy, corn, apples, and almonds can be associated with US$ 4.5 billion for the period 2024-2050. This is based on CO2 equivalent emissions associated with the production and use of pesticides used on these crops. This is a significant underestimate. It does not account for GHG emissions associated with agricultural production (e.g., fuel for farm machinery and volatilization of applied pesticides, which can create potent GHGs) nor does it account for pesticides' harm to soil ecosystems, which are the basis of soil carbon sequestration as well as farmers' resilience to climate change.
- While the commodity value of the four target crops in this report is approximately 10% of the value of US food retailers' food and beverage revenues, they are embedded in products that generate an estimated 55% of US food retailers' sales in food.
- Pesticides used on these four crops account for approximately 50% (484 million pounds) of all pesticides used in agriculture in the US annually. Soy and corn account for the bulk of the volume with approximately 465 million pounds or 46% of all pesticides used.
- A significant amount of these pesticides are chemicals classified as highly hazardous to human health and/or the environment. The highly hazardous pesticides applied to corn, soybeans, almonds, and apples account for 29% of total US pesticide use or 293 million pounds annually.
- Neonicotinoids are widely used in the supply chains of US food retailers and are of particular concern. Neonicotinoids are a class of systemic insecticides that are highly persistent in the environment and acutely toxic to insects.
- This report significantly underestimates the true, total harm done by toxic pesticides and the financial and environmental risks associated with that harm.
- US food retailers must urgently address the use of harmful pesticides in their supply chains to respond to the intertwined biodiversity and climate crises we face. To do so, food retailers must support the expansion of organic farming in the US and beyond and support non-organic growers to eliminate use of pollinator-harming and highly hazardous pesticides by shifting to ecological farming methods that reduce the need for pesticides in the first place. Companies must also make agrochemical input reduction a central pillar of all "regenerative" and "climate-smart" agriculture initiatives.

Conclusions and recommendations

The converging crises of biodiversity loss and climate change are increasingly costly to the global economy. The food sector is among the most vulnerable to the impacts of these crises and is also a major contributor. Pesticides — a term that includes insecticides, herbicides, and fungicides — contribute directly to both crises. They are responsible for widespread harm to biodiversity, including pollinators, which are required to maintain a third of our food supply, and soil organisms, which are central to building healthy soil, sequestering carbon, conserving water, and improving farmers' climate resilience.[1] Moreover, pesticides are derived from fossil fuels, the production and use of which are significant drivers of agriculture-related greenhouse gas emissions.[2] Pesticides also pose devastating risks to human health along the supply chain, from consumers to the farmers, farmworkers, and rural communities that are on the frontlines of exposure.[3]

This report investigates US food retailers' financial risks — including operational, financing, and reputation risks — and externalized environmental costs to biodiversity and the climate associated with the use of agricultural pesticides in their supply chains. It builds on a previous analysis of the material risks pesticides pose to the business model of pesticide giant, Syngenta.[4] Given the vulnerability of food production to environmental disruption, these risks are significant not only for the companies themselves but for the US food supply. These findings signal the magnitude of harm associated with pesticide use, but they are a profound underestimate. It is impossible to assess the true scope of the harm wrought by toxic pesticides in our food system. This is partly due to the complex nature of the issue but also due to the inherent limitations of trying to express the intrinsic value of a stable climate, biodiversity, and human life and health purely in terms of economic value.

Our findings indicate that the US food retail sector faces up to US$ 219 billion in financial, climate, and biodiversity costs and risks between now and 2050 from the use of pesticides in the domestic production of just four crops — soy, corn, apples, and almonds (see Table 1). A value equal to nearly one-third (32%) of US food retailers' current equity value — the total value of stock available to shareholders — would be lost if food retailers were held fully accountable for the risks associated with pesticide use in domestic production of these crops (see Table 2).

These four crops chosen for the analysis are embedded in products that generate 55% of US food retailers' sales in food. Apples and almonds are among the top crops sold directly to consumers. Corn and soy are the top crops processed into packaged foods (e.g. in the form of corn starch, corn syrup, soy lecithin and oil) and livestock feed for meat, dairy, and eggs. The scope of pesticide use on these four crops accounts for approximately 50% of all pesticides used on cropland in the US: 484 million pounds annually. Corn and soy account for the bulk of the volume. A significant amount of these pesticides are chemicals classified as highly hazardous to human health and/or the environment (see Table 3).

Externalized environmental risks

The connection between pesticides and biodiversity loss is increasingly recognized in the financial sector, as evidenced by pesticide guidance in emerging global frameworks on biodiversity-related disclosures and targets, including the Kunming-Montreal Global Biodiversity Framework, Science-Based Targets Initiative, Task Force on Nature-Related Financial Disclosures, and Global Reporting Initiative. However, there is a great deal more work that needs to be done to educate companies on the intersection of agrochemicals and climate change. Both pesticides and synthetic fertilizers, ubiquitous in conventional agriculture, have severe climate-related impacts.[5] Our report provides critical data to begin to quantify these impacts for US food retailers.

Biodiversity

According to the World Economic Forum, over half of global GDP — roughly $44 trillion — depends on biodiversity and healthy ecosystems.[6] Yet biodiversity is being lost at an extinction rate that is already 1,000 times the natural background rate, and this is projected to increase to 10,000 times the natural background rate in the future.[7] This catastrophic level of biodiversity loss not only threatens the survival of species and ecosystems but also undermines essential services such as clean air, water, and food production.[8]

One of the leading biodiversity-related risks for food retailers is the massive decline of pollinators and other beneficial insects that underpin food production. Pollinators contribute up to $577 billion to the global economy annually.[9] Scientists warn that 40% of invertebrate pollinator species face extinction, and food costs are predicted to rise as pollinator populations decline.[10] The loss of pollinators is a proxy for larger trends in insect declines. Scientists have concluded that 40% of the world's insect species face extinction in coming decades and warn of "catastrophic ecosystem collapse" if we don't take decisive action.[11] Insects, both above and below ground, are the basis of the food webs that feed us and are essential to maintaining a liveable planet.

We found that the **use of pollinator-harming pesticides on corn, soy, apples, and almonds is associated with biodiversity risk valued at a staggering US$ 34.3 billion for the US food retail sector between now and 2050.** This is a conservative estimate, as it is impossible to account fully for the damage done to ecosystem services and nature's intrinsic value by toxic pesticides.

Among the many pesticides that contribute to biodiversity loss, a class called neonicotinoids is particularly alarming. Since the introduction of neonicotinoids in the 1990s, US agriculture has become 48 times more toxic to insects, including pollinators.[12]

Climate

Greenhouse gas (GHG) emissions associated with the food sector represent about a third of all anthropogenic sources worldwide.[13] Moreover, the sector is also highly vulnerable to the effects of droughts, heat waves, floods, and infestations of invasive pests and diseases as climate change unfolds. For climate change, end-of-the-century damages are expected to run in the tens of trillions of dollars per year, representing an average GDP loss of 19.6% by 2050 and 63.9% by 2100 in the world's most vulnerable countries under current climate policies.[14]

The same pesticides that threaten biodiversity above ground also threaten the soil life that is the heart of regenerative agriculture. Healthy, living soil is the basis of soil carbon sequestration, water conservation, and farmers' resilience to the extreme weather events that come with climate change. It is, therefore, the foundation of sustainable food systems that allow us to feed ourselves and future generations. Research shows that pesticide use is associated with widespread harm to soil microorganisms and invertebrates and is incompatible with healthy soil ecosystems.[15,16]

Pesticides are also largely petroleum-based chemicals that are energy-intensive to produce. According to this analysis, the **CO_2 equivalent emissions associated with the production and use of pesticides result in US$ 4.5 billion in externalized climate costs linked to food retail sales of products containing soy, corn, apples, and almonds between now and 2050**. This is a significant underestimate. It does not account for GHG emissions associated with agricultural production (e.g., fuel for farm machinery or volatilization of applied pesticides, which can create potent GHGs). Nor does it account for pesticides' harm to soil ecosystems, which scientists have indicated is significant.

Table 1 Summary: financial risks of pesticides for US food retailers*

US$ million	Annual LOW	Long-term value effect** LOW	% of total	Annual HIGH	Long-term value effect** HIGH	% of total
Operational + financing + reputation						
Revenue-at-risk/gross profit-at-risk	1,670	18,537	33%	3,340	37,074	17%
Financing risk	191	2,116	4%	1,525	16,930	8%
Reputation risk		23,747	42%		126,389	58%
External environmental risks						
Climate damage	12	161	0%	335	4,529	2%
Pollinator-harming/ecosystem risk	1,053	11,687	21%	3,090	34,303	16%
Total value-at-risk (US$ million)	**2,925**	**56,249**	**100%**	**8,291**	**219,224**	**100%**

Source: Profundo, based on data summarized in this report.
Note: * For four commodities: soy, corn, apples, almonds; ** Multi-year risk value until 2050.

Table 2 Total risks versus US food retail sector's gross profit and equity value

US$ million	Data	Annual LOW	Long-term value effect** LOW	Annual HIGH	Long-term value effect** HIGH
Operational, financing, reputation risk		1,861	44,400	4,865	180,392
External risk – excluding dietary		1,065	11,849	3,426	38,832
Total profit/value-at-risk (US$ billion)		2,925	56,249	8,291	219,224
Gross profit US food retail sector (2021)	183,300				
Equity value (17 July 2024)	698,733				
Net-debt	76,261				
Enterprise value (EV) US food retail sector	765,993				
Operational/financing/reputation risk as %*					
Total risk as % of gross profit		1.0%		2.7%	
Total DCF value-at-risk as % of equity			6.4%		26.2%
Total DCF value-at-risk as % of EV			5.8%		23.6%
Total net-debt at risk			0.0%		0.0%
Operational/financing/reputation risk + external risk as %*					
Total risk as % of gross profit		1.6%		4.5%	
Total DCF value-at-risk as % of equity			8.2%		31.8%
Total DCF value-at-risk as % of EV			7.3%		28.6%
Total net-debt at risk			0.0%		0.0%

Source: Profundo.
Note: * Means including financing risk and reputation risk, although the annual costs do not include reputation damage. Reputation risk has a longer-term impact and is thus a multi-year 'value' and is compared to the equity and enterprise value; ** Multi-year risk value until 2050.

Putting pesticides on the ESG agenda

The results of our analysis show that, to meet their environmental, social, and governance (ESG) goals around biodiversity and climate, food retailers must take immediate action to phase out the use of toxic pesticides in their supply chains. Since 2018, thirteen major U.S. food retailers ranked on Friends of the Earth's Bee-Friendly Retailer Scorecard have established policies aimed at reducing pesticides in their supply chains, signaling a significant shift taking place across the sector.[17] Yet, despite this promising industry trend, efforts fall far short of what is needed to protect pollinators, people, and the planet from toxic pesticides.

Market leadership on this issue is critical, especially considering the failure of the US government to adequately regulate the environmental and health risks of industrial agriculture overall and of pesticides in particular. The US Environmental Protection Agency (EPA), under the influence of the pesticide industry, has regularly failed to follow the best available science and protect people and the environment from toxic pesticides.[18] U.S. agriculture uses more than 1.1 billion pounds of pesticides annually, representing approximately 15% of total global pesticide usage.[19] The EPA allows the use of 85 pesticides banned in other countries and continues to approve new pesticide products containing ingredients widely deemed to be highly hazardous.[20]

Food retailers have enormous market power and influence over the food system. The top six companies, Walmart, Costco, Kroger, Target, Albertsons, and Ahold Delhaize, command an estimated US$ 628 billion in annual grocery sales, representing 78% of the US$ 805 billion food retail sector.[a] Retailers have multiple levers to drive positive change toward a more sustainable, resilient, and economically stable food system – what they choose to ban or place on their shelves, how they shape their own brand product lines, whether they invest in supporting suppliers to shift to ecological farming approaches, and lobbying for policies that support organic and other forms of ecologically regenerative agriculture.

We recommend three overarching strategies to achieve that goal:

1. **Invest in Integrated Pest Management (IPM) and other ecological approaches in non-organic supply chains**

   Integrated Pest Management (IPM) is a framework that minimizes pesticide use and risks. Robust approaches to IPM rely on inspection and monitoring to detect and correct conditions that could lead to pest problems; guide farmers to implement biological, cultural, and physical strategies to prevent and suppress pest populations, such as rotating crops, planting resistant crop varieties, and fostering beneficial insects; use chemical controls only as a last resort and only when economically justified; and assess pesticide risks and prioritize the lowest risk options.

   Four major US food retailers — Walmart, Kroger, Whole Foods, and Giant Eagle — have established pollinator and biodiversity policies requiring all fresh produce suppliers to adopt IPM practices and to verify compliance using a vetted list of third-party certifications.[21] These are important first steps that should be widely adopted across the sector. Yet IPM alone will not be sufficient to achieve the needed reductions in pesticide use.

2. **Increase organic offerings, invest in the expansion of organic supply chains, and recognize organic as regenerative**

   Organic agriculture is the gold standard for pesticide reduction and is backed by a robust third-party certification governed by federal law. The organic certification prohibits over 900 synthetic pesticides allowed in conventional agriculture. A growing body of science highlights organic as a leading form of regenerative agriculture for its ability to build healthy soil,

---

[a] Source: Profundo, based on 2022 sales data from Bloomberg, US Census, company annual reports.

conserve water, enhance farmers' resilience to droughts and floods, protect biodiversity, and reduce greenhouse gas emissions.[22]

In the US, organic sales have increased by an average of 8% each year over the past decade, reaching nearly US$ 70 billion – or over 6% of total food sales.[23] Food retailers committed to addressing biodiversity loss and climate change in their value chains can invest in expanding organic offerings by providing financial, technical, and other forms of support to organic suppliers or suppliers in transition to organic; support public policies aimed at expanding organic production; and recognize organic certified and Regenerative Organic Certified as important parts of their regenerative agriculture strategies.

3. **Make agrochemical reduction a central pillar of regenerative agriculture initiatives**

   Many of the largest US food retailers, including Walmart, Costco, Target, and Ahold Delhaize, are investing in 'regenerative agriculture' as a means to achieve climate-related goals.[24] Yet, like the term 'sustainable,' regenerative agriculture has no clear definition. While some approaches are robust, others are well-intentioned but lack scientific merit, while others are greenwashing. Robust definitions of regenerative agriculture describe a holistic farming approach that challenges the status quo of conventional agriculture and its degenerative impacts on the environment and human health to achieve soil health, biodiversity protection, climate resilience, water conservation, increased soil carbon sequestration, and human well-being.

   This report contributes to a strong body of data showing that regenerative agriculture initiatives will fail to accomplish their primary objectives unless they embrace agrochemical reduction as a central tenant. Research shows that pesticides disrupt the soil microbiome and harm soil invertebrates that are central to building healthy soil, sequestering carbon, conserving water, and improving farmers' climate resilience.[25] Moreover, as mentioned above, pesticides are petrochemicals that contribute to GHG emissions.[26]

1

Rationale and methodology

Why does this study consider a link between the US food retail sector, pesticides, climate change, and biodiversity decline? This chapter explores the answer to this question by first providing the rationale for selecting four commodities that pose a particular risk to pollinators as proxies for biodiversity decline: soy, corn, apples, and almonds. Moreover, we outline the methodology and data sources for estimating the prevalence of these four commodities in US food retailers' product ranges and sales.

1.1 Overview

This chapter aims to provide the factual basis for the financial analysis. In doing so, we reference existing scientific studies from which data was extracted, which the analysis throughout this report draws on. Informed assumptions were used to obtain approximates for data that is not readily available. The following sections explain these choices. This study starts from the premise that food retailers' dependence on agricultural supply chains that use significant amounts of pesticides associated with biodiversity and climate impacts exposes them as essential sales channels to financial risk from commodities driving the use of these pesticides. We focus on pollinator decline as a proxy for biodiversity decline writ large as well as a material risk to food retailer supply chains.

1.2 Pesticides, pollinators, and soil health

Pollinators provide an essential ecosystem service, allowing for the reproduction of flowering plants worldwide. Our reliance on pollinators is evident when looking at food production, with an estimated third of world crops relying on pollination and 70% of fruit and vegetable crops needing pollination from insects and other animals.[27] As a result, pollinators are often examined as a barometer for risk to biodiversity and general environmental health.

Bees, in particular, are a key pollinator species, with studies showing how bees directly affect the profitability and productivity of agricultural products.[28] There is increasing evidence of the restricting impact on seed and crop production from a lack of pollinators, including managed honeybees and wild species.[29] Bees have seen their numbers and genetic diversity decline dramatically. Experts cite various interacting reasons for this decline, including habitat destruction, invasive species, climate change, and pesticides.[30] Agricultural chemicals have been a focus of public concern regarding pollinator population decline, particularly the pesticides used in most food and crop production. The term pesticides refers to insecticides, herbicides, and fungicides, all of which can all be harmful to bees and other pollinators, not only when leading to mortality but also by depleting crucial floral resources, causing habitat loss, and triggering subtle but worrisome effects on their memory and ability to reproduce and navigate.[31]

A growing body of data also show that pesticides are incompatible with healthy soil ecosystems, resulting in significant harm to the soil microorganisms and invertebrates that are necessary for key soil functions like water infiltration and conservation, nutrient cycling, carbon sequestration, and disease protection for plants and crops.[32]

At over 1 billion pounds per year, the US accounts for almost a quarter of global pesticide use. Many highly hazardous pesticides (HHPs, as defined by the Pesticide Action Network (PAN))[33] that have been banned in the EU, Brazil, or China are still used in the US.[34]

The following sections look at neonicotinoids and glyphosate as examples of the impacts of widely used pesticides on pollinators and soil organisms. However, many other pesticides commonly used in US agriculture pose significant risks to pollinators and other beneficial insects, including organophosphates, carbamates, and pyrethroids.

Neonicotinoids, a widely used group of highly hazardous insecticides, pose a severe risk to bees and other beneficial insects. Due to their high toxicity and persistence in the environment, neonics have made US agriculture nearly 48 times more toxic to insects since they were introduced in the 1990s.[35] The herbicide glyphosate is included in PAN's list of HHPs due to its long-term effects on health; however, it is profiled here due to the sheer volume used on corn and soy and increasing evidence that it harms pollinators and soil life.[36]

1.2.1 Neonicotinoids

Neonicotinoid insecticides, or neonics,[b] are the most widely used type of insecticide globally.[37] They are used to control piercing and sucking insects in agriculture, aquaculture, as well as non-agricultural settings. Neonics are systemic pesticides, which, unlike contact pesticides, are taken up and transported throughout the plant (leaves, flowers, roots, stems, pollen, and nectar), indiscriminately killing insects that are exposed. Moreover, their solubility and persistence enable them to spread into the wider environment.[38]

Although neonics are not meant to target pollinators like honeybees, they are, by design, highly toxic to these and other species. For this reason, environmental advocates have highlighted the role that neonics play in the decline of these essential species. Their prevalence in bee environments is demonstrated by the fact that 75% of honey samples collected worldwide were found to contain quantifiable amounts of at least one neonic (in North American honey, this proportion was even higher at 86% of honey samples collected).[39] Research also shows that neonicotinoids also harm soil organisms.[40]

In January 2020, the US Environmental Protection Agency (EPA) proposed interim actions on neonics to limit exposure to pollinators and workers handling the products.[41] Despite this public recognition of the destructive capabilities of these agrochemicals on human, insect, and environmental health, neonics continue to be used widely in agriculture worldwide, including in the US. According to data for 2014, the last available year, more than 7.5 million pounds of neonics were used on crops in the US, including seed treatments.[42]

The industry producing neonics benefits from markets with weak pesticide regulations. One investigation by Public Eye and Greenpeace UK found that five of the world's leading pesticide producers (BASF, Bayer Crop Science, Corteva Agriscience, FMC and Syngenta) generate 10% of their revenues from pesticides that are highly toxic to bees, including neonics.[43] Moreover, neonics are exported from European countries worldwide, even though the EU has banned the three most commonly used neonics for outdoor use since 2018 due to the threat they pose to pollinators.[c,44]

---

[b] Insecticides that were introduced in the 1990s that are chemically similar to nicotine.

[c] Active ingredients imidacloprid, clothianidin, and thiamethoxam.

1.2.2 Glyphosate

Glyphosate is by far the most widely used agrochemical globally. It is the active ingredient in Monsanto's (now Bayer's) Roundup weedkiller. Since the advent of Roundup Ready corn and soy varieties genetically engineered (GE) to withstand the spraying of glyphosate in the mid-1990s, the use of glyphosate has increased 32-fold on corn and 9-fold on soy in the US.

Glyphosate targets a broad range of weeds very effectively, and it is also relatively inexpensive, averaging between $2.5 and $32.1 per hectare across agricultural use sites. As a result, many high-value crops (e.g., tree nuts, grapes, vegetables) and large acreage field crops (e.g., soybean, cotton, corn) are heavily treated with glyphosate.[45] In 2021, over 178 million pounds of glyphosate were used on corn and soy acreage in the US.[46]

Glyphosate is included in PAN's HHP list because it is a probable carcinogen, as determined by the World Health Organization International Agency for Research on Cancer.[47] Like neonics, glyphosate is not strongly regulated in the US. For example, the EPA's limits for glyphosate exposure are upwards of 6 times higher than what is allowed in the EU which some argue is the direct result of corporate lobbying from agrochemical producers like Monsanto (acquired by Bayer in 2018).[48]

A growing body of science demonstrates the harm glyphosate and glyphosate-based herbicide formulations pose to bees and soil organisms.[49]

1.3 Four key HHP-reliant crops grown and consumed in the US

Crops were chosen from different segments of agricultural supply chains to understand the extent of the US food retail market's reliance on products that are grown with HHPs, particularly highly hazardous insecticides, which put bees and other critical pollinators at risk of being directly or indirectly harmed.

1.3.1 Corn and soy

Corn and soy crops in the US have become highly reliant on HHPs. More than 90% of all corn and 44–50% of soybeans are grown from seeds coated with neonics,[50] namely imidacloprid, clothianidin, and thiamethoxam. Seed treatments of corn and soy, in fact, account for the most significant uses of neonics in the US.[51] The development and widespread cultivation of seeds genetically engineered to tolerate herbicides (glyphosate, but also dicamba, glufosinate, and 2,4-D) since the mid-1990s has further increased the industry's reliance on agrochemicals. According to the USDA, more than 90% of US corn and soybean acreage is planted with GE herbicide-tolerant varieties.[52] An analysis of 2019 figures shows that just two states where the most corn and soy are grown, Iowa and Illinois, sprayed 15% of all glyphosate used in the country.[53]

Corn is wind-pollinated and soy is self-pollinating, meaning these crops do not rely directly on pollinators to propagate. Still, bees and other pollinators are commonly found in and around corn and soy fields, especially in landscapes with limited additional foraging sources. Moreover, during the planting process, dust from seeds treated with neonics can disperse in the environment. Bees and other beneficial insects can encounter this pesticide dust deposited on flowers, in the air, or on surface water.[54]

Advocates and scientists have been attempting to understand how pesticides used in corn and soy fields impact bees. Numerous studies have found neonics from corn seed treatments in bee-collected pollen and elevated honey bee mortality during corn planting,[55] while others have found impacts on wild and ground-nesting bees from neonic use in corn and soy.[56]

In addition to corn and soy's unparalleled reliance on HHPs and the pesticides' toxicity to bees, the choice to focus on these crops for this study also stems from the fact that the US is the leading global producer of corn and the second for soy, and among the top consumers and exporters of the two crops. Corn and soy are used domestically as critical components in feed to produce animal products like meat, dairy, and eggs, in various food applications (vegetable oils, derivatives like corn syrup, and starch or emulsifiers, etc.), and as feedstock for bioethanol and biodiesel production. Both crops have seen sharp rises in acreage expansion in the last decades.[57]

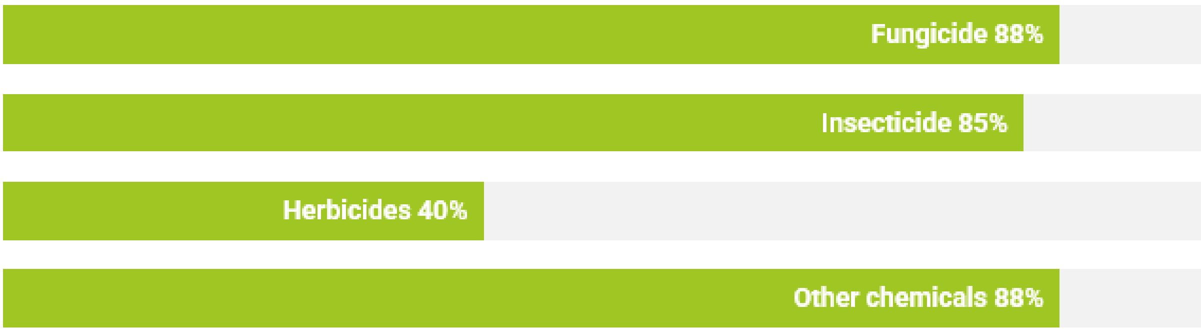
Because these crops are highly relevant domestically, their dominance in the food retail sector in the US can be safely assumed. Combined with the prevalence of neonic, glyphosate, and other HHP use on these crops and evidence of harm to bees, corn and soy were choice candidates for this study.

1.3.2 Apples and almonds

Apples and almonds are pollinated by bees and other insects and thus depend on these pollinators to propagate. Because pollinators have direct contact during bloom, the risk of lethal impact on bees could be higher than in soy or corn.

Apples are a quintessential product on American shelves, a ubiquitous children's snack eaten fresh, as juice, or as apple sauce. However, conventionally produced apples are known for pesticide contamination, consistently making the Environmental Working Group's "Dirty Dozen" list of consumer products with the highest levels of pesticide residues.[58] Even among the fruit categories, apples have a high pesticide use rate, specifically insecticide usage for pest management. For 2023, the USDA recorded that 85% of acres planted with apples were treated with insecticides (Figure 1).[59] Moreover, most apples (67%) are sold fresh, increasing the concern and debate around the overuse of pesticides and the risk to human health.[60]

Figure 1 Share of planted acres of apples with pesticides applied in 2023



Source: National Agricultural Statistics Service (2024), *2023 Agricultural Chemical Use Survey: Fruit Crops*, USDA.

Almonds are produced on a smaller scale than apples, exclusively in California, and are not consumed as widely in the US. Yet, this tree nut provides an important economic role to its majority family-farm-driven industry, with an almost threefold expansion in crop area since 1995[61] and two-thirds of almonds being exported yearly, totalling US$ 4.5 billion in 2022.[62]

The US almond industry depends on honey bee colonies for pollination services, requiring approximately 88% of managed honey bee colonies in the US during bloom.[63] Although almond growers have demonstrated good practice in reducing the use of pesticides labelled as 'bee-toxic',[64] legislation on agrochemical toxicity and usage in the country and California continue to lag far behind what advocates say the survival of bee colonies requires.[65]

Both crops are highly dependent on bees and other pollinators for their propagation. Their strong presence in the retail market, where they are sold whole and processed, made them valuable commodities to include in this study's financial analysis.

1.3.3 Quantifying the use of HHPs

In 2021, a total volume of around 1 billion pounds of pesticides — a term that includes herbicides, fungicides, and insecticides — were applied in US agriculture.[66] Data from the Pesticide Use Data

System (PUDS) on average application values per crop for the most recent year surveyed,[67] suggest that the pesticides used across the four crops in this study accounted for around 50% (484 million lb) of all pesticides used on cropland in the US. With around 465 million lb or 46% of all pesticides used, soy and corn accounted for the bulk of the volume.

A simplified indicator of the adverse effects of pesticides on health and the environment is the amount of HHPs used for the four commodities and how this compares to the total amount of pesticides used on all cropland throughout the country in 2021 (Table 3). This comparison suggests that around 293 million pounds, or 29% of the total pesticide use in the US, were accounted for by HHPs applied to corn, soybeans, almonds, and apples. Moreover, HHPs accounted for 45% (162 million hectares) of the total area under these four crops that was treated.[d,68]

To indicate the risk to bees and other pollinators and broader biodiversity, pesticides with high environmental toxicity (PHET), especially insecticides with high risk to bees according to the PAN classification, were analysed separately. This results in an estimated volume of at least 9 million pounds of PHETs applied to the four crops, accounting for 1% of total pesticide use in the US based on 2021 estimates, and 5% of 'the total area under these four crops treated with pesticides' (which is larger than the national crop area of the four commodities as explained in the footnotes of Table 3). This relatively small use of pesticides has an outsized environmental impact.

Table 3 Pesticides applied to four selected crops in the US (most recent year)

Crop	National crop acreage (million ha)	All pesticides		All HHPs				PHET			
		Total applied (million lb)	Total area treated (million ha)	Applied (million lb)	% of total pesticides applied to crop	Area treated (million ha)	% of total area treated with pesticides	Applied (million lb)	% of total pesticides applied to crop	Area treated (million ha)	% total treat-ments (w/o seeds)
Almonds	0.4	15.4	3.6	4.1	27%	2.8	78%	1.9	12%	1.1	30%
Apples	0.1	18.1	2.9	9.9	55%	1.3	46%	1.0	6%	0.7	22%
Corn	37.7	260.4	180.7	136.5	52%	66.5	37%	1.8	1%	6.7	4%
Soy	33.7	205.3	172.6	142.9	70%	91.1	53%	4.2	2%	9.8	6%
Total	**72.0**	**483.7**	**359.8**	**293.4**		**161.8**		**9.0**		**18.3**	
Including estimated neonic seed treatments				***298.4***				***14.0***			

Source: Profundo, based on C. Benbrook drawing on the Pesticide Use Data System (PUDS); USDA (n.d.), "Total pesticide use on crops in most recent year surveyed", viewed April 2024; FAOSTAT (n.d.), "Total pesticides used in agriculture in the United States of America 2021 in US tons", viewed April 2024; FAOSTAT (n.d.), "Agricultural land 2021 in hectares", viewed April 2024; Pesticide Action Network International (2021, March), *PAN International List of Highly Hazardous Pesticides*, Hamburg, Germany: PAN International; Wieben, C.M. (2020), "Estimated annual agricultural pesticide use by major crop or crop group for states of the conterminous United States, 1992-2017", ver. 2.0, *U.S. Geological Survey Data Release*.

Note: PHET=Pesticides with High Environmental Toxicity based on the definition of the PAN List of HHPs (i.e., not including glyphosate) (see Appendix 1 for the list of PHETs). The treated area considers multiple applications in the same area; therefore, treated area > national crop area. Data in PUDS is from the USDA QuikStat system and is based on periodic surveys; data is based on the most recent year surveyed (2018 for almonds, 2020-21 for the other crops); seed treatment with insecticides is not considered in this data.

[d] The treated area considers multiple applications on the same area; therefore, treated area > national crop area. Organic production excludes the use of HHPs; however, the share of organic production in the US is less than 1% for soy and corn, around 1% for almonds and 4% for apples.

Since 2015, seed treatment application of neonics has not been included in the US agricultural chemical use surveys (section 1.2.1), despite the fact that EPA data suggests that in 2014, seed treatments accounted for 84% of the total agricultural use of neonics. [69] Therefore, corn and soy's actual exposure to HHPs and PHETs is considerably higher but not easy to quantify. Applying the 2014 data for corn and soy as the last available data year,[70] seed treatments added an estimated 5 million lbs to the HHPs and PHETs volume used on the two crops.

1.3.4 Risks to pollinators

Building on the underlying data for the four selected crops in Table 3 and focusing on insecticides as the pesticides with the highest risk to pollinators, the risk to bees from cumulated lethal doses of insecticides was assessed using the acute bee indices in the Pesticide Risk Tool (PRT).[e,71] Almonds, apples, and soy were assumed to offer pollen and nectar; for corn, pollen only.

Two risks were calculated: the on-crop risk to a 'model' bee[f] foraging in the crop, but outside of flowering time,[g] and the risk to the model bee foraging on flowering plants in areas immediately adjacent to the crop. On-crop risks stem from eventual pollen/nectar contamination and systemic incorporation of residues once the crop does flower. The risk metric is the number of lethal doses a foraging bee accumulates during a day. As insecticides are typically labelled against spraying when crops are in bloom and high risks stem from the dust generated at planting and drifting to neighbouring areas, the off-crop toxicity risk is typically higher.[72]

Moreover, it was assumed that 100% of corn and 40% of soy seeds are currently treated with one of the neonic insecticides (imidacloprid, clothianidin and thiamethoxam).[h,73] Based on the PRT algorithms, a very high risk is expected from using neonic seed treatments due to the high proportion of the crop that is treated and the high bee toxicity of the products. It was assumed that only one active ingredient was used for seed treatments. For other insecticides, the critical information to assess how many of the insecticides are applied to the same crop was missing. Therefore, two scenarios were computed: 1) the minimum proportion of the crop area that is at risk of lethal intoxication for a model bee; that is, noting only the area treated with the most toxic pesticide for each condition; and 2) the foliar insecticides are not overlapping but used on different proportions of the crops.

Using an average of these two scenarios and considering that off-crop risk is higher than the on-crop risk, 89% of the almond crop area, 72% of apples, 100% of corn, and 40% of soy has more than one lethal dose per day (Table 4).

[e] Estimates computed by Pierre Mineau Consulting for Friends of the Earth US, building on data from the Pesticide Use Data System (PUDS). Additional data for almonds were obtained from the Pesticide Use Reporting (PUR) data summarised by the Pesticide Action Network (PAN) for the 50 most important pesticides used in that crop. The percentage of the California crop that was treated was obtained by dividing the PUR treated acres by the total crop acreage reported in 2022 by the California Almond Board. Due to the use of average application rates this is not a 'worst-case' analysis based on maximum application rates, with the possible exception of seed-treatments.

[f] The model bee is styled on a cross between a nurse and foraging bee with a sensitivity 10X that of a honeybee to capture the bulk of wild pollinators. The index cannot assess chronic or reproductive toxicity.

[g] It was assumed that crops would not be sprayed when in bloom as most insecticides are labelled against this.

[h] For both corn and soy, neonic use reported by the USDA dropped to almost zero after 2015, when seed treatment uses were no longer included in the USDA pesticide surveys, indicating that the bulk of the use was indeed from seed treatments.

Table 4 Average crop area with >1 lethal dose/day, on-crop and off-crop

Crop	Average est. % of crop with >1 lethal dose/day ON crop	Affected crop area (ha) >1 lethal dose/day ON crop	Average est. % of crop with >1 lethal dose/day OFF crop	Affected crop area (ha) >1 lethal dose/day OFF crop
Almond	5.4%	35,621	89%	583,781
Apple	61%	71,293	72%	83,564
Corn	0%	-	100%	37,737,804
Soy	40%	13,492,888	40%	13,492,888

Source: Profundo, based on Pierre Mineau Consulting, based on C. Benbrook drawing on the Pesticide Use Data System (PUDS).

This quantification of the risk of pesticides to pollinators in almond, apple, corn, and soy crops provides the values to conduct the financial analysis in this study. It also demonstrates the imperative to highlight these four crops for their impact on pollinator health in the US and establish their prevalence in US retail sales.

1.4 Exposure of the US retail market to HHP-reliant crops

1.4.1 Role of US retail market in crop sales

Soy, corn, apples, and almonds enter the US food market via different sales channels, with grocery retailers playing a pivotal role in food sales for home consumption. Based on US sales values in 2021-2022,[i] around 44% of food products not exported or used in industrial processes were sold by food retailers, and the remainder was sold in food service (restaurants, fast food, delis, catering, hotels, pubs). The financial analysis does not distinguish between individual grocery retailers but considers the US food retail market as a whole. Supply chain information is relevant to understanding the exposure of US retailers to risks from pollinator-harming pesticides:[74]

- Soybeans have been grown on more than 34 million hectares in the US in recent years. Most soybeans (95% of the domestically available volume)[75] are crushed into soybean meal and oil.[j] Soymeal is a source of high-quality protein in livestock feed. Therefore, soymeal is 'embedded' in the meat, dairy, and eggs produced and sold on the US market. Soybean oil is used as an edible oil and in industrial uses, including biodiesel. Roughly 75% of the soybean volume used domestically went into animal feed, 15% was consumed as edible oil and in food products, and 10% went to industrial uses and fuel.
- Corn has been grown on around 34 million hectares in recent years. Around 45% of the US corn consumption is accounted for by animal feed. Moreover, 44% is used to produce biofuel. The remaining 10% is used in food, of which around one-third is high fructose corn syrup.
- Apples have been grown on 133,000 hectares in recent years.[76] Around one-third of apple consumption takes place as whole fruit. The remaining two-thirds are processed into apple juice (52%), canned (9%), dried (2%), frozen (1%), and other (2%) products.
- The US is the largest producer of almonds, accounting for almost 80% of global output. Commercial production is concentrated in California[77] where around 660,000 hectares of almond trees are cultivated.[78] Almonds are consumed raw, blanched, or roasted as nuts and processed into various food products, including marzipan, gluten-free flour, and dairy alternatives.

[i] The use of sales value means that the estimates of volumes sold through food retailers may be somewhat too low as prices are higher in food service.

[j] For the resulting main products, a crush ratio of around 78.5% soybean meal and 18.5% soybean oil can be assumed.

In terms of cultivation area, corn and soy dominate the much smaller surface occupied by apples and almonds. US domestic consumption is more important for corn and apples, while a considerable share of the US soy and almond production is exported to international markets.[k]

A significant export share and important non-food uses influence the share of the total production volume that is eventually sold by US food retailers. At values between 12% and 21%, this share is lowest for almonds, soy, and corn, while apples have the highest share of production volumes sold by US food retailers at 38% (Table 5). When just looking at the domestically consumed volume, after exports, apples and almonds have the highest share sold by food retailers, as they are used only as food.

Table 5 Key metrics of four crops and food retailers' shares (2020/21-2021/22 average)

	Soy	Corn	Apples	Almonds	Total	Average %
Area (million ha)	34.2	33.9	0.1	0.5	68.7	
Total US production (thousand mt)	118,139	370,670	4,440	1,368	494,616	
For US domestic consumption (thousand mt)	61,911	311,888	3,798	376	377,972	
As % of total production	52%	84%	86%	27%		76%
US food retailers' relevance in volume						
Food retail share in consumption (thousand mt)	20,949	76,297	1,689	167	99,103	
As % of total production	18%	21%	38%	12%		20%
As % of US domestic consumption	34%	24%	44%	44%		26%
US food retailers' relevance in area						
% for US food retail	18%	21%	38%	12%		
Area (million ha) for US food retail	6.0	7.0	0.05	0.06	13.2	19%

Source: Profundo, based on USDA data.

Note: Difference with crop area in Table 3 due to differing reference period. mt=metric ton (1 mt equals 1.1 short tons or 2,204.62 lb).

1.4.2 Value share of crops in US food retail sales

Retailers sell food products in many categories, and many of these categories consist of processed products composed of various ingredients. Many of these ingredients are derived from corn and soy, including, for example, high-fructose corn syrup, corn starch, emulsifiers, or lecithin. Moreover, while no longer physically present in the end product, corn and soy are essential ingredients in livestock feed and, therefore, crucial inputs in manufacturing animal products like milk, meat, eggs, or farmed seafood. In comparison, the categories of apples and almonds on food retail shelves are less complex as they are more likely to be sold in unprocessed or less processed form.

The Economic Research Service of the US Department of Agriculture published data on weekly US retail sales by category for 2021.[79] Eleven broader categories are divided into 53 sub-categories. For this analysis, the weekly sales were summarised into annual sales. For each sub-category, an estimate was made on the share that may be constituted by one of the selected crops or contain it as an ingredient. This share can be a proxy for retailers' exposure to these crops.

[k] For all four crops, imports are small in comparison to domestic production and consumption and therefore not further disaggregated.

Table 6 Shares of almonds and apples in relation to larger retail product categories

Product in category	Share
Almonds in nuts	18%
Almonds in nuts and seeds (excl. organic)	15%
Apple juice in total fruit juice (excl. organic)	36%
Apple canned in total canned fruit (excl. organic)	33%
Apple in fresh fruit (excl. organic)	11%

Source: Profundo, based on USDA data and Grand View Research (2023), "Nuts market size, share & trends analysis report and Segment Forecasts, 2023 – 2030", viewed in April 2024.

Estimates for further processed products included, for example, the share of corn syrup in non-alcoholic drinks, the share of apple juice in total fruit juice, the share of aquaculture in seafood consumption, or the share of corn and soy oil in vegetable oil consumption in the US. For processed products, like snacks and ready-made meals, it was assumed that at least 80% contain one or more corn-or soy-derived ingredients, directly or indirectly. All animal products are considered to be exposed to embedded soy and corn. The estimates for animal products, apples, almonds, and edible oils were adjusted to exclude the average share of organic agriculture in US production, as organic production prohibits HHPs. The shares were estimated as 6% for eggs, 4% for apples, or less than 2% for meat.[80]

Combining these different values leads to an estimated value share of 55% of US food retailing exposed to the four crops and, with this, exposed to HHPs. Several sub-categories are too vague to come up with even a rough estimate of a value share that may be linked to the selected crops. Therefore, the 55% estimate can be considered conservative as it is likely on the low end of the scale.

2

Value impacts and externalized costs of pesticide use

This valuation and risk calculation focuses on soy, corn, apples, and almonds. These commodities are processed into many products sold by US food retailers. While the commodity value of these four crops is approximately 10% of the value of US food retailers' food and beverage revenues, they are embedded in products that generate 55% of US food retailers' sales in food (see section 1.4.2).

The impact of using HHPs and pollinator-harming pesticides in these products sold by US food retailers can lead to externalized environmental costs and financial risks for companies. US food retailers' sales and profits can be affected. Also, purchasing costs might increase, financing costs might increase, and reputation can be affected. Financiers might also weigh externalized costs in their valuation approach, resulting in lower stock market valuation multiples.

This section calculates the total value-at-risk, ultimately impacting financial assets and pension payments.

2.1 Overview

There are various dimensions in which the use of pesticides affects pollinators, biodiversity, and climate. This accumulates in direct risks and costs for food retailers as well as in externalized or societal costs:

- Pesticides create direct costs from purchase and application.
- Pesticides used in the production of soy, corn, apples, and almonds can hurt pollinators and other biodiversity, affect crop yields, and have broader effects on agriculture and the economy.
- The production and use of these pesticides lead to greenhouse gas emissions (CO_2equivalent, CO_2e) and consequently contribute to climate change.

As a consequence, pesticides have an impact on the companies that sell products that have been produced with them. US food retailers have a crucial role in selling the products in focus in the current report: soy, corn, apples, and almonds. US food retailers' revenues, costs, and profits may be affected, and consequently, their valuation. As a result, food retail financiers could face an impact on the value of their loans and/or investments. Lower values of shares, bonds, and loans lead to a lower value of the assets of pension providers. Subsequently, this could hurt the payment and level of pensions to millions of US citizens.

The current report categorizes the various risks. Existing literature was reviewed for calculations or guidance on specific risk categories and for estimates of major economic and environmental losses due to the application of pesticides in the US, including, among others, pesticide resistance, crop losses, and water contamination.[81]

2.2 Various risks for US food retailers – a description

This section describes the various (financial) risks associated with the use of pesticides in products on food retailer shelves with a focus on highly hazardous and pollinator-harming pesticides.

2.2.1 Physical risks and transition risks

US food retailers, which are the focus of the current report, could face various pushbacks from the use of pollinator-harming pesticides. Food retailers can be confronted with multiple risks:

- The use of pollinator-harming pesticides can reduce the number of pollinators. This can affect the turnover/sales opportunities for US food retailers and lead to lower revenues and profits, and even stranded assets.
- Because of the impact on pollinators and human health, stricter legislation on pesticides has been or will be developed and/or consumers have or will change their preferences, as indicated by the continued growth of the organic market. This impacts the revenue opportunities of US food retailers. The commodities in focus in the current report (soy, corn, apples, and almonds) and the products in which they are embedded might be affected or avoided and consequently generate less income than under 'normal' conditions. Consumers could switch to other products and consumption patterns that are not in the food retailers' portfolios. The calculations in the section 2.4 implicitly consider that the sector as a whole might sell fewer apples, for instance, and that meat/dairy contains less soy; consumers adjust their apple and meat/dairy consumption slightly per year and might look for alternatives for these consumption changes outside the regular food retail sector.

The above-mentioned risks and changes create uncertainties for US food retailers' financial accounts. Regulation and preference changes might impact turnover and profits, and, consequently, food retailers' financial or enterprise value. The risks above can be called transition risks.

Physical risks occur if the assets of food retailers (like stores) are hurt by the use of pesticides. There is no evidence for this.

2.2.2 External costs and liability

There is increasing evidence that large parts of global agricultural land are 'at risk'[I] of pesticide pollution by more than one active ingredient: 64% or 2,450 million hectares, and 31% is 'at high risk'. Of the high-risk areas, 34% are in high-biodiversity regions.[82]

Therefore, while US food retailers might be affected by transition risks linked to the use of pesticides in soy, corn, apples, and almonds, the use of these pesticides also leads to external costs which weigh on society as a whole:

- Climate damage costs related to the production and use of pesticides.
- Biodiversity damage and environmental costs, like reduction of pollination.
- Health damage costs. This includes occupational disease impacts, water treatment costs to reduce the effect of pollution, and risks related to pesticide food residues, particularly for infants in utero, children, and other vulnerable populations.
- Regulation costs.

These external costs accumulate into a value risk for companies active in the supply chain of products linked to pesticides. US food retailers are part of the downstream segment of the value

---

I The quoted study considered a region to be at risk of pollution if pesticide residues in the environment exceeded the no-effect concentrations, and to be at high risk if residues exceeded this by three orders of magnitude.

chain and sell products that contain all these costs, including the emissions from their direct and indirect suppliers.

2.2.3 Financing risks for food retailers

In addition to the direct costs (purchase and application costs), transition risks, and external costs, food retailers might be affected by financing risks and/or higher financing costs.

This can be due to the food retailers' links with highly hazardous and pollinator-harming pesticides. An increasing number of banks and investors are weighing ESG factors into their activities. Financiers are confronted with their clients' demand for de-risking pension assets from climate change risk and biodiversity loss. Financiers might even divest from US food retailers if they do not show enough progress in de-risking their portfolios.

Another reason for financing risks is that free cash flows weaken due to less availability of certain products, impacting financing costs, as financiers might conclude that US food retailers' financial strength has been or will be affected. Therefore, when re-financing debt, US food retailers could be confronted with higher interest rates. Higher interest rates on debt lead to lower net profits and, consequently, lower valuations of US food retailer assets.

2.2.4 Reputation value risk

When de-risking from the impact of pesticides is not a priority for certain US food retailers, certain companies or the whole sector might be confronted with reputation risk.

Overall, reputation risk covers a broad range of issues, including climate change, board gender composition, workplace culture and treatment of health issues of supply chain personnel and customers, human rights, anti-corruption efforts, and data privacy.

The consequence of reputation risk might lead to a decline in the reputation value, which in the long term will have a negative impact on cash flow generation and, therefore, the value of a company and a sector.

2.2.5 Total value risk for food retailers regarding pesticides

The total value risk related to pesticides will be a sum of physical and transition costs, externalized costs, financing costs, and reputation value risk. This sum creates a financial risk for food retailers and their financiers.

In the subsequent sections, the calculations are focused on highly hazardous and pollinator-harming pesticides and their impacts on soy, corn, apples, and almonds sold by US food retailers. The climate calculations are based on total pesticide use for the four target crops sold by US food retailers.

2.3 The importance of the four crops to US food retailers

Soybeans, corn, apples, and almonds represent a certain part of grocery sales at US food retailers. Chapter 1 explained the number of hectares used in the US and affected by pollinator-harming and highly hazardous pesticides, the percentage of domestic US consumption, and the share of the products that end up at US food retailers. This supply chain information is relevant to understanding how US food retailers can be linked to risks of pesticides used on US land.

When the four commodities are processed into various products, value is added to them, and the (embedded) price/value moves up at every step of the supply chain. For example, soybeans go to crushers, which make soymeal and soy oil. Soymeal goes to animal feed companies which sell the product to farmers and operators of Confined Animal Feeding Operations (CAFOs). Those livestock operations process the animal feed into dairy products and meat, which are subsequently processed into branded or private-label products. These are shipped to food retailers and food service outlets and sold to consumers. At every step, the commodities gain value and become more expensive.

Profundo has developed a pricing-up model for soybeans, but not yet for corn, apples, and almonds. The available pricing-up models can be used as proxies to fill this gap. Table 7 is based on various studies executed by Profundo, showing the pricing-up in four value chains. In the example of soy, the pricing-up from farmer to retailer/food service goes from an index of 100 to 302. Sugarcane faces the largest pricing-up and is a good example of how branded product ingredients develop. The global soft drink industry drives up the value strongly due to its high gross margins.

Table 7 Pricing-up model for various supply chains

Index = 100	Beef	Soymeal	Sugarcane	Palm	Average
Farmer	100	100	100	100	100
Average trader/cruncher		111	130	115	119
Animal feed		139			
Farmer in sourcing country		139			
Midstream/downstream animal products	123	183			
Downstream dairy		198			
Egg packer		162			
Average downstream or brand company		181	280	160	207
Retailer/food service	202	302	350	194	262

Source: Profundo, Chain Reaction Research.

As there are no pricing-up models for corn, apples, and almonds yet, existing models of comparable supply chain structures can be applied. Corn might have the same pricing-up model as soy. Apples will be sold as a combination of fresh and branded products. Therefore, a 34% weight of a fresh product (like beef) and a 66% weight of a branded product (like sugarcane) leads to a pricing-up of 100 to 300. This approach is also followed for almonds (Table 8).

Table 8 Pricing-up for soy, corn, apples, and almonds

Index	Soy	Corn	Apples	Almonds
Farmer	100	100	100	100
Food retail	302	302	300	300

Source: Profundo.

By multiplying the ‘US consumption through the US food retailers in million metric tons’ (see Table 9, line 1) with the end price of the products at farm-gate (line 2), the values linked to the index of 100 for each commodity in the upstream part are calculated (a total of US$ 27.6 billion). By applying the pricing-up factor, the retail value of each commodity on the food retail shelf can be concluded as US$ 83.2 billion.

As a percentage of US grocery stores’ sales (approximately US$ 800 billion in 2022), this US$ 83.2 billion is slightly above 10%. Note that this US$ 83.2 billion number only concerns the embedded value of the four commodities and not the value of the products in which they are embedded. For instance, soy and corn form only a certain part of a product like meat or milk. Thus the value of the products which contain soy and corn is much higher than 10% of food retail sales. The value of the products which contain the four commodities was calculated to be at least 55% (see section 1.4.2).

Table 9 Retail value of the four commodities (embedded value)

	Soy	Corn	Apples	Almonds	Total
US consumption food retailers (million mt)	20.95	76.30	1.69	0.17	
Price end 2022 (per mt)	493.3	198.0	883.0	3,876.7	
Value farm-gate (US$ million)	10,334.8	15,106.9	1,491.5	648.0	27,581.3
Pricing-up factor (x)	3.02	3.02	3.00	3.00	3.02
Retail/food retail value (US$ million)	31,211.2	45,622.8	4,470.5	1,942.4	83,247.0

Source: Profundo, Tradingeconomics and various other sources.

2.4 US food retailers' revenue-at-risk

Three factors could affect US food retailer revenues:

- A reduction in pollinators and other beneficial insects might reduce the supply of soy, corn, apples, and almonds. This can push up the prices of products containing these commodities, which might affect volumes.
- Stricter legislation may be developed to regulate HHPs.
- Consumers may change their preferences. The continued growth of the organic market indicates' consumer interest in foods produced without harmful pesticides. A YouGov survey commissioned by Friends of the Earth found that 83% of Americans believe it is important to eliminate pesticides that are harmful to pollinators from agriculture and 74% believe food retailers should support efforts to protect pollinators. 81% want their food to be free of pesticide residues, and 67% feel it is important that the food retailers they shop at sell organic food.[83]

No studies have concluded how the financial accounts of US food retailers will be affected by the described potential changes in supply and/or regulation. Therefore, the second-best solution is a scenario analysis that calculates potential profit and value effects from changing consumption patterns and gross margins. A scenario analysis needs some 'guidance' about the potential impact.

Regarding the availability of the four commodities from a lack of pollination, it is important to consider that soy and corn are not too dependent on pollination services. Table 10 calculates pollinator insect dependency. While corn is unaffected by the absence of insects, apples and almonds are highly dependent. The third line in Table 10 applies the scenarios for the production decline for the four commodities. Then, the total impact on supply can be calculated. The result is that a decline in production of the four commodities due to less pollination can have an effect of US$ 11.97 billion, or 14% of the total value (US$ 83.2 billion) of the embedded volumes.

Table 10 Dependency on pollinator insects (embedded value)

	Soy	Corn	Apples	Almonds	Total
Level of dependency	Modest	No	High	High	
Yield impact	-10% to -40%	0%	-40% to -90%	-40% to -90%	
Volume impact applied in scenario	-25%	0%	-65%	-65%	-14%
Retail/food retailer value (US$ million)	31,211.2	45,622.8	4,470.5	1,942.4	83,247.0
US food retailer value impact (US$ million)	-7,802.8	0.0	-2,905.8	-1,262.6	-11,971.2

Source: Profundo, based on Aizen (2019) and Klein (2006) and Our World in Data (2021, August), "How much of the world's food production is dependent on pollinators?", online: https://ourworldindata.org/pollinator-dependence, viewed in April 2024.

The third row in Table 10 can be used as a proxy of volume impact at food retailers. Assuming less supply, food retailers would make less profits (assuming a stable profit per unit). In a high-end scenario (-14% in total), this would lead to a gross margin loss of US$ 3.34 billion (Table 11). In a Discounted Cash Flow (DCF) context (with a 7% discount rate and 25% tax rate), and assuming that this loss lasts forever, the DCF value loss is US$ 37.07 billion. Nearly two-thirds of the loss occurs in soy products, and no loss in corn products. In a low-end scenario, the assumption is that imports will compensate for 50% of the supply loss. Then, the value loss is US$ 18.5 billion.

Table 11 Revenue and gross profit at risk (High and low scenario)

US$ million	Soy	Corn	Apples	Almonds	Total
Revenue of food retailers	31,211.2	45,622.8	4,470.5	1,942.4	83,247.0
High-end scenario					
% supply impact	-25%	0%	-65%	-65%	-14%
Loss of revenue	7,802.8	0.0	2,905.8	1,262.6	11,971.2
Gross margin (%)	27.9%	27.9%	27.9%	27.9%	
Loss of gross profit	2,177.0	0.0	810.7	352.3	3,340.0
DCF multiply factor (X)*	11.1	11.1	11.1	11.1	
DCF value loss	24,164.5	0.0	8,999.1	3,910.0	37,073.6
Low-end scenario**					
% supply impact	-12.5%	0.0%	-32.5%	-32.5%	
Loss of gross profit	1,088.5	0.0	405.4	176.1	1,670.0
DCF value loss	12,082.3	0.0	4,499.6	1,955.0	18,536.8

Source: Profundo, based on Aizen and Klein and Our World in Data: https://ourworldindata.org/pollinator-dependence.

Note: * The multiplying factor of 11.1X is based on the following Discounted Cash Flow (DCF) assumptions: a weighted cost of capital (WACC) of 7%, a growth rate of 0% from year 1 into eternity, a 25% tax rate. This 11.1X factor needs to be multiplied by the annual impact, assuming it is constant, to calculate the DCF value. The choice for a 7% WACC and a 25% tax rate are in line with stock market valuations of relevant sectors; ** Assuming that imports replace 50% of the supply loss from fewer pollinators.

2.5 Financing risk – a rise in interest charges

Another risk is that financing might become more expensive for the US food retail sector. US food retail chains work with debt and cash positions to operate their businesses and acquire other companies. The top six listed companies (based on 2022 grocery sales, including Walmart, Costco, Kroger, Target, Albertsons/Safeway, and Ahold Delhaize), have total net debt (gross debt minus cash) of US$ 109.5 billion.

Financiers are increasingly engaging in Environmental, Social, and Governance (ESG) issues, including external effects like biodiversity loss. For example, investors with US$ 3 trillion in assets have launched a nature-protection campaign in 2022.[84] If these financiers demanded one per cent extra interest on their lending to the six US food retail chains mentioned above, borrowing costs would increase by US$ 1.1 billion (1% of US$ 109.5 billion).

To calculate the net debt of the US grocery sector, the debt of the top-6 companies is used as an indicator of the debt level of the whole sector. The first step is to calculate the market share of the top-6 companies in the US grocery sector. Of the total 2022 revenues of US$ 1,285 billion of the top-6, US$ 628 billion is in groceries (Profundo calculation). This is 78% of the total 2022 grocery sales (CPI adjusted by US Census data). Assuming that the rest of the grocery sector has an equal net-debt pattern as the top-6 companies, the total grocery net-debt level is estimated at US$ 76 billion (Table 12).

The enterprise value (market capitalisation, or equity value, plus gross debt minus cash position) of the whole sector and the equity value of the whole grocery sector are calculated on the same basis. They will be applied in subsequent tables on the financial risks for the whole sector.

Table 12 Key value numbers US food retail sector

US$ million	Top-6* retail activity	Top-6 grocery activity	Grocery as % of total	Top-6 as % of sector	Sector
Revenues (all - 2022)	1,284,500	627,960	49%	78%	805,566
Enterprise value (EV) – 17 July 2024	1,221,400	597,112	49%	78%	765,993
Net-debt	121,600	59,447	49%	78%	76,261
Equity value	1,099,800	537,665	49%	78%	689,733
EV/revenues (x)**	0.95				

Source: Profundo, based on Bloomberg, US Census, company annual reports.

Note: * Walmart, Costco, Kroger, Target, Albertsons/Safeway, Ahold Delhaize. Values of equity, net-debt, and enterprise value of 17 July 2024; grocery activity based on company reporting or, where unavailable, estimated based on average distribution of sales reported by peers; ** As the enterprise value is based on 2024 data and the revenues on 2022 data, the EV/revenues ratio is higher than in publications using the same years.

The next step (see Table 13) is the introduction of low/high-risk scenarios. In a low-risk scenario, the assumption is that the interest costs for debt might move up by 25 basis points (+0.25%), and in a high-risk scenario, the assumption is +200 basis points (+2.0%). This would lead to US$ 191 million and US$ 1.53 billion higher annual interest charges, respectively. A DCF factor of 11.1x is applied to calculate a value number. Then, US$ 2.12 billion and US$ 16.93 billion financing/interest cost risk is estimated, respectively.

Table 13 Financing/interest cost risk

US$ million	Low (+25 bps)	High (+200 bps)
Net-debt	76,261	76,261
bps-change	0.25%	2.00%
Increase in interest charges	191	1,525
DCF factor	11.1	11.1
Value 10 years	2,116	16,930

Source: Profundo; net-debt based on Bloomberg per 17 July 2024.

2.6 Reputation risk

The reputation value of US food retailers can be affected when the sector does not consider the risks of pesticides. Reputation loss will come on top of the loss in revenues and profits, higher financing costs, and external costs, although there might also be some overlap, which is difficult to calculate. Note that an important part of the reputation loss for the US food retailers in selling the four commodities (some of them embedded) could be visible in the equity value on the stock market. Investors could be less tempted to hold shares linked to hazardous pesticides and move their money to more sustainable investments.

Chain Reaction Research (CRR) calculated the potential reputation loss for individual companies and compared this number with the equity value of the companies. Reputation events can impact a company's value by 30%. This value impact has increased in the last 20 years through social media's 'distribution' effect. Scientific studies show that events harming a company's reputation have a material negative impact on the value of a company. However, acknowledging the situation and taking proper supply chain management measures can reverse the negative reputation impact. In the long term, a positive reputation improves earnings. This positive impact can stem from better client and supply chain relationships, quality personnel, and ultimately enhanced earnings capacity. Companies with stronger reputations tend to see lower costs of capital. [85] With societal awareness of sustainability events like pollinator-harming pesticides' risk rising quickly, value gaps of up to 70%[m] might develop between downstream companies (such as food retailers): the leaders in adjusting their policies and execution could outperform laggards substantially – highlighting the investment hazard related to reputation risk from links to sustainability events.

In a follow-up report,[86] the weighting of fast-moving consumer goods companies (FMCGs) to the specific sustainability event has been considered, as a company is often involved in several activities, and its operations often do not depend on one contested commodity. Regarding the exposure and accountability for the impact of highly hazardous and pollinator-harming pesticides, not all food retailers' activities and sales will be affected. Therefore, the impact on food retailers' equity or enterprise value might be less than 30%.

Considering the discussion in the preceding paragraph, the current report calculates the reputation value-at-risk in a 'low' and 'high' scenario:

- The low-risk reputation risk scenario will be based on 30% of the enterprise value related to the retail value of (embedded) soy, corn, apples and almonds.
- The high-risk scenario is based on 30% of the enterprise value of the food retail sector related to the sale of products that are exposed to the four commodities. Section 1.4.2 concluded that

[m] The 70% value gap is the difference between 'reactive' companies losing value from an index of 100 to approximately 70, and 'proactive' companies gaining value from an index of 100 to approximately 120.

55% of US food retail sales are based completely or partly on the four commodities. This means that 55% of the reputation of the whole grocery sector might be affected.

The first step is calculating the enterprise value of the part related to the four commodities. This is based on the enterprise value, revenues, and enterprise value/revenue ratio (0.95x, see Table 12) of the grocery sector. The 0.95X is applied to the revenues of the four commodities (Table 14). The US$ 83.2 billion embedded revenue value of soy, corn, apples, and almonds contributes US$ 79.2 billion to the total enterprise value of the US grocery sector.

Table 14 Enterprise value groceries and four commodities

US$ million	Total grocery sector	Four commodities
Embedded revenue at the food retailer level	805,566	83,247
EV/revenue (x)	0.95	0.95
Enterprise value	765,993	79,158

Source: Profundo, based on Table 12.

The second step calculates the reputation-at-risk by multiplying the 30% by, respectively, the value of the four commodities (low-risk) and that part of the total value of the grocery sector which is exposed to product sales that are based on the four commodities, which is 55% of all sales (high-risk). Consequently, the low/high-risk range in reputation value is US$ 23.7 billion to US$ 126.4 billion (Table 15).

Table 15 Reputation value-at-risk

US$ million	Low-risk scenario	High-risk-scenario
Enterprise value food retail sector	79,158	765,993
Correction factor in high-risk scenario*		55%
Enterprise value relevant for reputation risk calculation	79,158	421,296
Reputation risk %	30.0%	30.0%
Reputation value-at-risk	23,747	126,389

Source: Profundo.

Note: * The 55% correction factor is based on the share of food retail sales exposed to the four commodities.

2.7 Climate damage costs linked to pesticides

Pesticides contribute to climate change and damage, both directly and indirectly. Fossil fuels are used in the production and transportation of pesticides, their use supports unsustainable food and farming systems, and they affect the soil's ability to sequester carbon. Not all elements are yet fully understood (like their full impact on carbon sequestration). Therefore, the full impact is likely significantly underestimated.[87]

2.7.1 The emissions of pesticides globally

According to CropLife, the global trade group representing the agrochemical industry, pesticides contribute a low 1-4% of a group of five products' total emissions (including cotton, wheat, and rice). The contribution is 2% and 1% for soybeans and corn, respectively. The large contributors are fertilizer production and use, and a smaller role for energy and fuels.

However, independent research shows that pesticides can contribute much higher percentages to CO_2e footprint. In one study, pesticides accounted for 51% of CO_2e emissions associated with the production and application of agrochemicals (including pesticides and fertilizers) in apple production.[88] Another study from 2022 also concluded that the pesticide supply chain is highly carbon-intensive, with product synthesis, distribution, and field application generating 23.5 to 136.6 million tons of CO_2e per year globally (averaged over 2016-2018, mid-point: 80.5).[89] Researchers admit that it is a 'highly conservative' estimate as new pesticidal compounds are often more energy-intensive than older ones (the compound part is based on a 2004 study). The US and Brazil are the largest contributors, followed by China. Insecticides, fungicides, and herbicides contribute 18.7%, 18.2%, and 62.9% respectively to these emissions. For the US, the range is 3.5 to 20.9 million tons of CO_2e[90] (recalculated with 3.67x from carbon to CO_2e).

These data can be confronted with Syngenta's reporting on emissions (Table 16). Syngenta AG, the global leader in pesticide production, reports on Scope 1, 2, and 3 emissions in its sustainability reporting. As these emissions come mainly from pesticides (81% of Syngenta's 2022 revenues were pesticides, the rest were seeds) and grams of emissions per US$ revenues are given, these can be recalculated to the US$57.6 billion (2018)[91] global pesticides market.

Syngenta, however, indicates that its Scope 3 emissions are mainly from purchased products but exclude the 'use of sold products' due to *"the absence of externally validated methodologies that consider both benefits and emissions from the use of agricultural inputs*."[92] The company admits that the category (use of the products) is not applicable in alignment with its Science Based Target Initiative (SBTi) commitment.

Table 16 Syngenta AG: Reporting on CO_2e

	2020	2021	2022
Volume CO_2e(million mt)			
Scope 1 + 2	0.8	0.7	0.8
Scope 3	9.0	9.1	10.9
Total	9.7	9.8	11.7
Emissions per revenue (g per US$)			
Scope 1 + 2	54	43	40
Scope 3	627	542	544
Total	681	585	584

Source: Syngenta AG.

Syngenta's 2022 emission per US$ revenues is applied to the global pesticides market number (A), see Table 17), which had an estimated value of US$ 68.1 billion in 2022 (2018 adjusted with CPI US). Based on Syngenta's emissions per US$ revenue (B), the global emissions would amount to 39.8 million CO2e (C). This is close to the low end of Wyckhuys' calculations (23.5 million, (D)[93] and halfway to the midpoint (80.5 million, (E).

Table 17 Sanity check global emissions from pesticides

	Data	Comment
Market US$ million (2022; adjusted with CPI to 2022) (A)	68,088	CPI-adjusted (+18% 2018-2022)
CO_2e emissions (gram) per US$ revenue at Syngenta (2022) (B)	584	Excluding Scope 3 from "use of sold product"
Global emissions (million mt CO_2e), based on Syngenta's per US$ output (C = A x B)	39.8	
Nature 2022 publication range (D)	23.5-136.6	2016-2018 pesticide volumes, but older pesticides compound data
Nature 2022 publication mid-point (E)	80.5	2016-2018 pesticide volumes, but older pesticides compound data

Source: Profundo based on Syngenta AG, Kris A. G. Wyckhuys, Michael J. Furlong, Wei Zhang and Yubak D. GC (2022, 5 May), "Carbon benefits of enlisting nature for crop protection", and Public Eye.

2.7.2 Pesticides emissions linked to soy, corn, apples, and almonds through food retailers

The next step is to calculate two scenarios (low/high risk, see Table 18) based on the US pesticide emissions according to Wyckhuys (A), and the estimate that of all pesticides applied in the US, approximately 50% (see Table 3) are used for soy, corn, apples, and almonds (D). Again, the adjustment factors for the US food retail share have been applied (B, C). The total emissions of pesticides linked to soy, corn, apples, and almonds are estimated at 0.4 million to 2.1 million CO_2e per year (E).

Table 18 US food retailers' CO_2e emissions from pesticides on four key commodities

	Low-risk scenario	High-risk scenario
Pesticides CO_2e emissions (million mt 2016-2018 per year, average) (A)	3.5	20.9
% for US domestic consumption (B)	76%	76%
% of US consumption for US food retailers (C)	26%	26%
% of pesticides for soy, corn, apples, and almonds (D)	50%	50%
Of which for soy, corn, apples, and almonds (E = A x B x C x D)	0.4	2.1

Source: Profundo, based on preceding tables and paragraphs.

2.7.3 Climate damage cost methodology

The development of methodologies to value climate damage is still underway, and there has yet to be an internationally accepted standard. The International Monetary Fund (IMF) has adopted the approach that carbon dioxide pricing per ton is a good proxy to value the climate damage or the Social Costs of Carbon (SCC). The IMF states that, based on the development in literature, the SCC is a measure that is conditional on the level of CO_2 in the atmosphere. The higher that level, the more powerful the greenhouse effect and, therefore, the higher the expected physical damages. For simplicity reasons, a constant SCC (or carbon price) per ton was assumed in their analysis, as the real growth in costs every year (3%) would be nearly 'neutralised' by the need to use a discount rate[n] to calculate a present value of future costs.[94] The carbon dioxide price as a proxy for damage has also been used in various other studies.[95,96]

The US jurisdiction, which is the focus of the current report, does not apply a carbon dioxide cost system for Scope 1, 2 and 3. Many parts of the world neglect to price a major part of emissions, particularly the Scope 3 emissions.

The World Bank's Carbon Pricing Dashboard[97] shows that various US jurisdictions have implemented, scheduled, or have under consideration various forms of carbon pricing (see Table 19). These average US$ 34.05 per ton CO2e, which will be used in scenario 1 (see below).

Table 19 Carbon pricing initiatives US

7/8/23	US$/ton CO_2e
Massachusetts	12.05
RGGI (Regional Greenhouse Gas Initiative)	15.39
Alberta	48.03
California	29.84
New Brunswick	48.03
Newfoundland and Labrador	48.03
Northwest Territories	48.03
Nova Scotia	20.87
Ontario	48.03
Washington	22.20
Average	**34.05**

Source: World Bank's Carbon Pricing Dashboard, Profundo.

In the meantime, the EU ETS (Emission Trading System) price per ton CO_2e has shown an upward-moving trend since 2017, although in recent quarters, the price has declined because of less economic activity and less use of coal and gas. On 8 March 2024, the EU ETS price was € 61 (US$ 67) per ton after € 105 (US$ 112) one year ago (6 March 2023).[98] This ETS price mechanism is a trading platform for coping with Scope 1 and 2 emission rights for certain energy-intensive industries. The EU system does not yet consider Scope 3 emissions and is, for instance, not applied to food producers.

One could say that the EU price per ton of CO_2e is relatively high due to the competition for emissions rights in a 'crowded' continent. However, an EU ETS price, or prices based on other policy recommendations as a proxy for societal costs, continues to be a relatively conservative concept:

- Firstly, policymakers' estimates are often relatively low as a global average price on CO_2e emissions is used, with many jurisdictions still not applying CO_2e costs for scopes 1, 2 and 3.
- Secondly, policymakers often underestimate the (economic) impacts by using a high discount rate assumption for future damages. When applying a high discount rate, a future value is calculated back to the present into a low value. Consequently, the future costs seem low in a Discounted Cash Flow calculation. Companies often use this methodology to compare current investments and costs in year 0 with future profits from these investments in the years thereafter. However, is the loss of one litre of water in year 10 less valuable than in year 0?

[n] A discount rate is used to calculate the Net Present Value (NPV) of a business or activity as part of a Discounted Cash Flow (DCF) analysis. The principal thought is that 1 Euro in year 2 is seen as less valuable than 1 Euro in year 1.

- Current policy recommendations can exceed US$ 150 per ton.[99]

Conservative societal cost models focus on short-term damage, assuming that climate change has no lasting effect on economic growth despite growing evidence to the contrary.

Societal costs: However, extreme events like droughts, fires, heatwaves, and storms are likely to cause long-term economic harm because of their impact on health, savings, labour productivity, agriculture, and social disruption. Expert groups of economists and climate scientists calculated values of US$ 171 and US$ 310 per ton, respectively. Recent calculations for economic damage have increased further due to the inclusion of higher damages in the Global South.[100] These latest societal costs of carbon dioxide ($SCCO_2$) have a more forward-looking component based on the projected cost to society of releasing an additional ton of CO_2, including climate damage costs and economic damages (economic feedback). One study shows that by 2100, the global gross domestic product (GDP) could be 37% lower than it would be without the impacts of global warming when taking the effects of climate change on economic growth into account (without accounting for lasting damages - excluded from most estimates - GDP would be around 6% lower). This means that in a 'wider' societal cost concept, the impacts on growth may increase the economic costs of climate change by a factor of six. When taking more robust climate science and updated models into account, one study suggests that the economic damage could in fact be over US$ 3,000 per ton of CO_2.[101]

Prevention costs: For Friends of the Earth in the Netherlands, Profundo applied prevention costs per ton of CO_2e emission. This resulted in a CO_2e price of US$ 160 (€ 149) per ton. This is based on a conservative external cost approach. In the Netherlands, it is used by the Netherlands Environmental Assessment Agency (PBL). PBL is the research institute that advises the Dutch government on environmental policy. However, it is important to note that this methodology does not cover the actual damage caused, but only prevention costs (the costs to prevent emissions). The price is based on the analysis of CE Delft[102] and adjusted for inflation.[103]

The prevention costs methodology is used because the estimates of the Societal Cost (see above) methodology are too uncertain. Therefore, the prevention number applied by Profundo is relatively conservative.

Two scenarios: In scenario 1, a price is applied based on various North American jurisdictions, assuming that the calculated emissions would be charged with a CO_2 price (31 March 2023) as a proxy for climate damage costs. Scenario 2 uses a prevention cost for CO_2e emissions.

2.7.4 Climate damage costs from US pesticide production and use for the four commodities

Applying a low and higher carbon dioxide cost per ton, the total costs would be US$ 11.9 million to US$ 335.5 million per year. Assuming that the food retail sector's target might move to 2050 carbon neutrality through a path of linear reduction, the total emissions costs until 2050 would range between US$ 161 million and US$ 4.5 billion (Table 20).

Table 20 US food retailers' climate damage cost from emissions related to pesticide production and use on four key commodities

	Low-risk scenario	High-risk scenario
CO_2e emissions from corn, soy, apples, almonds sold by US food retailers (E)	0.4	2.1
CO_2e price (US$ per ton) (F)	34.1	160.2
Total costs/climate damage (US$ million) (G = E x F)	11.9	335.5
Total costs/climate damage (US$ million) in 2050 carbon neutral	161.2	4,528.7

Source: Profundo, based on preceding tables and paragraphs.

2.8 Biodiversity loss

In calculating biodiversity loss, it must be considered that it is impossible to calculate the intrinsic value of nature. Current methodologies are based on the damage to ecosystem services and other economic activities. Non-economic values cannot be calculated. This is why some stakeholders are opposed to focusing on a value approach to biodiversity, as focusing on ecosystem services (for humankind) and the value of tourism gives the impression that a trade-off is possible between nature and the economy.

This section on pollinator-harming pesticides' impact on biodiversity focuses on how important bees are for GDP and how GDP has been affected because of the use of pollinator-harming pesticides. In this narrow definition, the biodiversity value of pollinators consists of the following:

4. The ecosystem services value of pollinators to the four focus crops.
5. The impact of use of pesticides on the four focus crops on pollinator health and the effect of this on the rest of the economy.

This section focuses on factor 1. Factor 2 is investigated in section 2.9.

2.8.1 Valuation of biodiversity loss and the impact of pollinator reduction

CE Delft has compared many valuations for nature based on various studies, of which Constanza et al. and Groot et al. are crucial. This CE Delft study and handbook calculates the average biodiversity value of cropland at US$ 5,567 per hectare per year.[104] This value includes all relevant ecosystem services like carbon dioxide sequestration, water cleaning/purification, and soil improvement. These outcomes correspond with data and methodology in studies collected in the ESVD (Ecosystem Services Valuation Database).[105]

In 2019, the UN mentioned that up to US$ 577 billion in annual global crops are at risk from pollinator loss.[106]

While the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) and other organizations have been active in valuing the impact of, for instance, pesticides, bee loss, and declining pollination, these have not yet been applied to companies and sectors, such as US food retailers.

In 2022, the FAO summarized that *"87 of 115 of the top global crops depend, to some degree, on animal pollinators, such as bees, birds, and bats."* Also, FAO re-iterated that "5 to 8% of current global crop production would be lost without animal pollination, representing an annual market value of US$ 235–577 billion" and that "40% of these crops would lose 40 to >90% of production in the absence of pollinators."[107]

All of these studies calculate the value of ecosystem services. As mentioned above, this means that the loss of landscape aesthetics, wild plant diversity, and crop genetic characteristics for present and future generations, essential for social welfare, have no valuation methodology.

2.8.2 The current report focuses on the ecosystem services of pollinators

The current report's methodology to calculate biodiversity loss is based on the number of hectares affected by pollinator-harming treatment and the ecosystem services damages per hectare.

The hectares of US cropland treated with neonicotinoids have increased every year, with large increases in potential use when approvals were obtained for high-acreage commodity crops like corn, soybeans, cotton, wheat, and alfalfa, already 75% of cropland. Seed coatings comprise the largest contribution to increasing use.[108]

The ecosystem services

Estimates of the economic benefits of pollinators can vary strongly between countries, regions, and crops. These estimates/studies, shown in Table 21 and collected by IPBES, are not easy to compare. They express different things, from the market price of crops to the estimated 'welfare value' of pollination services, and do not always use purchasing power parities (PPP). If PPP is used on a global scale, hectare values of ecosystem services from bees are relatively low versus US outcomes. Calculations for different crops on the same hectare can lead to different outcomes, as, for instance, the crop value outcomes for apples differ from almonds. Also, outcomes for the same commodity differ for each country. For example, the biodiversity loss for a hectare with apples in the US is much higher than in China.[109]

Table 21 Ecosystem value of pollination services

Study	Crops	Year	2015 US$/ha	Total (2015 US$ billion)	Region
US					
Calderone (2012)	All	1997-2009	4,666-7,311	15.8-17.1	US
Morse & Calderone (2000)	All	1996-1998	Na	30.8*	US
Calderone (2012)	All	2009	Na	17.9	US
Diffendorfer (2014)	Na	2012	Na	5.0-6.9**	US
Global					
Lautenbach (2012)	All	2009	717-1,760	235-577	Global
Other global	All	1986-2005	Na	176-689	Global
Apples					
Calderone (2012)	Apples	2010	17,365	Na	US
Calderone (2012)	Apples	2007	21,774	Na	US
Losey and Vaughn (2006)	Apples	2003	13,078	Na	US
Calderone (2012)	Apples	2002	15,639	Na	US
Morse & Calderone (2008)	Apples	1996-1998	10,654	Na	US

Source: IPBES.

Note: * US$ 21.8 bln to honeybees, US$ 9 bln to wild pollinators; ** The existence value of Monarch butterflies; Na = Not available.

The IPBES report emphasizes that the cited "US$ 235-577 billion" loss of value due to pollinator damage (from Lautenbach) is linked to damage of US$ 717 to US$ 1,760 per hectare. This US$ 717-1,760 damage range per hectare is much lower than the damage estimates for the US. The value damage for the US is between US$ 5.0 billion to US$ 31.8 billion. Per hectare, there is one number available, US$ 4,666 to US$ 7,311 (Table 21, from Calderone, with re-pricing to 2015).

The next step is to assume a value per hectare for the various crops or estimate the financial impact of reducing insect pollination services on the proceeds.

One could choose the approach that soy and corn are the dominant commodities in the US, which also dominate the value in Calderone's estimates. These 2015 numbers are updated to 2022 with Consumer Price Index (CPI) USA data (sourced via The World Bank). For apples, the lowest and highest numbers from the specific apples section have been used as a range and adjusted for inflation. Almonds have a similar relatively high proceed/harvest value per hectare, and the hectare values from apples have been applied.

Table 22 A 'general' approach to estimating biodiversity value per hectare

	2023 US$/ha - low	2023 US$/ha - high
Soy, corn	5,761	9,027
Apples, almonds	13,155	26,885

Source: Profundo, based on IPBES, The World Bank.

However, in a 'reality check' (Table 23), these numbers do not reflect the real impacts for all commodities. If the annual US$ proceeds per hectare of soy and corn are calculated, these are much lower than the ecosystem services assumed in 0. Against end-of-2022 prices, the proceeds per hectare of soy and corn in the US were US$ 1,705 and US$ 2,164, respectively. As both are not very dependent on insect pollination and much more on wind pollination, the approach of Table 23/Table 22 seems sub-optimal.

Table 23 'Reality check': Biodiversity value per hectare versus proceed per hectare

	Soy	Corn	Apples	Almonds
Number hectares (million) (A)	34.18	33.92	0.12	0.52
Total US production (million mt) (B)	118.14	370.67	4.44	1.37
Proceeds per hectare (ton) (C = B/A)	3.46	10.93	37.44	2.63
Price per ton (farm-gate) end 2022 (D)	493	198	883	3,877
Proceed per hectare (US$) (E= C x D)	1,705	2,164	33,063	10,195
Biodiversity value per hectare (US$) – Low (F)	5,761	5,761	13,155	13,155
as % of proceed/hectare (F/E)	337.9%	266.3%	39.8%	129.0%

Source: Profundo based on previous tables.

Then, a better approach is to apply data from the original studies cited in 0. These indicate the following for the four commodities: corn is nearly not dependent on pollination, soy limited (10-40% yield reduction in case of absence of pollinators), and apples and almonds strongly dependent (40-90%) (Table 24).[110]

Table 24 A commodity-specific approach to estimate biodiversity value per hectare

	Soy	Corn	Apples	Almonds
Level of dependency	Modest	No	High	High
Yield impact	-10% to -40%	0%	-40% to -90%	-40% to -90%
Low impact	-10%	0%	-40%	-40%
High impact	-40%	0%	-90%	-90%

Source: Profundo, Klein, IPBES, The World in Data.

This decline in ecosystem services from pollinators (Table 24) has been applied to the number of hectares used to supply US food retailers and then to those hectares that have received acute pollinator-harming toxicity from pesticides (see Table 4 and applied in line D in Table 25).

The low-high impact ranges (K and L in Table 25) are applied to the values (J) of the four commodities that have been treated with and affected by pollinator-harming pesticides and sold by US food retailers.

The outcome (M and N) is a proxy for biodiversity loss by pollinator-harming pesticides in soy, corn, apples, and almond production. Note that these are mainly based on (potential) lost volumes for these commodities and do not take into account the impact insecticides have on water quality and other sectors (like tourism), the overall welfare of the population, and other 'services' to humankind. Of course, the impact on the intrinsic value of nature cannot be calculated.

A low-end scenario (M) leads to a US$ 1.05 billion annual ecosystem impact from US food retailer sales of the four commodities if they have been treated with and affected by pollinator-harming pesticides. In a DCF context, this is US$ 11.7 billion (P). In a high scenario, the annual impact is US$ 3.1 billion (N), and US$ 34.3 billion in a DCF context (Q).

Table 25 Biodiversity value impact from US food retailers - four commodities

	Soy	Corn	Apples	Almond	Total
Number hectares (million) (A)	34.18	33.92	0.12	0.52	68.74
% non-organic (B)	99.7%	99.7%	96.0%	99.0%	
Number of hectares (million) non-organic (C)	34.08	33.82	0.11	0.51	68.52
% with pollinator-harming pesticides (D)*	40%	100%	72%	89%	
% for US domestic consumption (E)	52%	84%	86%	27%	
% of US consumption for US food retailers (F)	34%	24%	44%	44%	
Number hectares with pollinator-harming pesticides (million) sourcing to US food retailers (E = CxDxExF)	2.42	6.96	0.03	0.06	9.47
Proceeds per hectare (ton) (G)	3.46	10.93	37.44	2.63	
Price per ton (farm-gate) end 2022 (H)	493	198	883	3,877	
Proceeds per hectare (US$) (I = GxH)	1,705	2,164	33,063	10,195	
Total proceeds (US$ million), farm-gate for US food retailers, pollinator-harming pesticides applied (J = ExI)	4,122	15,062	1,031	571	20,785
Impact bee-pollination services (%)					
Low impact (K)	-10%	0%	-40%	-40%	
High impact (L)	-40%	0%	-90%	-90%	
Ecosystem value-at-risk (US$ million) - annual, from four key commodities					
Low impact (M = -JxK)	412	0	412	228	1,053
High impact (N = -JxL)	1,649	0	928	514	3,090
Ecosystem value-at-risk (US$ million) - DCF-based					
DCF factor (x) (O)	11.1	11.1	11.1	11.1	
Low impact (P = M x O)	4,575	0	4,577	2,535	11,687
High impact (Q = N x O)	18,300	0	10,299	5,704	34,303

Source: Profundo, based on preceding tables.

Note: * see Table 4.

2.8.3 Omissions in the 'biodiversity loss calculation' and side-effects

Four crucial values cannot be calculated as methodologies do not exist:

- The values do not include the biodiversity loss by switching nature into cropland.
- The values do not include the loss of intrinsic value of nature.
- Table 25 does not consider that pollinator-harming pesticides' active ingredients can be found many miles from where they have been applied.
- The calculations do not account for the persistence of pollinator-harming pesticides. This is crucial to understanding the long-term and cumulative ecosystem toxicity beyond the initial pesticide application to a crop.

2.9 Economic effects on other sectors affecting US food retailers

In the preceding sections, calculations have been made on how pollinator-harming pesticides can lead to business and reputation risk for the US food retail sector and have external impacts like climate damage and biodiversity effects related to the supply chain of pesticides.

Pollinators' functioning affects not only the yield of the commodity to which it is applied. The treatment of large areas of land is affecting the total population of pollinators and, consequently, also sectors other than soy, corn, apples, and almonds. Both soy, corn, and fruits and vegetables are leading contributors and thus responsible for the cumulative toxic burden that persistent pesticides create in the environment, measured in one study as acute insecticide toxicity loading (AITL).[111]

In a broader context, pollinator-harming pesticides contribute to a biodiversity crisis that affects the gross domestic product (GDP) on a global scale. Various studies have emphasized the materiality of these risks. Considering the current study and the focus on the financial risk for US food retailers, the following data could be relevant:

- Industries that are 'highly' dependent on biodiversity and nature generate 15% of global GDP (US$ 13 trillion), and 'moderately' dependent industries generate 37% (US$ 31 trillion), says the World Economic Forum/PricewaterhouseCoopers). Together, the three largest sectors that are 'highly' dependent on nature generate approximately US$ 8 trillion of GDP. These are construction (US$ 4 trillion), agriculture (US$ 2.5 trillion) and food and beverages (US$ 1.4 trillion). In the US, US$ 2.1 trillion of GDP, or added value, is generated in sectors highly dependent on nature.[112]
- A study from the World Bank Group says that collapsing ecosystems could take 2.3%, or US$ 2.7 trillion, of global GDP in 2030. This is based on a collapse in selected ecosystem services: wild pollination, provision of food from marine fisheries and timber from native forests. North America (including the US) would be hurt by 0.5% GDP change in 2030, while Sub-Sahara Africa would be affected by -9.7% as the region is much more exposed to pollination-dependent agriculture. The negative effects in North America are mostly due to the decline of pollination, much more than by the other investigated ecosystem services (fisheries/marine) and forests (timber, carbon sequestration).[113] If, in the case of the US, 75% of the 0.5% negative impact on 2030 GDP is due to pollination loss, the annual loss in GDP in 2030 is US$ 8 billion. A collapse of ecosystem services (like insect pollination) will result in productivity losses in crops. Lower productivity, in turn, will result in less output and higher output prices. Next, higher output prices will lead to greater demand for inputs by the affected sectors, which will drive up input costs for the whole economy, eventually affecting export and import flows.[114]
- In the absence of animal pollination, changes in global crop supplies could increase prices for consumers and reduce profits for producers, resulting in a potential annual net loss of economic benefits of US$ 160-191 billion globally to crop consumers and producers, and a further US$ 207-497 billion to producers and consumers in other, non-crop markets (e.g., non-crop agriculture, forestry, and food processing).[115,116]

These value impacts come on top of the values calculated in the preceding sections, as they also include other economic sectors. The studies emphasize the impact on the (US) GDP from a loss of biodiversity services, of which insect pollination is an important one. The US$ 207-497 billion (third bullet) refers to damage to other sectors, but a number for the US is lacking.

Conclusion: currently, no calculation for the damage to other sectors can be executed.

2.10 Summary

2.10.1 Summary of costs and values

This section adds up all the operational and external costs calculated in the preceding sections. The total annual operational and external costs for US food retailers are US$ 2.93 billion in a low-end scenario and US$ 8.29 billion in a high-end scenario (Table 26).

It is necessary to calculate a value number to compare the data with the current stock market valuations of food retailers. In the preceding sections, this was done for each risk category. The sum of all the value impacts, which have been calculated in each sub-section, is materially higher than the annual numbers. In the low-end scenario, the external risks are 21% of total damages; in the high-end scenario, the external risks are 18% of the total, due to the size of reputation risk in the high-end scenario. In the value/multi-year analysis, the low/high range is US$ 56.25 billion and US$ 219.22 billion.

Table 26 Summary: financial risks of pesticides in supply chains of US food retailers*

US$ million	Annual LOW	Long-term value effect** LOW	% of total		Annual HIGH	Long-term value effect** HIGH	% of total
Operational + financing + reputation							
Revenue-at-risk/gross profit-at-risk	1,670	18,537	33%		3,340	37,074	17%
Financing risk	191	2,116	4%		1,525	16,930	8%
Reputation risk		23,747	42%			126,389	58%
External environmental risks							
Climate damage	12	161	0%		335	4,529	2%
Pollinator-harming/ecosystem risk	1,053	11,687	21%		3,090	34,303	16%
Total value-at-risk (US$ million)	**2,925**	**56,249**	**100%**		**8,291**	**219,224**	**100%**

Source: Profundo, based on preceding sections and tables.

Note: * For four commodities: soy, corn, apples, almonds; ** multi-year risk value until 2050.

The annual operational and financing costs, relative to the annual gross profit of food retailers (including grocery departments at big box stores), are 1.0% in a low-end scenario (Table 27) and 2.7% in a high-end scenario. When external risks are added to this, the totals for low-end and high-end move up to 1.6% and 4.5%, respectively.

The value outcomes have been compared to the current value of the food retailers: equity value (market capitalisation) and enterprise value (equity value + net-debt). In the low-end scenario, the various value outcomes, including and excluding external risks, are respectively 6.4% and 8.2% of equity value. The numbers for enterprise value are respectively 5.8% and 7.3%.

In the high-end scenario, the relative values are significantly higher. Excluding external risks, the risks are 26.2% versus equity value and 23.6% versus enterprise value. Including external risks, the total risk is 31.8% of equity value and 28.6% of enterprise value, respectively. This means that in a high-end scenario, assuming that the risks are not yet discounted in the equity value, 31.8% of equity value, or nearly one-third of the value, would be lost if food retailers were held fully accountable for all risks associated with pollinator-harming pesticides. In an enterprise, shareholders absorb the losses in the first instance, reflected in lower share prices. The 31.8% number means that 68.2% of the current shareholders' value would still be left. Debt-owners (loans by banks, bonds by investors) will not be hurt, and their financing can be repaid by the food retail sector.

Table 27 Total risks versus US food retail sector's gross profit and equity value

US$ million	**Data**	**Annual LOW**	**Long-term value effect** LOW**	**Annual HIGH**	**Long-term value effect** HIGH**
Operational, financing, reputation risk		1,861	44,400	4,865	180,392
External risk – excluding dietary		1,065	11,849	3,426	38,832
Total profit/value-at-risk (US$ billion)		2,925	56,249	8,291	219,224
Gross profit US food retail sector (2021)	183,300				
Equity value (17 July 2024)	698,733				
Net-debt	76,261				
Enterprise value (EV) US food retail sector	765,993				
Operational/financing/reputation risk as %*					
Total risk as % of gross profit		1.0%		2.7%	
Total DCF value-at-risk as % of equity			6.4%		26.2%
Total DCF value-at-risk as % of EV			5.8%		23.6%
Total net-debt at risk			0.0%		0.0%
Operational/financing/reputation risk + external risk as %*					
Total risk as % of gross profit		1.6%		4.5%	
Total DCF value-at-risk as % of equity			8.2%		31.8%
Total DCF value-at-risk as % of EV			7.3%		28.6%
Total net-debt at risk			0.0%		0.0%

Source: Profundo.

Note: * Means including financing risk and reputation risk, although the annual costs do not include reputation damage. Reputation risk has a longer-term impact and is thus a multi-year 'value' and is compared to the equity and enterprise value; ** Multi-year risk value until 2050.

2.10.2 More research is needed

Readers need to consider that there are still many issues related to pesticides that need to be investigated:

- The current study does not include all the impacts that US food retailers cause by their actions. For example, US food retailers sell products produced in other countries. These groceries, fruits, and vegetables use pollinator-harming and highly hazardous pesticides in their production that can have a negative impact on production. This impact could be relatively high as the economies of many countries exporting produce is relatively more dependent on agriculture. In case studies in three countries (Honduras, Nigeria, Nepal), the calculation showed that the economic value of crop production would be 12% to 31% lower than if pollinators were abundant (due to crop production losses of 3%–19%), mainly due to lost fruit and vegetable production.[117] These impacts are linked to US food retailers' purchase/sourcing policy, but these externalized costs were not relevant in the study on the four focus commodities.
- The application of pollinator-harming pesticides to a certain crop and area pollutes neighbouring crops and pollinator populations, which could have a large additional financial impact, e.g. due to increased costs of production associated with lower pollinator populations. US food retailers could be impacted by this and held accountable for it.
- This report did not compare the various operational, financial, and biodiversity impacts of conventional agriculture practices using pesticides against organic farming, which prohibits the use of over 900 synthetic pesticides otherwise allowed in agriculture.
- Finally, the report does not include an analysis of the health impacts of pesticides. Early indications point to high damage numbers which dwarf the risks calculated above.
- The calculated costs and damages in this report are values that can be linked to the food retail sector as this sector is the ultimate seller of the products to the end consumer. The direct impact, like lower sales, higher financing costs and reputation loss, will be felt by the retailers. The external damages, like climate costs and biodiversity loss, are passed on to society. The share of accountability of the food retail sector for these external costs and damages depends on 1) the level of knowledge that the various actors in the whole supply chain have (had) of these costs and damages; and 2) the profits and benefits that the various actors in the whole supply chain generated on the four commodities.

References

1 DiBartolomeis, M., Kegley, S., Mineau, P., Radford, R. and K. Klein (2019), "An assessment of acute insecticide toxicity loading (AITL) of chemical pesticides used on agricultural land in the United States", *PloS one*, *14*(8), e0220029;

Sánchez-Bayo, F. and K.A. Wyckhuys (2019), "Worldwide decline of the entomofauna: A review of its drivers", *Biological Conservation*, *232*, 8-27;

Puglisi, E. (2012), "Response of microbial organisms (aquatic and terrestrial) to pesticides", *EFSA Supporting Publications*, *9*(11), 359E;

Gunstone, T., Cornelisse, T., Klein, K., Dubey, A. and N. Donley (2021), "Pesticides and soil invertebrates: A hazard assessment", *Frontiers in Environmental Science*, *9*, 643847.

2 Sharma, A., Reeves, M. and C. Washburn (2023), *Pesticides and Climate Change: A Vicious Cycle*, Pesticide Action Network North America.

3 Farmworker Justice (2013), *Exposed and Ignored,* Washington D.C., United States: Farmworker Justice;

Gerken, J., Vincent, G.T., Zapata, D., Barron, I.G. and I. Zapata (2024), "Comprehensive assessment of pesticide use patterns and increased cancer risk", *Frontiers in Cancer Control and Society,* 2:1368086, online: https://www.frontiersin.org/journals/cancer-control-and-society/articles/10.3389/fcacs.2024.1368086/full, viewed in April 2024;

Ahmad, M. F., Ahmad, F.A., Alsayegh, A.A., Zeyaullah, M., AlShahrani, A.M. et al. (2024), "Pesticides impacts on human health and the environment with their mechanisms of action and possible countermeasures", *Heliyon*.

4 Rijk, G. (2022, November), *Syngenta's IPO: High Investment Risk*, Amsterdam, Netherlands: Profundo, commissioned by Public Eye.

5 Pesticide Action Network, (2023), "Pesticides and climate change: A vicious cycle", online: https://www.panna.org/resources/pesticides-and-climate-change-a-vicious-cycle, viewed in April 2024;

CIEL (2022), "Fossils, fertilizers and false solutions: How laundering fossil fuels into agrochemicals puts the climate and the planet at risk", online: https://www.ciel.org/reports/fossil-fertilizers/, viewed in April 2024.

6 World Economic Forum (WEC) (2020), *Nature Risk Rising: Why the Crisis Engulfing Nature Matters for Business and the Economy,* Cologny, Switzerland: World Economic Forum.

7 De Voss, J.M., Joppa, L.N., Gittleman, J.L., Stephens, P.R., Pimm, S.L. (2015), "Estimating the normal background rate of species extinction", *Conservation Biology*, 29(2): 452-62.

8 Duffy J.E., Godwin C.M., Cardinale B.J. (2017), "Biodiversity effects in the wild are common and as strong as key drivers of productivity", *Nature,* 549: 261–264;

Venter, O. et al. (2016), "Sixteen years of change in the global terrestrial human footprint and implications for biodiversity conservation", *Nature Communications.* 7:12558.

9 Gilbert, N. (2016, February 26), "Global biodiversity report warns pollinators are under threat", *Nature*, https://doi.org/10.1038/nature.2016.19456.

10 Bedada, A.H. (2020), "CAHFS Weekly Topic: Bee decline – A great concern for US food security", University of Minnesota Center for Animal Health and Food Safety: St. Paul, MN.

11 Sánchez-Bayo, F. and K.A. Wyckhuys (2019), "Worldwide decline of the entomofauna: A review of its drivers", *Biological Conservation*, 232, pp.8-27.

12 DiBartolomeis, M., Kegley, S., Mineau, P., Radford, R., & Klein, K. (2019), "An assessment of acute insecticide toxicity loading (AITL) of chemical pesticides used on agricultural land in the United States", *PloS one*, *14*(8), e0220029.

13 Crippa, M., Solazzo, E., Guizzardi, D. et al. (2021), "Food systems are responsible for a third of global anthropogenic GHG emissions", *Nature Food,* 2**:** 198–209.

14 Andrijevic, M. and J. Ware (2021), *Lost & Damaged: A Study of the Economic Impact of Climate Change on Vulnerable Countries.* London, UK: Christian Aid.

15 Gunstone, T., Cornelisse, T., Klein, K., Dubey, A., & Donley, N. (2021), "Pesticides and soil invertebrates: A hazard assessment", *Frontiers in Environmental Science*, *9*, 643847.

16 Puglisi, E. (2012), "Response of microbial organisms (aquatic and terrestrial) to pesticides", *EFSA Supporting Publications*, *9*(11), 359E.

17 Friends of the Earth (n.d.), "Bee-friendly retailer scorecard", online: https://foe.org/retailer-report-card/, viewed in November 2024.

18 Lerner, S. (2021, June 30), "The department of yes: How pesticides companies corrupted the EPA and poisoned America", *The Intercept*;

Donley, N. (2022), *How the EPA's Lax Regulation of Dangerous Pesticides is Hurting Public Health and the US Economy,* Washington, D.C., United States: The Brookings Institution.

19 US Environmental Protection Agency (2017), "Pesticide industry sales and usage 2008 – 2012", online: https://www.epa.gov/pesticides/pesticides-industry-sales-and-usage-2008-2012-market-estimates, viewed in April 2024.

20 Donley, N. (2019), "The USA lags behind other agricultural nations in banning harmful pesticides", *Environmental Health*, 18(1), p.44;

Donley, N. (2020), *Toxic Hangover: How the EPA is Approving New Products With Dangerous Pesticides It Committed to Phasing Out,* Center for Biological Diversity.

21 Friends of the Earth (n.d.), "Retailer commitments", online: https://foe.org/nursery-retailer-commitments/, viewed in April 2024.

22 Friends of the Earth (n.d.), *Organic is Regenerative*.

23 Organic Trade Association (2024, May 14), "US Organic Marketplace Posts Record Sales in 2023, online: https://www.globenewswire.com/news-release/2024/05/14/2881459/0/en/US-organic-marketplace-posts-record-sales-in-2023.html, viewed in May 2024.

24 Costco (2023), *Climate Action Plan*;

Walmart (2023, October), "General Mills and Walmart join forces to advance regenerative agriculture", online: https://corporate.walmart.com/news/2023/10/17/general-mills-and-walmart-join-forces-to-advance-regenerative-agriculture-across-600000-acres-by-2030, viewed in April 2024;

Target (n.d.), "Responsible resource use", online: https://corporate.target.com/sustainability-governance/responsible-resource-use, viewed in April 2024;

Goldschmidt, B. (2024, June 18), "Ahold Delhaize USA taking part in farm-to-shelf regenerative agriculture pilot", online: https://progressivegrocer.com/ahold-delhaize-usa-taking-part-farm-shelf-regenerative-agriculture-pilot, viewed in April 2024.

25 Puglisi, E. (2012), "Response of microbial organisms (aquatic and terrestrial) to pesticides", *EFSA Supporting Publications*, *9*(11), 359E;

Gunstone, T., Cornelisse, T., Klein, K., Dubey, A. and N. Donley (2021), "Pesticides and soil invertebrates: A hazard assessment", *Frontiers in Environmental Science*, *9*, 643847.

26 California Certified Organic Farmers Foundation (2019), *Roadmap to an Organic California: Benefits Report,* Santa Cruz, CA, United States: CCOF Foundation;

Friends of the Earth (2024), *Organic is Regenerative*. Washington, D.C., United States: Friends of the Earth.

27 Ritchie, H. (2021, August 2), "How much of the world's food production is dependent on pollinators?" *Our World in Data,* online: https://ourworldindata.org/pollinator-dependence, viewed in March 2024.

28 Khalifa, S.A.M., Elshafiey, E.H., Shetaia, A.A., Abd El-Wahed, A.A., Algethami, A.F., Musharraf, S.G. et al. (2021), "Overview of Bee Pollination and Its Economic Value for Crop Production," *Insects*, 12(8): 688.

Porto, R.G., de Almeida, R.F., Cruz-Neto, O., Tabarelli, M., Viana, B.F., Peres, C.A. and A.V. Lopes (2020), "Pollination ecosystem services: A comprehensive review of economic values, research funding and policy actions," *Food Security*, 12: 1425-1442.

29 Khalifa, S.A.M., Elshafiey, E.H., Shetaia, A.A., Abd El-Wahed, A.A., Algethami, A.F., Musharraf, S.G. et al. (2021), "Overview of Bee Pollination and Its Economic Value for Crop Production," *Insects*, 12(8): 688;

Reilly, J.R., Artz, D., Biddinger, D., et al. (2020, July 29), "Crop production in the USA is frequently limited by a lack of pollinators", *Proceedings of the Royal Society Biological Sciences*, 287(1931).

30 Potts, S.G., Biesmeijer, J.C., Kremen, C., Neumann, P., Schweiger, O. and W.E. Kunin (2010), "Global pollinator declines: trends, impacts and drivers," *Trends in Ecology & Evolution,* 25(6): pp345-353.

31 Xerces Society for Invertebrate Conservation (n.d.), "The risks of pesticides to pollinators", online: https://www.xerces.org/pesticides/risks-pesticides-pollinators, viewed in April 2024;

Rondeau, S. (2022, July), "Fungicides and bees: a review of exposure and risk ", *Environment International*, 165(107311);

Pesticide Action Network UK (2021, October), *Herbicides: A Threat to Bee and Pollinator Survival*, Brighton, UK: PAN UK.

32 Puglisi, E. (2012), "Response of microbial organisms (aquatic and terrestrial) to pesticides", *EFSA Supporting Publications*, *9*(11), 359E;

Gunstone, T., Cornelisse, T., Klein, K., Dubey, A., & Donley, N. (2021), "Pesticides and soil invertebrates: A hazard assessment", *Frontiers in Environmental Science*, *9*, 643847.

33 Pesticide Action Network International (2021, March), *PAN International List of Highly Hazardous Pesticides*, Hamburg, Germany: PAN International.

34 Donley, N. (2022, September 29), "How the EPA's lax regulation of dangerous pesticides is hurting public health and the US economy", Brookings, online: https://www.brookings.edu/articles/how-the-epas-lax-regulation-of-dangerous-pesticides-is-hurting-public-health-and-the-us-economy/, viewed in March 2024.

35 DiBartolomeis, M., Kegley, S., Mineau, P. Radford, R. and K. Klein (2019, August 6), "An assessment of acute insecticides toxicity loading (AITL) of chemical pesticides used on agricultural land in the United States", *PLoS ONE*, 14(8): e0220029.

36 Battisti, L., Potrich, M., Sampaio, A.R. et al. (2021, May), "Is glyphosate toxic to bees? A meta-analytical review", *Science of the Total Environment*, 767(145397);

Abraham, J., Benhotons, G.S., Krampah, I. et al. (2018, July 5), "Commercially formulated glyphosate can kill non-target pollinator bees under laboratory conditions", *Entomologia Experimentalis et Applicata*, 166(8): 695-702;

University of California (n.d.), "Bee precaution pesticide ratings", UC IPM, online: https://ipm.ucanr.edu/bee-precaution-pesticide-ratings/, viewed in May 2024.

37 Tabacek, K. (2023, May 17), "EU exporting over 10,000 tonnes of banned bee-killing pesticides a year, investigation finds," online: https://www.greenpeace.org.uk/news/eu-exporting-over-10000-tonnes-of-banned-bee-killing-pesticides-a-year-investigation-finds/, viewed in April 2024.

38 European Academies Science Advisory Council (EASAC) (2023, February), *Neonicotinoids and their Substitutes in Sustainable Pest Control*, p3.

39 Mitchell, E.A.D., Mulhauser, B., Mulot, M. Mutabazi, A., Glauser, G. and A. Aebi (2017), "A worldwide survey of neonicotinoids in honey," *Science*, 358(6359), pp109-111.

40 Gunstone, T., Cornelisse, T., Klein, K., Dubey, A., & Donley, N. (2021), Pesticides and soil invertebrates: A hazard assessment. *Frontiers in Environmental Science*, *9*, 643847.

41 United States Environmental Protection Agency (n.d.), "EPA Actions to Protect Pollinators," online: https://www.epa.gov/pollinator-protection/epa-actions-protect-pollinators, viewed in April 2024.

42 Tooker, J.F., Douglas, M.R. and C.H. Krupke (2017), "Neonicotinoid seed treatments: limitations and compatibility with Integrated Pest Management", *Agricultural and Environmental Letters*, 2.

43 Public Eye (2020, February 20), "Pesticide giants make billions from bee-harming and carcinogenic chemicals", online: https://www.publiceye.ch/en/media-corner/press-releases/detail/pesticide-giants-make-billions-from-bee-harming-and-carcinogenic-chemicals, viewed in April 2024.

44 European Commission (n.d.), "Some facts about neonicotinoids," online: https://food.ec.europa.eu/plants/pesticides/approval-active-substances/renewal-approval/neonicotinoids_en, viewed in April 2024.

45 United States Environmental Protection Agency (EPA) (2019, 18 April), *Glyphosate: Response to Comments, Usage, and Benefits*, Washington DC, US: EPA.

46 Pesticide Use Data System (PUDS) drawing on USDA QuikStat data accessed at https://hygeia-analytics.com/pesticides/usage/puds-the-pesticide-use-data-system/

47 International Agency for Research on Cancer (2018, July 19), “IARC monograph on glyphosate”, online: https://www.iarc.who.int/featured-news/media-centre-iarc-news-glyphosate/, viewed in May 2024.

48 Environmental Working Group (online). Americans at Greater Risk of Glyphosate Exposure than Europeans. https://www.ewg.org/news-insights/news/americans-greater-risk-glyphosate-exposure-europeans#:~:text=Americans%20are%20more%20likely%20than,forages%20derived%20from%20such%20crops.%E2%80%9D

49 Simon, G. (2023, March 21), *Glyphosate-based Herbicides & Their Impacts on Bees’ Health*, Brussels, Belgium: Pesticide Action Network Europe;

Battisti, L., Potrich, M., Sampaio, A.R., de Castilhos Ghisi, N., Costa-Maia, F.M., Abati, R., Bueno dos Reis Martinez, C., and S.H. Sofia (2021, 1 May), “Is glyphosate toxic to bees? A meta-analytical review,” *Science of the Total Environment*, 767;

Druille, M., Cabello, M.N., Omacini, M., Golluscio R.A. (2013), Glyphosate reduces spore viability and root colonization of arbuscular mycorrhizal fungi, *Applied Soil Ecology*. 64: 99–103;

Yamada, T., Kremer, R., Castro, P. and Wood, B. (2009), Glyphosate interactions with physiology, nutrition, and diseases of plants: Threat to sustainability. *European Journal of Agronomy*. 31(3): 111-113;

Gaupp-Berghausen, M., Hofer, M., Rewald, B. and Zaller, J.G. (2015), Glyphosate-based herbicides reduce the activity and reproduction of earthworms and lead to increased soil nutrient concentrations. *Scientific Reports*. 5: 12886;

Dobberstein, J. (2017, October 28), “Is Glyphosate harming your no-tilled soil?”, *No-Till Farmer*, online: https://www.no-tillfarmer.com/articles/7169-is-glyphosate-harming-your-no-tilled-soils?v=preview, viewed in April 2024.

50 Cimino, A.M., Boyles, A.L., Thayer, K.A. and M.J. Perry (2017), “Effects of Neonicotinoid Pesticide Exposure on Human Health: A Systematic Review,” *Environmental Health Perspectives*, 125(2): 155-162.

51 Mourtzinis, S., Krupke, C.H., Esker P.D. et al. (2019, September 9), “Neonicotinoid seed treatments of soybean provide negligible benefits to US farmers”, *Nature Scientific Reports*, 9(11207).

52 US Department of Agriculture (USDA) (2024), “Adoption of genetically engineered crops in the United States, 1996–2023”, online: https://www.ers.usda.gov/webdocs/charts/58020/biotechcrops2023_d.html?v=9147.1, viewed in April 2024.

53 Jefferies, D. (2022, October 28), “A potentially cancer-causing chemical is sprayed on much of America’s farmland. Here is where it is used the most,” *NBC News*, online: https://www.nbcnews.com/data-graphics/toxic-herbicides-map-showing-high-use-state-rcna50052, viewed in April 2024.

54 Lin, C-H., Sponsler, D.B., Richardson, R.T., Watters, H.D., Glinski, D.A., Henderson, J.M., Minucci, J.M., Lee, E.H., Purucker, S.T., and R.M. Johnson (2020), “Honey bees and neonicotinoid-treated corn seed: Contamination, exposure, and effects,” *Environmental Toxicology and Chemistry*, 40(4): 1212-1221, p. 1213.

55 Lin, C-H., Sponsler, D.B., Richardson, R.T., Watters, H.D., Glinski, D.A., Henderson, J.M., Minucci, J.M., Lee, E.H., Purucker, S.T., and R.M. Johnson (2020), “Honey bees and neonicotinoid-treated corn seed: Contamination, exposure, and effects,” *Environmental Toxicology and Chemistry*, 40(4): 1212-1221;

Purdue University (2017, May 22), “Corn seed treatment insecticides pose risks to honey bees, yield benefits elusive,” online: https://www.purdue.edu/newsroom/releases/2017/Q2/corn-seed-treatment-insecticides-pose-risks-to-honey-bees,-yield-benefits-elusive.html, viewed in April 2024.

Purdue University (2012, January 11), “Researchers: Honeybee deaths linked to seed insecticide exposure,” online: https://www.purdue.edu/newsroom/research/2012/120111KrupkeBees.html, viewed in April 2024.

Lin, C-H., Sponsler, D.B., Richardson, R.T., Watters, H.D., Glinski, D.A., Henderson, J.M., Minucci, J.M., Lee, E.H., Purucker, S.T., and R.M. Johnson (2020), “Honey Bees and Neonicotinoid-Treated Corn Seed: Contamination, Exposure, and Effects,” *Environmental Toxicology and Chemistry*, 40(4): 1212-1221;

Christopher Cutler, G. C.D. Scott-Dupree, C. D. (2014). A field study examining the effects of exposure to neonicotinoid seed-treated corn on commercial bumble bee colonies. *Ecotoxicology*, *23*, 1755-1763;

Samson-Robert, O., Labrie, G., Chagnon, M., & Fournier, V. (2017), « Planting of neonicotinoid-coated corn raises honey bee mortality and sets back colony development", *PeerJ*, *5*, e3670.

56 Gaudreault, E. (2020), *The impact of neonicotinoid pesticides on wild bees in an intensive agriculture system* (Doctoral dissertation, Université d'Ottawa/University of Ottawa);

Main, A. R., Webb, E. B., Goyne, K. W., Abney, R., & Mengel, D. (2021), "Impacts of neonicotinoid seed treatments on the wild bee community in agricultural field margins", *Science of the Total Environment*, *786*, 147299.

57 US Department of Agriculture (USDA) (n.d.), "Oil crops sector at a glance," online: https://www.ers.usda.gov/topics/crops/soybeans-and-oil-crops/oil-crops-sector-at-a-glance/, viewed in April 2024;

US Department of Agriculture (USDA) (n.d.), "Feed grains sector at a glance," online: https://www.ers.usda.gov/topics/crops/corn-and-other-feed-grains/feed-grains-sector-at-a-glance/, viewed in April 2024;

US Department of Agriculture (USDA) (2015, February), *USDA Coexistence Fact Sheets: Soybeans,* Washington, DC, USA: USDA Office of Communications.

58 Environmental Working Group (2019, March 20), "Apples doused with chemical after harvest," online: https://www.ewg.org/foodnews/apples.php, viewed in April 2024.

59 National Agricultural Statistics Service (NASS) (2016), *2015 Agricultural Chemical Use Survey: Fruit Crops*, USDA.

60 Gerlach, C. (2022), *Industry Outlook 2022,* Falls Church, VA, USA: U.S. Apple Association.

61 Durant, J.L., Goodrich, B., Chang, K.T. and E. Yoshimoto (2020), "Growers follow the label: An analysis of bee-toxic pesticide use in almond orchards during bloom," *California Agriculture,* 75(2): 90-99.

62 US Department of Agriculture (USDA) (2024, January 11), "Cracking Open New Markets for California Almonds," online: https://fas.usda.gov/newsroom/cracking-open-new-markets-california-almonds, viewed in April 2024.

63 Goodrich, B.K. and J.L. Durant (2020), "Going Nuts for More Bees: Factors Influencing California Almond Pollination Fees," *ARE Update,* 24(1): 5-8.

64 Durant, J.L., Goodrich, B., Chang, K.T. and E. Yoshimoto (2020), "Growers follow the label: An analysis of bee-toxic pesticide use in almond orchards during bloom," *California Agriculture,* 75(2): 90-99.

65 Ricke, D.F., Lin, C-H. and R.M. Johnson (2021), "Pollen treated with a combination of agrochemicals commonly applied during almond bloom reduces the emergence rate and longevity of honey bee (Hymenoptera: Apidae) queens," *Journal of Insect Science*, 21(6), p5.

66 FAOSTAT (n.d.), "Total pesticides used in agriculture in the United States of America 2021 in US tons", viewed in April 2024.

67 Hygeia Analytics (n.d.), "PUDS – The Pesticide Use Data System", online: https://hygeia-analytics.com/pesticides/usage/puds-the-pesticide-use-data-system/, viewed in April 2024.

68 US Department of Agriculture Economic Research Service (USDA ERS) (2021. August), "U.S. organic corn and soybean acreage increases but remains less than 1 percent of total", online: https://www.ers.usda.gov/data-products/chart-gallery/gallery/chart-detail/?chartId=101938, viewed in May 2024;

Ag MRC (2021, September), "Apples", online: https://www.agmrc.org/commodities-products/fruits/apples, viewed in May 2024;

Farm Progress (2021, June 2), "Organic almond acreage is increasing", online: https://www.farmprogress.com/tree-nuts/organic-almond-acreage-is-increasing, viewed in May 2024.

69 Center for Food Safety (CFS) (2021, October 25), *Comments on Draft Biological Evaluations for the Neonicotinoid Insecticides Clothianidin, Imidacloprid and Thiamethoxam*, Letter to the U.S. Environmental Protection Agency (EPA).

70 Wieben, C.M. (2020), "Estimated annual agricultural pesticide use by major crop or crop group for states of the conterminous United States, 1992-2017", ver. 2.0, *U.S. Geological Survey Data Release*.

71 Mineau, P. (2014, October), *Pesticide Risk Tool (PRT). Acute Pollinator Index White Paper*.

72 McArt, S.H., Fersch, A.A., Milano, N.J., Truitt, L.L. and K. Böröczky (2017), "High pesticide risk to honey bees despite low focal crop pollen collection during pollination of a mass blooming crop," *Scientific Reports*, 7.

73 Douglas, M.R. and J.F. Tooker (2015), “Large-scale deployment of seed treatments has driven rapid increase in use of neonicotinoid insecticides and preemptive pest management in U.S. field crops”, *Environmental Sci. Technol*., 49(8): 5088-97;

Hitaj, C., Smith, D.J., Code, A., Wechsler, S., Esker, P.D., Douglas, M.R. (2020), “Sowing uncertainty: What we do and don’t know about the planting of pesticide-treated seed”, *BioScience,* 70: 390–403.

74 Profundo estimates based on:

US Department of Agriculture (USDA) (n.d.), “National agricultural statistics service”, online: https://www.nass.usda.gov/, viewed in April 2024;

US Department of Agriculture (USDA) (n.d.), “Production, supply, distribution”, online: https://apps.fas.usda.gov/psdonline/app/index.html, viewed in April 2024;

US Department of Agriculture Economic Research Service (USDA ERS) (n.d.), “Food availability per capita system”, online: https://www.ers.usda.gov/data-products/food-availability-per-capita-data-system/, viewed in April 2024.

75 US Department of Agriculture (USDA) (n.d.), “Production, supply, distribution”, online: https://apps.fas.usda.gov/psdonline/app/index.html, viewed in April 2024.

76 Agricultural Marketing Resource Centre (2021, September), “Apples”, online: https://www.agmrc.org/commodities-products/fruits/apples, viewed in April 2024.

77 Agricultural Marketing Resource Centre (2021, September), “Almonds”, online: https://www.agmrc.org/commodities-products/nuts/almonds, viewed in April 2024.

78 California Almonds (2023, November), “California almond acreage drops again in 2023”, online: https://www.almonds.com/about-us/press-room/california-almond-acreage-drops-again-2023¸ viewed in April 2024.

79 US Department of Agriculture Economic Research Service (n.d.), “Weekly retail food sales”, online: https://www.ers.usda.gov/data-products/weekly-retail-food-sales/, viewed in April 2024.

80 Ag MRC (2021, September), "Apples", online: https://www.agmrc.org/commodities-products/fruits/apples, viewed in April 2024;

Farm Progress (2021, June 2), "Organic almond acreage is increasing", online: https://www.farmprogress.com/tree-nuts/organic-almond-acreage-is-increasing, viewed in April 2024;

United Egg Producers (n.d.), "Facts & stats", online: https://unitedegg.com/facts-stats/, viewed in April 2024;

Meat & Poultry (2020, April 20), "Organic meat demand continues to grow", online: https://www.meatpoultry.com/articles/22971-organic-meats-demand-continues-to-grow, viewed in April 2024.

81 For example, Pimentel, D. (2004), “Environmental and economic costs of the application of pesticides primarily in the United States”, *Environment, Development and Sustainability*, 7: 229-252.

82 Tang, F.H.M., Lenzen, M., McBratney, A. and F. Maggi (2021), “Risk of pesticide pollution at the global scale”, *Nature Geoscience*, 14: 206–210.

83 Based on a survey FOE commissioned from YouGov, online: https://docs.cdn.yougov.com/fsfz3hb9u6/Topline-Only-Results%20for%20Friends%20of%20The%20Earth%20(Pesticides%20and%20Pollinators)%20128%206.3.2021.pdf, viewed June 2024.

84 White, N. (2022, 12 December), “Investors with $3 trillion launch nature-protection campaign“, *Bloomberg*, online: https://www.bloomberg.com/news/articles/2022-12-11/investors-with-3-trillion-launch-nature-protection-campaign?leadSource=uverify%20wall#xj4y7vzkg, viewed in April 2024.

85 Rijk, G., Steinweg, T. and M. Piotrowski, (2020, 9 May), *Deforestation-Driven Reputation Risk Could Become Material for FMCGs*, Washington DC, US: Chain Reaction Research.

86 Rijk, G., Wiggs, C., and M. Piotrowski (2020, 2 July), *FMCGs’ Lagging Efforts in NDPE Execution Lead to Deforestation, USD 16-82B Reputation Risk*, Washington DC, US: Chain Reaction Research.

87 Bhopal, R. (2021, November 9), “Pesticides And Climate Change”, Pesticides Action Network North America, online: https://www.panna.org/news/pesticides-and-climate-change/, viewed in April 2024.

88 Ramona Cech, Friedrich Leisch, and Johann G. Zaller (2022, 17 June), “Pesticide use and associated greenhouse gas emissions in sugar beet, apples, and viticulture in Austria from 2000 to 2019 “, online: https://www.mdpi.com/2077-0472/12/6/879, viewed in April 2024.

89 Grist (2008, 26 March), “A factor of 3.67 makes a big difference when discussing climate”, online: https://grist.org/article/the-biggest-source-of-mistakes-carbon-vs-carbon-dioxide/, viewed in April 2024.

90 Wyckhuys, K.A.G., Furlong, M.J., Wei Zhang and D. Yubak (2022, 5 May), “Carbon benefits of enlisting nature for crop protection”, *Nature Food*, Vol. 3: 2099-301.

91 Public Eye (2020, 20 February), “Pesticide giants make billions from bee-harming and carcinogenic chemicals”, online: https://www.publiceye.ch/en/topics/pesticides/pesticide-giants-make-billions-from-bee-harming-and-carcinogenic-chemicals, viewed in April 2024.

92 Syngenta AG (2023, May), *ESG Report 2022*, p. 56, note 13.

93 Wyckhuys, K.A.G., Furlong, M.J., Wei Zhang and D. Yubak (2022, 5 May), “Carbon benefits of enlisting nature for crop protection”, *Nature Food*, Vol. 3: 2099-301.

94 IMF (2022, June 1), “The great carbon arbitrage”, online: https://www.imf.org/en/Publications/WP/Issues/2022/05/31/The-Great-Carbon-Arbitrage-518464, viewed in April 2024.

95 Pham Van, L. and G. Rijk (2022, April), *European Big Oil – Big Liability in Carbon, Pollution and Health Care Costs*, Amsterdam, Netherlands: Profundo, report commissioned by Transport & Environment.

96 Rijk, G. and B. Kuepper (2023, July), *€ 0.7 Billion in Profits, € 66 Billion in Damages*, Amsterdam, Netherlands: Profundo, report commissioned by Greenpeace Netherlands.

97 The World Bank, “Carbon Pricing Dashboard”, online: https://carbonpricingdashboard.worldbank.org/map_data, viewed in April 2024.

98 Trading Economics (n.d.), “Carbon”, online: https://tradingeconomics.com/commodity/carbon, viewed in in March 2024.

99 Rijk, G., Kuepper, B., Boev, P. and D. Quiroz (2024, April), *Unilever’s Climate Bill: € 268 Billion,* report commissioned by Milieudefensie.

100 Kikstra, J.S., Waidelich, P., Rising, J., Yumashev, D., Hope, C. and C.M. Brierley (2021, September 6), “The social cost of carbon dioxide under climate-economy feedbacks and temperature variability”, *Environmental Research Letters*, 16: 094037.

101 UCL News (2021, September 6), “Economic cost of climate change could be six times higher than previously thought”, online: https://www.ucl.ac.uk/news/2021/sep/economic-cost-climate-change-could-be-six-times-higher-previously-thought, viewed in April 2024.

102 CE Delft (2023, February), *Handboek Milieuprijzen 2023*;

Brink, C., A. Trinks, H. Vollebergh, P. Zwaneveld (2023, October), *Afschaffing fossiele-energiesubsidies: Eerder een hersenkraker dan een no-brainer*, The Hague, Netherlands: PBL.

103 Brink, C. And H. Vollebergh (2024, February), *Klimaatverandering in de prijzen in 2022 met een doorkijk naar 2030*, The Hague, Netherlands: PBL.

104 CE Delft (2023, February), *Handboek Milieuprijzen 2023*, p. 248.

105 Ecosystem Services Valuation Database (ESVD), online: https://www.esvd.net/#:~:text=The%20Ecosystem%20Services%20Valuation%20Database%20%28ESVD%29%20has%20been,nature%20conservation%2C%20ecosystem%20restoration%20and%20sustainable%20land%20management, viewed in April 2024.

106 UN Sustainable Development Goals, (2019, 6 May), “UN Report: Nature’s dangerous decline ‘unprecedented’; Species extinction rates ‘accelerating’”, online: https://www.un.org/sustainabledevelopment/blog/2019/05/nature-decline-unprecedented-report, viewed in April 2024.

107 Food and Agriculture Organization of the United Nations (FAO), (2022), *Protecting Pollinators from Pesticides*, Rome, Italy: FAO.

108 DiBartolomeis, M., Kegley, S., Mineau, P., Radford, R. and K. Klein (2019, August), "An assessment of acute insecticide toxicity loading (AITL) of chemical pesticides used on agricultural land in the United States", *PLOS ONE*: doi.org/10.1371/journal.pone.0220029.

109 Stanisavljević, L. and U. Partap (2016), *Assessment Report on Pollinators, Pollination and Food Production*, Bonn, Germany: IPBES.

110 Based on:

Díaz, S., Settele, J., Brondízio, E.S. et al. (2016), *Summary for Policymakers of the Assessment Report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services on Pollinators, Pollination and Food Production*, Bonn, Germany: IPBES;

Klein, A.M., Vaissière, B.E., Cane, J.H. et al. (2006, October), "Importance of pollinators in changing landscapes for world crops", *Proceedings of the Royal Society Biological Sciences,* Vol. 274(1608);

Ritchie, H. (2021, August), "How much of the world's food production is dependent on pollinators?", Our World in Data, online: https://ourworldindata.org/pollinator-dependence, viewed in April 2024;

UN Environmental Programme (UNEP) (2022, 18 May), "Why bees are essential to people and planet", online: https://www.unep.org/news-and-stories/story/why-bees-are-essential-people-and-planet, viewed in April 2024;

Brandizio, E.S., Settele, J., Días, S. and H.T. Ngo (eds.) (2019), *The Global Assessment Report on Biodiversity and Ecosystem Services,* Bonn, Germany: IPBES.

111 DiBartolomeis, M., Kegley, S., Mineau, P., Radford, R. and K. Klein (2019, August), "An assessment of acute insecticide toxicity loading (AITL) of chemical pesticides used on agricultural land in the United States", *PLOS ONE*: doi.org/10.1371/journal.pone.0220029.

112 World Economic Forum (WEC) (2020, January), *Nature Risk Rising: Why the Crisis Engulfing Nature Matters for Business and the Economy*, Geneva, Switzerland: WEC.

113 Johnson, J. A., Ruta, G., Baldos, U. et al. (2021), *The Economic Case for Nature*, Washington DC, US: The World Bank Group.

114 Johnson, J. A., Ruta, G., Baldos, U. et al. (2021), *The Economic Case for Nature*, Washington DC, US: The World Bank Group.

115 UN Environment Programme (UNEP), World Health Organization (WHO) and Food and Agriculture Organization of the United Nations (FAO) (2022, March), *The Environmental, Human Health and Economic Impacts of Pesticides*, Chapter 5.

116 IPBES (2017), "The assessment report on pollinators, pollination and food production", viewed in April 2024.

117 Smith, M.R. et al. (2022, December 14), "Pollinator deficits, food consumption, and consequences for human health: A modeling study", *Environmental Health Perspectives*, Vol. 130(12).

Appendix 1 Pesticides with high environmental toxicity

Pesticides identified as environmentally toxic the PAN List of Highly Hazardous Pesticides (PAN International List of HHPs, 2021) and reported as being applied to soy, corn, apples and/or almonds in Pesticide Use Data System (PUDS) data.

Table 28 Pesticides with high environmental toxicity (PHET)

Abamectin*	Cypermethrin*	Permethrin*
Acephate*	Diazinon*	Phosmet*
Alpha cypermethrin*	Emamectin benzoate*	Propargite
Aluminum phosphide*	Esfenvalerate*	Pyrethrins*
Azinphos-methyl*	Fenbutatin-oxide	Pyridaben*
Beta-cyfluthrin*	Fenpropathrin*	Spinetoram*
Bifenthrin*	Flupyradifurone*	Spinosad*
Carbaryl*	Imidacloprid*	Sulfoxaflor*
Chlorantraniliprole	Indoxacarb*	Tebupirimifos
Chlorpyrifos*	Lambda-cyhalothrin*	Tefluthrin*
Clothianidin*	Methidathion*	Thiamethoxam*
Copper hydroxide	Methomyl*	Trifluralin
Cyfluthrin*	Pendimethalin	Zeta-cypermethrin*

Note: * toxic to bees

Profundo
Research & advice

Radarweg 505
1043 NZ Amsterdam
The Netherlands
+31-20-8208320
profundo@profundo.nl
www.profundo.nl