Pesticides and the Climate Crisis: A Vicious Cycle

PESTICIDE ACTION NETWORK UK

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THE PESTICIDE COLLABORATION

Contents

Executive Summary

Climate change is one of the greatest challenges facing humanity today. Scientific evidence indicates that pesticides contribute significantly to greenhouse gas emissions while also making our agricultural systems more vulnerable to the effects of climate change. However, the reduction of synthetic pesticide use has been omitted from climate change solutions, and synthetic pesticide use is even presented as a climate change mitigation strategy by industrial agriculture interests.

Pesticides contribute to climate change throughout their lifecycle via manufacturing, packaging, transportation, application, and even through environmental degradation and disposal. Importantly, 99% of all synthetic chemicals — including pesticides — are derived from fossil fuels, and several oil and gas companies play major roles in developing pesticide ingredients.[1] Other chemical inputs in agriculture, such as nitrogen fertiliser, have rightly received significant attention due to their contributions to greenhouse gas emissions. Yet research has shown that the manufacture of one kilogram of pesticide requires, on average, about 10 times more energy than one kilogram of nitrogen fertiliser.[2,3] Like nitrogen fertilisers, pesticides can also release greenhouse gas emissions after their application, with fumigant pesticides shown to increase nitrous oxide production in soils seven to eight-fold. Many pesticides also lead to the production of ground-level ozone, a greenhouse gas harmful to both humans and plants. Some pesticides, such as sulfuryl fluoride, are themselves powerful greenhouse gases, having nearly 5,000 times the potency of carbon dioxide.

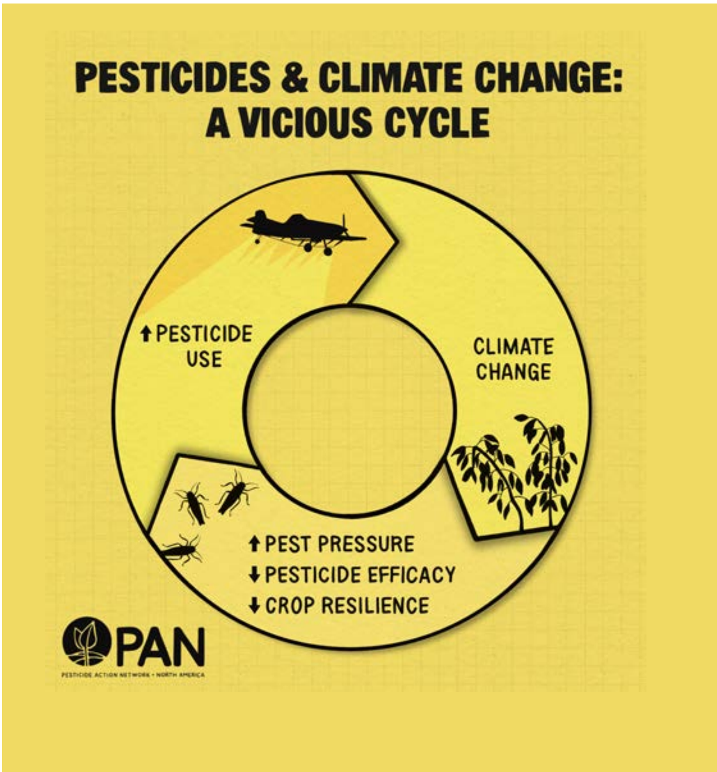
Meanwhile, climate change impacts are expected to lead to increases in pesticide use, creating a vicious cycle between chemical dependency and intensifying climate change (see Figure 1). Research shows that declining efficacy of pesticides, coupled with increases in pest pressures associated with a changing climate, will likely increase synthetic pesticide use in conventional agriculture. An increase in pesticide use will lead to greater resistance to herbicides and insecticides in weeds and insect pests, while also harming public health and the environment. The effects of higher synthetic pesticide use will disproportionately impact populations already under stress from a wide range of climate change effects, such as higher summer temperatures and milder, wetter winters.

Adoption of alternative agricultural systems such as agroecological farming minimises or eliminates synthetic pesticide use while increasing the resilience of our agricultural systems to better withstand climate change impacts. Agroecology is a way of farming rooted in social justice that focuses on working with nature rather than against it. It relies on ecological principles for pest management, minimizing the use of synthetic pesticides and adopting nature friendly solutions that prioritise the decision-making power of farmers and agricultural workers. In terms of dealing with pests, weeds and diseases, the approach known as Integrated Pesticide Management (IPM) is key to agroecology. Under IPM, chemical pesticides are used only as a last resort, if at all. IPM strategies based on sound agroecological science help prevent pest organisms from reaching problematic levels where they start to cause economic damage to the farmer. Agroecology and diversified organic agriculture, when paired with social justice principles, have been shown to have significant climate benefits, while supporting the health and rights of agricultural workers and protecting natural ecosystems.

The UK government must take action to reduce the contribution of pesticides to greenhouse gas emissions and improve the climate resilience of food and farming systems. To accomplish this, the UK government should:

- take a more joined-up approach to transforming agriculture in order to tackle the climate and nature crises
- introduce ambitious pesticide reduction targets
- support farmers to adopt Integrated Pest Management (IPM)
- implement a ban on the use of pesticides in urban areas
- For a full list of recommendations, see page 13.

Figure 1



Introduction

Pesticides: The foundation of industrial agriculture

In modern industrial agriculture, farm operations are viewed as ecologically simplified systems with highly controlled and monetised inputs (pesticides, fertilisers and seeds) and outputs (crops). In the absence of highly diverse and vigorous plant and soil ecosystems that provide necessary crop nutrients and natural controls of pests and diseases, these "conventional" agricultural systems rely on regular inputs of synthetic pesticides and fertilisers. The primary objective of conventional agriculture is to maximise short-term profits through increased yields and sales while minimising internal costs (e.g. labour) and ignoring external costs. The most obvious external costs ignored by industrial agriculture are associated with human health impacts[4,5] and the degradation of ecosystem services such as clean air, water and healthy soil.

Agricultural policies and export-focused agriculture continue to aggressively promote the production of chemical-intensive commodity crops. Commodity crops are those produced primarily for trade in large-scale international markets, such as maize, rice, soybeans, wheat and cotton.[6] These crops are among those with the greatest use of pesticides and fertilisers globally.[,] The United Nations Food and Agriculture Organization reported global pesticide use in 2020 at about 2.7 million tonnes (UK total for 2020 is 13,018 tonnes) of pesticide active ingredients, with herbicide use at about 1.4 million tonnes (UK total 6,101 tonnes), fungicides and bactericides at 0.6 million tonnes (UK total 4,869 tonnes) and insecticides at 0.5 million tonnes (UK total 147 tonnes) (see Table 1).[7,8] Pesticide active ingredients are the chemicals in a pesticide formulation meant to control the target pest, while pesticide inert ingredients help the overall performance of the pesticide. Only pesticide active ingredients must legally be publicly disclosed on pesticide labels. Inert ingredients are considered company proprietary information, even though many are toxic chemicals. As Table 1 displays, while the use of pesticides overall increased 17% between 2005 and 2020, herbicide use increased 34%, with China, the U.S., Argentina, Thailand and Brazil as the top pesticide consumers.[9] These pesticide use figures likely underestimate actual use significantly due to issues of underreporting and unrecorded use, including the fact that pesticides applied as seed treatments tend not to be regulated and are not included in the UN Food and Agriculture database.

In 2020, the UK used over 13,018 tonnes of pesticide active ingredients. Cereal crops (including wheat, barley and oats) accounted for some 8,409 tonnes of this total, approximately 65% of all pesticides used. Other significant users of pesticides in the UK in terms of crops are oilseeds (including oil seed rape and linseed) which accounted for 1,123 tonnes of active substance (9%) and potatoes which used 1,936 tonnes of active substance (15%), 1,307 tonnes of which were fungicides.[10] One of the most widely used active substances was the herbicide, glyphosate. A total of 2,602 tonnes of glyphosate was sprayed on all UK crops in 2020, a figure that ignores the large amount that is used in other areas such as towns and cities and private gardens.[11] Glyphosate is known to present a long-term health risk to humans and is increasingly being shown to be harmful to biodiversity and the wider environment.[12]

The human and biodiversity impacts of pesticides use

Health impacts from exposure to hazardous pesticides include both acute illnesses such as skin rashes, gastro-intestinal and respiratory illnesses, and central nervous system problems. In addition, pesticide exposure is associated with many chronic diseases, including cancers, reproductive and developmental disorders and long-term neurological dysfunction. A recent review of acute pesticide poisoning cases in 141 countries estimated that about 385 million cases of unintentional, acute pesticide poisoning occur annually worldwide, including around 11,000 fatalities.[13] Based on a global farming population of approximately 860 million, this means that about 44% of farmers are poisoned by pesticides every year.[14]

In addition to farmers, those most directly affected by the use of

Table 1. Pesticide use in 2005 and 2020

Geographic Area	Pesticide	2005 tonnes	2020 tonnes	% increased change
World	Pesticides (total)	2,280,626	2,661,124	16.7
World	Herbicides	1,043,223	1,397,465	34.0
World	Insecticides	470,360	471,238	0.2
World	Fungicides and Bactericides	529,860	605,986	14.4

Source: **Food and Agriculture Organization of the United Nations. FAOSTAT Online Database. https://www.fao.org/faostat/en/#data/RP. Accessed on Sept. 7, 2022.**

Note: The totals also include pesticide groups not listed, such as mineral oils and rodenticides. Not all countries provide data for all pesticide groups in the FAO database.

hazardous pesticides in agriculture include agricultural workers and residents of rural communities, including farmers' families. For people not living adjacent to or working directly with pesticides, the primary routes of exposure to hazardous pesticides are the food they eat and the water they drink. Urban residents can also be exposed to pesticides in public spaces such as parks and pavements, since herbicides are routinely sprayed by local councils and other land managers. Because children eat, drink and breathe more per kilogram of bodyweight than adults, and because their bodies are actively developing, they are particularly vulnerable to pesticides in their environments and in their food.[15]

For farmworkers, primary routes of exposure are from pesticides in the air, contact with pesticide residues on crops, or when mixing, loading or applying pesticides. The effects of exposure are exacerbated by effects of climate change such as high heat, which leads to heat stress and makes the human body more susceptible to pesticides, increasing the risk of long and short-term health effects.[16] In hot weather, agricultural workers are faced with the tradeoff between increased heat stress from wearing gear to protect themselves from pesticides and not using protective gear to lower their body temperature.

Pesticides also harm the biodiversity that our agricultural systems and natural world depend upon. They have been long known to directly poison or lead to population declines of birds, mammals, amphibians and beneficial plant and insect species. They are now widely recognised to be among the top drivers of biodiversity losses worldwide. In the UK, there has been a 50% decrease in farmland bird numbers since the 1970s.[17] There have also been huge decreases in insect abundance and diversity, including key pollinator species such as bees and butterflies, as much as 60% according to some studies.[18] UK mammals, such as hedgehogs, are seeing ongoing declines. The overuse of herbicides is adding to the depletion of our already threatened wildflower species. The UK has lost 95% of its wildflower meadows since 1945 due to landscape use changes which include the expansion of industrial agriculture.[19]

Neonicotinoids, a type of insecticide, have received public attention due to their significant harm to pollinators, like honey bees. Honey bees play essential roles in pollinating agricultural crops. The service they provide to pollinating crops has been estimated to be worth approximately £691 million per year for the UK.[20] Pesticides also have profound effects on soil macro- and micro- fauna, which in turn impact the long-term structure and function of agricultural soil. For example, the use of insecticides and other pesticides can result in the death of soil invertebrates like earthworms.[21] Soil invertebrates are crucial in creating structure and aeration in soils and in preventing soil compaction, roles that help soil retain water and perform other desirable functions.[22]

Climate Policy and Solutions Ignores Pesticides

Globally, food systems account for over one-third of all greenhouse gas (GHG) emissions, with 31% of that from agricultural production, including the production of associated inputs like pesticides.[23] While agriculture's contributions to climate change are increasingly recognised in public policy, there are two glaring issues with current approaches to the problem.

First, the role of pesticides in GHG emissions is infrequently addressed, and farming solutions like agroecology and IPM that would reduce their impact are rarely considered. For example, certain practices labeled climate-smart, such as no-till, often rely heavily on synthetic herbicides to control weeds on conventional farms and can lead to increased weed resistance to herbicides. In the UK, the weed 'black-grass' has developed resistance to a number of key herbicides.[24] Resistance was first seen in 1982 and has since spread so that there are now black-grass resistant populations in every county of England and, to a lesser extent, Scotland and Wales. While glyphosate resistant weeds have been seen in the USA for many years,[25] the UK is now also starting to see glyphosate resistant species developing.[26] This was first noted in 2018 and, whilst at the moment is not widespread, there are serious concerns among some in the farming community that resistance is likely to increase over the coming years if the issue is not addressed. Climate solutions that rely on herbicides tend to ignore this serious and increasing problem.

The second key issue is that many proposed solutions to climate change would not result in meaningful GHG emission reductions, or would further exacerbate inequities in food and farming. For example, both in the UK and globally, far too much focus is put on precision agriculture, which promises to reduce the use of petroleum-derived pesticides and fertilisers by using computer-aided technologies to more accurately determine need (pest presence) and then more accurately apply pesticides to intended targets. Whilst there is a place for innovation of this type, it is certainly not the silver bullet that it is presented as. Precision agriculture is often expensive, only available to a very limited number of farmers or areas and maintains a system dependent upon chemical and energy-intensive technologies and materials, while diverting attention from and investment in more effective climate-friendly strategies in agriculture that have additional social and public health co-benefits, such as agroecology. Precision agriculture also increases the power and control of agrochemical companies, many of which own the precision agriculture platforms and the data inputted by farmers. Policy makers should recognise that low-tech, nature-based solutions that support agroecology and IPM will be more beneficial for farmers and the planet if adopted and supported whilst still being innovative.

Another flawed solution, carbon markets, allows agribusinesses or farmers to sell carbon credits to corporations to "offset" continued greenhouse gas emissions — perpetuating reliance on fossil fuels. Carbon markets have a poor track record in terms of long-term climate mitigation, and have been shown to worsen economic disparities.[27]

In contrast, farming systems that do not rely on use of synthetic pesticides, such as those based on agroecological principles or diversified organic farming, can reduce GHG emissions and increase carbon sequestration. They also increase farm resilience to climate change and pests by enhancing many ecosystem services, such as water quality and water availability to crops, soil health, crop resilience to pests and disease, and greater pollinator and natural pest control resources. Utilising ecological pest and crop management practices reduces the need for petroleum-derived pesticides and fertilisers, and therefore reduces associated emissions of greenhouse gases. Public policy should support demonstrably effective, ecologically based practices that mitigate climate change while also making farms and rural communities more resilient as climate conditions change.[28] Beyond practice change, ultimately a societal transformation of agricultural systems is urgently needed to avert further exacerbation of today's climate, food and biodiversity crises. International experts agree that, unlike incrementalist tweaks that leave a fundamentally fossil-fuel dependent system in place, agroecology offers a transformative approach.[29]

Impacts of Climate Change on Pests and Pesticide Use

Scientists expect climate change to dramatically alter how toxic chemicals like synthetic pesticides are used, adversely impacting the environment and public health. Research detailed below shows that the effects of our changing climate will likely lead farmers to increase the use of synthetic pesticides unless we begin to transition toward safer forms of agriculture that use smaller-scale, diversified agroecological practices.

How agricultural pests will respond to climate change

Climate change is expected to have variable effects on agricultural pests, depending on regional climatic changes, type of cropping systems and type of pest. Pressure from agricultural pests — including insects, other animals, weeds and diseases that impact crop productivity — can increase or decrease depending on regional climatic shifts, such as changes in precipitation and temperature.

i) Declining crop resilience

The latest science demonstrates that in the era of rising temperatures, crop resilience (the crops' ability to withstand external forces, such as climate impacts or pests) is decreasing on farms, making crops more vulnerable to pests generally.[30] Heat stress and changing rainfall patterns both decrease crop resilience to pests. Drought conditions in particular, which are expected to worsen in many regions, can weaken plants' natural defences against pests, and changes in plant biology due to drought may attract pests. Insects can sense changes that indicate plants are more vulnerable, such as higher plant surface temperatures, leaf yellowing, biochemical changes, and possibly even the sound waves produced when water columns in plant tissue break apart due to water stress. Given that 80% of the world's cropland is rainfed, global crop yield is highly susceptible to changes in rain patterns and the increased pest pressures that can accompany changes in precipitation.

ii) Shifting pest populations and reach

In addition to decreasing crop resilience, higher global temperatures will likely stimulate a general increase in the rate of insect development and population growth in certain regions. There are already reports of certain crops in the UK extending their northern range as the climate changes, which means that their associated pests and diseases will potentially impact previously unaffected areas. A recent report suggests that due to reduced rainfall and higher temperatures it might become impossible to graze livestock on pasture in the southern half of the UK by 2100.[31] Rising temperatures and shifts in moisture levels can increase or shift insect pests' geographic range and their ability to survive through the winter.[32] Researchers have predicted that rising CO_2 and temperature will accelerate insect pests' metabolism and consumption, ultimately leading to declining crop yields.

In a report published by the UK Government in 2021, It is clearly stated that climate change is already having an impact on the ability of the UK to maintain food security. The following passage identifies some of the main issues that are currently faced; *"As a consequence of unusual weather patterns linked to climate change, wheat yields in 2018 were 7% below the 2016 to 2020 average, and 17% down in 2020. Total economic losses for wheat, potatoes and oilseed rape in the UK caused by ozone were calculated to be £185 million in 2018, with more than 97% of those losses occurring in England. Based on modelling by the Met Office, significant future risks to UK food production include heat stress to livestock, drought, pests and pathogens, and increased soil erosion risks."*[33]

iii) Impacts on pests' natural enemies

Scientists predict climate change will negatively affect certain natural enemies of insect pests (also referred to as beneficials), further increasing crops' susceptibility to insect pest damage. For instance, climate change could cause insect pests to migrate to new areas where their natural enemies may be unable to follow, or the synchronisation between the life cycles of pests and their natural enemies may be disrupted. Pesticide applications are known to be harmful to beneficial organisms that control pest populations, and predicted increases in pesticide applications would further reduce these beneficial populations. Specific impacts of a changing climate on these interactions between pests and beneficials are often regional- and cropping system-dependent.

iv) Increase In weeds

Researchers have also predicted that changing environmental conditions, such as CO_2 and temperature increases, will likely increase weed pressures in cultivated crops. Weeds are more likely to be resilient and better adapted to climate change effects than cultivated crops because they have more diversity in their gene pool and greater ability to physiologically acclimate to different environmental conditions.

Climate change is also anticipated to introduce weeds to new regions and shift the composition of regional weed species, particularly favouring invasive species. Expected increases in herbicide applications would also increase the prevalence of herbicide-resistant weeds.[34] These factors suggest that weeds will have an increased ability to outcompete agricultural crops in many regions, leading to declining yields.

v) Rise in regionalism and unpredictability

Researchers find certain climatic changes affect different pests in different ways. For instance, smaller pests, such as aphids, mites or whiteflies, can be washed away during intense precipitation. In areas that might experience more periods of prolonged precipitation, plant fungal and bacterial diseases are likely to become more common.[35] Therefore, specific regional climatic impacts will have a significant influence on which pests become more prevalent, and more comprehensive research is needed to predict effects for each specific region, crop and pests. However, certain agricultural system shifts, like diversifying our agricultural systems, could serve as universal solutions since they increase ecosystem resilience and therefore agricultural resilience to climate change, regardless of region.

What does this mean for pesticide use under climate change?

The latest science reveals that climate change will likely increase the movement of pesticides away from their intended targets, polluting the environment and endangering public health. Increased temperatures are anticipated to result in more pesticide volatilisation (when pesticides transform into a gas)— meaning more pesticides will end up in our air, rather than on their application target. Volatilisation is a key source of pesticide drift, which can cause pesticide poisoning for anyone exposed to the toxic vapor. An increase in severe rain events is expected to increase pesticide loss to our waterways, with one US study showing concentrations of pesticides in waterways to be 84–2100% higher after 100-year storms as compared to two-year storms.[36]

Climate change is also expected to affect pesticide degradation, or the process by which pesticides break down in the environment. The breakdown products of the pesticide degradation process can either be less toxic or at times more toxic than the original product. Researchers anticipate that certain climate change effects will cause faster pesticide degradation, meaning pesticides will break down faster and become less effective over time. For instance, increasing soil temperatures have been linked to reduced duration of weed control by herbicides because of faster degradation. In contrast, low soil moisture has been linked to slower degradation of herbicides. However, overall, faster pesticide degradation is expected, likely leading to more frequent pesticide applications at higher application rates.[37] These combined factors are expected to contribute to a likely increase (both in volume and frequency) of pesticide use across a variety of products.

< Herbicide and drought damage to cornfield. Credit JJ Gouin / Shutterstock.com

Greenhouse Gas Emissions of Pesticides

In recent decades, the greenhouse gas emissions and other negative environmental impacts of synthetic nitrogen fertilisers have garnered a great deal of attention. Although more nitrogen fertilisers are used in agriculture than pesticides, comparatively little attention has been directed toward the greenhouse gas emissions that result from pesticide production and use. This is despite evidence that manufacturing one kilogram of pesticide active ingredient requires, on average, about 10 times more energy than one kilogram of nitrogen fertiliser.[38,39] As nations seek to mitigate climate change and develop more sustainable agricultural systems, it is crucial to measure and reduce the GHG emissions associated with pesticide use.

Current scientific literature is divided into two focus areas for GHG emissions of pesticides. Some studies focus on the emissions that result from the production, transportation, and field application of pesticides, and other studies focus on the short- and long-term GHG emissions that result from pesticides' interactions with the environment after application. Virtually no studies calculate the GHG emissions of pesticide use over the full life cycle of the chemicals, which likely causes underestimates of true emissions. Research to date also omits the emissions associated with pesticide waste, such as obsolete stockpiles (stockpiles of pesticides that have expired, been made illegal to use or are otherwise unwanted) and their disposal through burning and other methods—practices common in parts of the Global South.

GHG emissions associated with pesticide production, transportation, and field application

The greenhouse gas emissions associated with the production, transportation, and application of pesticides are linked to fossil fuel consumption during these processes. Importantly, 99% of all synthetic chemicals — including pesticides — are derived from fossil fuels, and several oil and gas companies play major roles in developing pesticide ingredients.[40] Since World War II, pesticides have typically been synthesised from petroleum or petroleum by-products. ExxonMobil, ChevronPhillips Chemical and Shell all produce pesticides or their chemical precursors.[41] Many pesticides are also coated in microplastics, which are derived from fossil fuels, to ensure more controlled release of the product. Multiple pesticide corporations self-report high CO_2 equivalent emissions (CO_2e) related to their operations. For instance, 9.8 million tonnes of CO_2e directly or indirectly resulted from Syngenta's operations in 2021. This is equivalent to the annual carbon dioxide emissions of more than 2 million passenger vehicles. Bayer's Crop Science Division, responsible for their pesticide operations, reported that their direct emissions totaled about 2.7 million tonnes of CO_2e in 2021. The company also stated that 8.94 million tonnes of CO_2e emissions were linked indirectly to the company's value chain in 2021, though it did not specify how much of those emissions were related to their Crop Science division.[42]

Although more updated research is needed, researchers have calculated the energy use associated with the production of specific pesticides, which can then be used to estimate CO_2e emissions. The production of herbicides creates between 18.22 and 26.63 kilograms of CO_2e per kilogram produced on average.[43] The production of insecticides creates between 14.79 and 18.91 kilograms CO_2e per kilogram and the production of fungicides creates between 11.94 and 29.19 kilograms CO_2e per kilogram on average.[44] The GHG emissions of glyphosate, the world's most popular herbicide, produces 31.29 kilograms of CO_2e per kilogram while other pesticides produce greater than 40 kilograms CO_2e per kilogram.[45] To put this in perspective, the energy used to produce the amount of glyphosate used globally in 2014 equals the energy needed to fuel about 6.25 million cars for one year.

These estimates of GHG emissions by pesticides only factor in the energy used to produce the active ingredients. A true estimate must also include the energy needed to formulate the pesticide products and manufacture the inert ingredients, which can make up the majority of a product. For instance, inert ingredients make up as much as 50–75% of glyphosate products. More than 500 of these so-called inert ingredients have been or are currently used as active ingredients, yet due to proprietary protections, the identification and volume of these ingredients are kept secret from the public,[46] making it impossible to calculate energy requirements for the manufacture of pesticide products in their entirety.

The transportation and application processes add to the GHG emissions associated with pesticide use. The farther a pesticide must travel to reach its application site and the more times per season that a pesticide is applied, the greater the pesticide use emissions. Pesticide transportation and application produce fewer emissions than pesticide manufacturing, but research shows these emissions are still significant.

Short- and long-term GHG emissions post-pesticide application

GHG emissions that result from pesticide use are not limited to the emissions involved in pesticide manufacturing, transportation and application. Additional emissions result from the release of the pesticide into the environment and the pesticide's subsequent interactions with organisms in the soil and with the atmosphere, both in the short- and long-term.

Some pesticides are themselves greenhouse gases. The fumigant sulfuryl fluoride (used to fumigate commodities during transport and storage), is a powerful greenhouse gas. Emitting just one ton (0.91 tonnes) of sulfuryl fluoride is the equivalent of emitting 4,780 tons (4,336 tonnes) of CO_2.[47] Meanwhile, other pesticides interact with the environment to produce greenhouse gases in a variety of ways. Since often less than 0.1% of applied pesticides reach their target, with the rest ending up on plant leaves, in the soil, in water, or in the air, the implications for GHG emissions of these pesticides' fate (their off-target movement) in the environment is significant.

While the adverse effects of physical soil disturbances such as intensive tillage on soil micro- and macro-organisms has been widely researched and documented, far fewer studies have focused on the impacts of chemical disturbances such as pesticides on soil life. However, studies to date indicate that long-term pesticide use has serious impacts on soil health. Many different pesticides have negative effects on beneficial bacteria and fungi in the soil. These soil microbial and fungal communities play a crucial role in soil carbon sequestration. Research indicates soil microbes are responsible for producing the most stable forms of soil organic carbon that will remain in the soil for long periods of time.[48] Soil microorganisms serve a number of other important functions, such as building healthy soil and by extension healthy crops, and increasing crop resilience. They also regulate carbon and nitrogen cycles that control emissions of carbon dioxide, methane and nitrous oxide (N_2O).

When researchers studied the effects of soil fumigants on N_2O emissions, they found that the use of chloropicrin — a commonly used fumigant approved for use in the US but never approved in the UK — could increase N_2O production seven to eight-fold.[49] Nitrous oxide is a greenhouse gas 300 times more potent than carbon dioxide. Similar effects on nitrous oxide production have been documented after application of other pesticides and these effects were evident even after 48 days for some applications. Researchers have suggested that the large N_2O emissions associated with certain pesticide applications may be a result of impacts on soil microbes.[50, 51] Thus, pesticide use can increase GHG emissions, while negatively impacting soil microbial activity and soil health.

Solutions: From Vicious to Vivacious Cycle

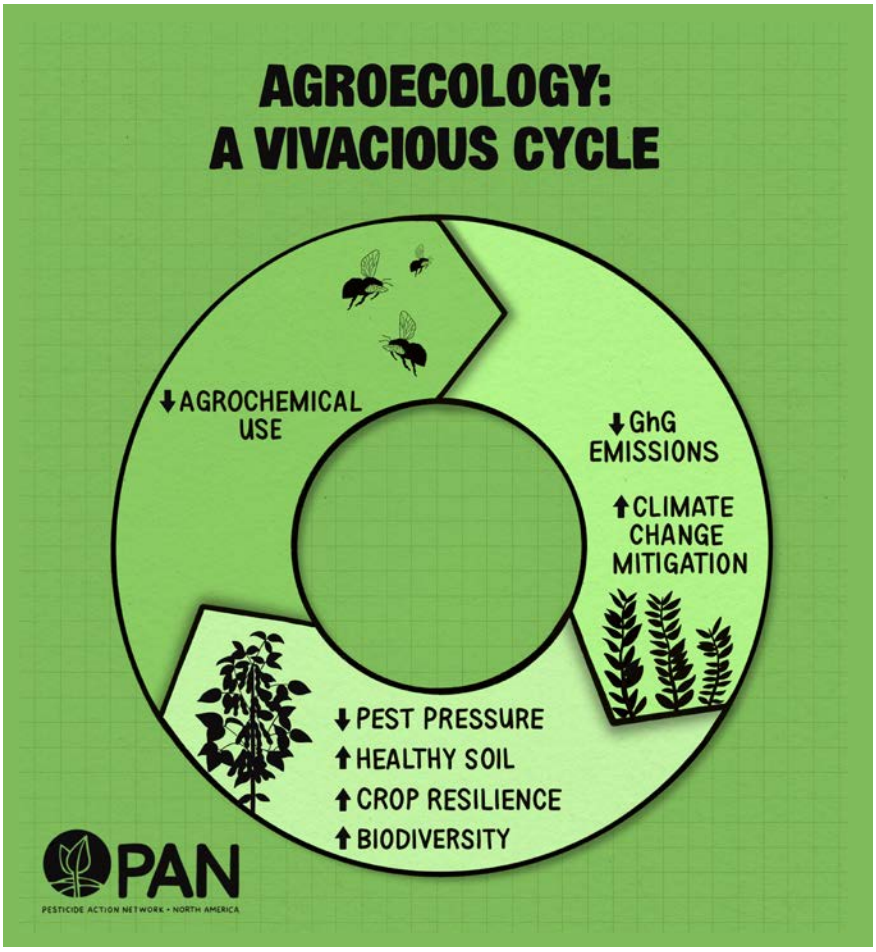


Figure 2

Current conventional agricultural systems reliant on synthetic chemicals compromise the integrity and function of the agroecosystem and its ability to support vigorous, pest-resistant crops. These systems necessitate continual soil disturbance and frequent application of pesticides and fertilisers — **a vicious cycle of ecosystem destruction.**

In contrast, highly diverse, agroecological cropping systems that utilise IPM can build healthy soil and above-ground ecosystems that supply nutrients and natural pest control without added synthetic chemicals[52] — **a vivacious cycle of nutrients and pest prevention.**

We've seen growing and widespread high-level support for replacing the currently dominant chemical-input approach to agriculture with a biological approach. A number of United Nations agencies and high-level expert reports have recognised the need for agroecology.[53] These evolving perspectives have been informed by decades of research and millennia of Indigenous Peoples' and farmers' practices using agroecological approaches that have shown multiple benefits. Benefits include improved yields, greater profitability and increased gender equity, particularly in the Global South.[54] Agroecological farming is also more resilient to climate change effects and mitigates climate change. Additional benefits of agroecological farming include better public health, improved food security and sovereignty, and enhanced biodiversity and social benefits, such as better cooperation between farmers and communities.[55]

However, many structural barriers exist that prevent farmers from transitioning to agroecological, diversified farming practices. These barriers must be addressed through government policies that provide farmers with a comprehensive package of support, including financial subsidies geared towards pesticide reduction, guidance and opportunities for peer-to-peer learning on IPM and access to agronomic advice independent of the pesticide industry. A full list of policy recommendations can be found below.

Recommendations for the UK government

The UK government must take action to transform agriculture in order to avoid the worst effects of today's climate and nature crises. Governmental policies addressing climate change should, therefore, include a focus on pesticide reduction as a key strategy for tackling greenhouse gas emissions and improving the climate resilience of food and farming system. Policies should be based on an approach underpinned by the growing body of evidence showing that pesticide use is both a direct and indirect driver of climate change, and not part of the solution.

The UK government must:

1. Take joined-up action to tackle the climate and nature crises together

By adopting agroecological farming methods, including Integrated Pest Management (IPM), agriculture can play a key role in climate change mitigation and adaptation. The government has committed to the legally binding target of net zero emissions by 2050. One third of global greenhouse gas emissions come from the food system and, of this total, two-thirds are as a result of agriculture. The government must therefore recognise that the UK's net-zero target cannot be achieved without transforming agriculture including a major reduction in pesticide use.

2. Introduce ambitious pesticide reduction targets

It is vital that the UK significantly reduces both the amount and toxicity of pesticides being used if we are to tackle the climate crisis and related harms to human health and the environment.

The UK has committed to "reducing the overall risk from pesticides and highly hazardous chemicals by at least half" in the Kunming-Montreal Global Biodiversity Framework agreed at COP15. This should now be reflected in national policy.

Setting measurable targets makes it easier to quantify how pesticide reduction can contribute towards other legally binding targets, such as the species abundance target and net-zero. Setting a clear direction of travel is important to drive innovation, focus attention on safer and more sustainable alternatives, and to provide reassurance to farmers and other pesticide users that they will receive support to enable them to contribute towards meeting reduction targets. The Pesticide Collaboration has published a detailed report outlining how targets should be designed in order to most effectively drive a reduction in pesticide-related harms: **https://pesticidecollaboration.org/wp-content/uploads/2023/03/Reduction_targets_report_Jan2023.pdf**

3. Support farmers to adopt Integrated Pest Management (IPM)

Genuine Integrated Pest Management (IPM) is an approach to managing pests, diseases or unwanted plants under which chemical pesticides are used only as a last resort, if at all. Pest, diseases and weeds are monitored and impacts understood at farm level to decide when and how to act, and natural pest control methods using ecological principles are prioritised. The government should implement the following measures to drive pesticide reduction and uptake of IPM;

a. Ensure that farmers are able to access agronomic advice that is independent from the pesticide industry.

b. Fund research into non-chemical alternatives and facilitate peer-to-peer learning between farmers

c. Provide financial incentives for farmers, including via the Environmental Land Management Scheme. The government should increase its ambition for the IPM standard, which will be introduced in 2023 as part of the Sustainable Farming Incentive scheme in England, by requiring farmers to adopt a package of practical actions thereby avoiding a piecemeal, pic'n'mix situation.

4. Commit to a phase out of pesticides use in urban areas

The phase out of urban and amenity use of pesticides is essential. Many towns and cities around the UK and globally have already ended pesticide use in urban areas. Most urban pesticide use is purely for cosmetic reasons, and there are plenty of non-chemical alternatives available. Introducing a ban on urban use, as France did in 2019, would be a clear recognition of the harmful impacts of pesticides on human health, as well as on the local environment.

The vast majority of pesticides used in towns and cities are herbicides. While some areas do need to be cleared of vegetation for accessibility reasons, many others (such as road verges and tree pits) can be left to grow. Thriving green spaces enhance the climate resilience of cities, by providing a cooling effect which helps with high temperatures and heatwaves. They also contribute to sustainable urban drainage which reduces flood risk, provides carbon sequestration, and can improve local biodiversity and protect pollinators who are increasingly under threat from climate change.


1-108

References

1 Drugmand, D., Feit, S., Fuhr, L., & Muffett, C. (2022). Fossils, Fertilizers, and False Solutions: How Laundering Fossil Fuels in Agrochemicals Puts the Climate and the Planet at Risk. The Center for International Law. https://www.ciel.org/wp-content/uploads/2022/10/Fossils-Fertilizers-and-False-Solutions.pdf

2 Choudhury, P. P., & Saha, S. (2020). Dynamics of pesticides under changing climatic scenario. Environmental Monitoring and Assessment, 192(1), 1-3

3 Audsley, E., Stacey, K. F., Parsons, D. J., & Williams, A. G. (2009). Estimation of the greenhouse gas emissions from agricultural pesticide manufacture and use. Cranfield University

4 Boedeker, W., Watts, M., Clausing, P., & Marquez, E. (2020). The global distribution of acute unintentional pesticide poisoning: estimations based on a systematic review. BMC public health, 20(1), 1-19.

5 Watts, M., & Williamson, S. (2015). Replacing Chemicals with Biology: Phasing out highly hazardous pesticides with agroecology. Pesticide Action Network Asia and the Pacific, Penang, Malaysia. https://www.panna.org/sites/default/files/Phasing-Out-HHPs-with-Agroecology.pdf

6 The Pesticide Atlas 2022 https://eu.boell.org/sites/default/files/2023-04/pesticideatlas2022_ii_web_20230331.pdf

7 UN Food and Agriculture Organisation, "Pesticides use, pesticides trade and pesticide indicators – 1990-2020" https://www.fao.org/3/cc0918en/cc0918en.pdf

8 FERA Pesticide Usage Surveys https://pusstats.fera.co.uk/data

9 Sharma, A., Kumar, V., Shahzad, B., Tanveer, M., Sidhu, G. P. S., Handa, N., ... & Thukral, A. K. (2019). Worldwide pesticide usage and its impacts on ecosystem. SN Applied Sciences, 1(11), 1-16

10 FERA Pesticide Usage Surveys https://pusstats.fera.co.uk/data

11 FERA Pesticide Usage Surveys https://pusstats.fera.co.uk/data

12 PAN International "The Glyphosate Monograph" 2016 https://issuu.com/pan-uk/docs/glyphosate_monograph_complete

13 Boedeker, W., Watts, M., Clausing, P., & Marquez, E. (2020). The global distribution of acute unintentional pesticide poisoning: estimations based on a systematic review. BMC public health, 20(1), 1-19

14 Boedeker, W., Watts, M., Clausing, P., & Marquez, E. (2020). The global distribution of acute unintentional pesticide poisoning: estimations based on a systematic review. BMC public health, 20(1), 1-19

15 Schafer, K.S., & Marquez, E.C. (2012). A Generation in Jeopardy: How pesticides are undermining our children's health & intelligence. Pesticide Action Network North America, Oakland, CA. https://www.panna.org/sites/default/files/KidsHealthReportOct2012.pdf

16 Ferguson, R., Dahl, K., & DeLonge, M. (2019). Farmworkers at Risk: The Growing Dangers of Pesticides and Heat. Union of Concerned Scientists. https://www.ucsusa.org/resources/farmworkers-at-risk

17 DEFRA, "Wild bird populations in the UK 1970-2021" 13/04/2023 https://www.gov.uk/government/statistics/wild-bird-populations-in-the-uk/wild-bird-populations-in-the-uk-1970-to-2021

18 Buglife Technical report https://cdn.buglife.org.uk/2022/05/Bugs-Matter-2021-National-Report.pdf

19 The Guardian "97% of Britain's wildflower meadows have gone – here's why it matters" 18/05/2018 https://www.theguardian.com/commentisfree/2015/may/18/losing-97-percent-britain-wildflower-meadows-matters-butterfly

20 Living with environmental change partnership "The benefits for managing pollinators for crop production" November 2014 https://www.ukri.org/wp-content/uploads/2021/12/081221-NERC-LWEC-PPN13-BenefitsManagingPollinatorsCropProduction.pdf

21 Pelosi C, Barot S, Capowiez Y, Hedde M, Vandenbulcke F. Pesticides and earthworms. A review. Agron. Sustain. Dev. 2014;34:199–228

22 Gunstone, T., Cornelisse, T., Klein, K., Dubey, A., & Donley, N. (2021). Pesticides and soil invertebrates: A hazard assessment. Frontiers in Environmental Science, 122

23 Audsley, E., Stacey, K. F., Parsons, D. J., & Williams, A. G. (2009). Estimation of the greenhouse gas emissions from agricultural pesticide manufacture and use. Cranfield University.

24 Hull, R., Tatnell, L.V., Cook, S.K., Beffa, R. and Moss, S.R. (2014). Current status of herbicide-resistant weeds in the UK. Aspects of Applied Biology, 127.

25 Heap I, Duke SO. Overview of glyphosate-resistant weeds worldwide. Pest Manag Sci. 2018 May;74(5):1040-1049. doi: 10.1002/ps.4760. Epub 2017 Nov 29. PMID: 29024306 https://pubmed.ncbi.nlm.nih.gov/29024306/

26 NFU "First signs of glyphosate resistance found in UK" 23/10/2018 https://www.nfuonline.com/updates-and-information/first-signs-of-glyphosate-resistance-found-in-uk/

27 FERN "What is carbon trading?" 08/01/2014 https://www.fern.org/publications-insight/what-is-carbon-trading-584/?gad=1&gclid=EAIaIQobChMIysnA3NT8_gIVZJRoCR0CLQ2jEAAYASAAEgJRi_D_BwE; Klenert, David, Linus Mattauch, Emmanuel Combet, Ottmar Edenhofer, Cameron Hepburn, Ryan Rafaty and Nicholas Stern, 2018, "Making Carbon Pricing Work for Citizens," Nature Climate Change 8: 669–677.

28 National Sustainable Agriculture Coalition. (2012). Climate Solutions for Farmers: Invest in proven federal programs, not carbon markets. National Sustainable Agriculture Coalition, Washington, D.C. https://sustainableagriculture.net/wp-content/uploads/2021/06/Climate-Solutions-for-Farmers_-Invest-in-Proven-Conservation-Programs-Not-Carbon-Markets-1.pdf

29 HLPE. (2019). Agroecological and other innovative approaches for sustainable agriculture and food systems that enhance food security and nutrition. High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security

30 UK Centre for Ecology & Hydrology, "Climate change is testing resilience of UK wheat yields" 13/10/2022 - https://www.ceh.ac.uk/press/climate-change-testing-resilience-uk-wheat-yields

31 IOP Science "Large changes in Great Britain's vegetation and agricultural land-use predicted under unmitigated climate change" 29/10/2019 https://iopscience.iop.org/article/10.1088/1748-9326/ab492b

32 Skendžić, S., Zovko, M., Živković, I. P., Lešić, V., & Lemić, D. (2021). The impact of climate change on agricultural insect pests. Insects, 12(5), 440

33 United Kingdom Food Security Report 2021, https://www.gov.uk/government/statistics/united-kingdom-food-security-report-2021/united-kingdom-food-security-report-2021-theme-2-uk-food-supply-sources

34 Peters, K., Breitsameter, L., & Gerowitt, B. (2014). Impact of climate change on weeds in agriculture: a review. Agronomy for Sustainable Development, 34(4), 707-721

35 Sutherst, R. W., Constable, F., Finlay, K. J., Harrington, R., Luck, J., & Zalucki, M. P. (2011). Adapting to crop pest and pathogen risks under a changing climate. Wiley Interdisciplinary Reviews: Climate Change, 2(2), 220-237

36 Chiovarou, E. D., & Siewicki, T. C. (2008). Comparison of storm intensity and application timing on modeled transport and fate of six contaminants. Science of the Total Environment, 389(1), 87-100

37 Choudhury, P. P., & Saha, S. (2020). Dynamics of pesticides under changing climatic scenario. Environmental Monitoring and Assessment, 192(1), 1-3

38 Audsley, E., Stacey, K. F., Parsons, D. J., & Williams, A. G. (2009). Estimation of the greenhouse gas emissions from agricultural pesticide manufacture and use. Cranfield University

39 Ahlgren, S., Baky, A., Bernesson, S., Nordberg, Å., Norén, O., & Hansson, P. A. (2008). Ammonium nitrate fertiliser production based on biomass–environmental effects from a life cycle perspective. Bioresource Technology, 99(17), 8034-8041. Note: Calculation is based on comparing Audsley et al. 2009 calculation in Table 1 of 370 MJ/kg pesticide active ingredient to Ahlgren et al. 2008's 35.14 MJ/kg nitrogen for commonly used fertilizers produced conventionally using natural gas

40 Drugmand, D., Feit, S., Fuhr, L., & Muffett, C. (2022). Fossils, Fertilizers, and False Solutions: How Laundering Fossil Fuels in Agrochemicals Puts the Climate and the Planet at Risk. The Center for International Law. https://www.ciel.org/wp-content/uploads/2022/10/Fossils-Fertilizers-and-False-Solutions.pdf

41 Drugmand, D., Feit, S., Fuhr, L., & Muffett, C. (2022). Fossils, Fertilizers, and False Solutions: How Laundering Fossil Fuels in Agrochemicals Puts the Climate and the Planet at Risk. The Center for International Law. https://www.ciel.org/wp-content/uploads/2022/10/Fossils-Fertilizers-and-False-Solutions.pdf

42 Bayer. (2021). Sustainability Report 2021. https://www.bayer.com/sites/default/files/2022-03/Bayer-Sustainability-Report-2021.pdf

43 Audsley, E., Stacey, K. F., Parsons, D. J., & Williams, A. G. (2009). Estimation of the greenhouse gas emissions from agricultural pesticide manufacture and use. Cranfield University

44 Audsley, E., Stacey, K. F., Parsons, D. J., & Williams, A. G. (2009). Estimation of the greenhouse gas emissions from agricultural pesticide manufacture and use. Cranfield University

45 Audsley, E., Stacey, K. F., Parsons, D. J., & Williams, A. G. (2009). Estimation of the greenhouse gas emissions from agricultural pesticide manufacture and use. Cranfield University

46 Cox, C., & Surgan, M. (2006). Unidentified inert ingredients in pesticides: implications for human and environmental health. Environmental Health Perspectives, 114(12), 1803-1806

47 Mühle, J., Huang, J., Weiss, R. F., Prinn, R. G., Miller, B. R., Salameh, P. K., ... & Simmonds, P. G. (2009). Sulfuryl fluoride in the global atmosphere. Journal of Geophysical Research: Atmospheres, 114(D5)

48 National Sustainable Agriculture Coalition. (2012). Climate Solutions for Farmers: Invest in proven federal programs, not carbon markets. National Sustainable Agriculture Coalition, Washington, D.C. https://sustainableagriculture.net/wp-content/uploads/2021/06/Climate-Solutions-for-Farmers_-Invest-in-Proven-Conservation-Programs-Not-Carbon-Markets-1.pdf

49 Spokas, K., & Wang, D. (2003). Stimulation of nitrous oxide production resulted from soil fumigation with chloropicrin. Atmospheric Environment, 37(25), 3501-3507

50 Spokas, K., Wang, D., & Venterea, R. (2005). Greenhouse gas production and emission from a forest nursery soil following fumigation with chloropicrin and methyl isothiocyanate. Soil Biology and Biochemistry, 37(3), 475-485

51 Jezierska-Tys, S., Joniec, J., Bednarz, J., & Kwiatkowska, E. (2021). Microbiological Nitrogen Transformations in Soil Treated with Pesticides and Their Impact on Soil Greenhouse Gas Emissions. Agriculture, 11(8), 787

52 Watts, M., & Williamson, S. (2015). Replacing Chemicals with Biology: Phasing out highly hazardous pesticides with agroecology. Pesticide Action Network Asia and the Pacific, Penang, Malaysia. https://www.panna.org/sites/default/files/Phasing-Out-HHPs-with-Agroecology.pdf

53 HLPE. (2019). Agroecological and other innovative approaches for sustainable agriculture and food systems that enhance food security and nutrition. High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security. https://www.fao.org/3/ca5602en/ca5602en.pdf

54 Watts, M., & Williamson, S. (2015). Replacing Chemicals with Biology: Phasing out highly hazardous pesticides with agroecology. Pesticide Action Network Asia and the Pacific, Penang, Malaysia. https://www.panna.org/sites/default/files/Phasing-Out-HHPs-with-Agroecology.pdf

55 Watts, M., & Williamson, S. (2015). Replacing Chemicals with Biology: Phasing out highly hazardous pesticides with agroecology. Pesticide Action Network Asia and the Pacific, Penang, Malaysia. https://www.panna.org/sites/default/files/Phasing-Out-HHPs-with-Agroecology.pdf

< Fire hydrant at the edge of a cornfield in Quebec.
Credit RenineR / Shutterstock.com

Pesticide Action Network UK

PAN UK is the only UK charity focused on tackling the problems caused by pesticides and promoting safe and sustainable alternatives in agriculture, urban areas, homes and gardens. We work tirelessly to apply pressure to governments, regulators, policy makers, industry and retailers to reduce the impacts of harmful pesticides to both human health and the environment.

PESTICIDE ACTION NETWORK *UK*

Pesticide Action Network (PAN) North America

We work to create a just, healthy, and equitable food system. For too long, pesticide and biotech corporations have dictated how we grow food, placing the health and economic burdens of pesticide use on farmers, farmworkers and rural communities. PAN works with those on the frontlines to tackle the pesticide problem — and reclaim the future of food and farming.

PAN
PESTICIDE ACTION NETWORK • NORTH AMERICA

The Pesticide Collaboration

Hosted by PAN UK and the RSPB, the Pesticide Collaboration is a coalition of environmental and health groups, academics, farming networks, trade unions and consumer rights organisations working under a shared vision to urgently reduce pesticide-related harms in the UK.

THE PESTICIDE COLLABORATION