Phillips McDougall
Agribusiness intelligence | informa

Evolution of the Crop Protection Industry since 1960

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Contents

Figures

Tables

Introduction

Today, the world's leading manufacturers of crop protection products invest more than $3 billion annually into research and development of new products, and the overall R&D investment by the major research-based companies has remained consistently high at 7%-10% of annual sales over the last 50 years (Phillips McDougall AgriService). With this high level of investment, companies have continued to develop and improve the efficacy and safety profiles of products to ensure high and enhanced regulatory standards are met and farmers are provided with effective tools to provide nutritious, safe and affordable food.

The publication of Rachel Carson's 'Silent Spring' book in 1962 was an important milestone in the development of the crop protection industry. It emphasized the need to improve the safety and environmental profiles of pesticide products, and its public and political impact was instrumental in the formation of the US Environmental Protection Agency (EPA). In order to illustrate how the industry has evolved, it is helpful to compare key aspects of the crop protection industry around the time of Silent Spring's release, with where it stands today.

In this report, the following aspects were researched and, where the data is available, the situations in the 1960s and the present day are compared.

- Product diversity: the number of products and product groups available
- Product efficacy: comparative application rates per hectare
- Innovation: the number of new products introduced per year/decade
- Regulatory costs and requirements
- Product safety and environmental aspects
- Product benefits

Methodology

The study, commissioned by CropLife International, was undertaken by Phillips McDougall, crop protection and seed industry analysts. Data was drawn from a variety of sources including the Phillips McDougall product archives and The Pesticide Manual.

The analysis does not include products which have been discontinued, like organochlorines such as heptachlor and DDT. A complete set of historical data, particularly relating to sales and volumes, is not available for these products, many of which have been off the market for years. The inclusion of such products, many of which were used at high rates with less favorable profiles, would be likely to reinforce the conclusions of this study.

In terms of the contribution of crop protection products to increased production and food security, data was sourced from the United Nations Food and Agriculture Organization (FAO) and United States Department of Agriculture (USDA) databases.

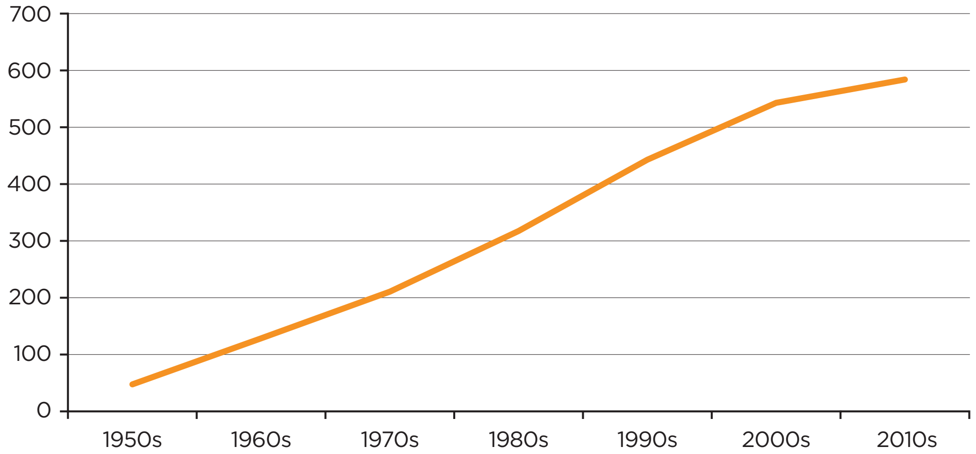
In cases where it was not possible to obtain data going back to 1960 the earliest data which could be found was used. In cases where solid data was available prior to 1960, that data has also been included.

A more detailed bibliography and list of sources is provided at the end of the report.

Size of the industry and product diversity

In 1960 the crop protection industry was worth less than $10 billion, and there were around 100 active ingredients available to farmers. Today the industry is valued at over $50bn and there are around 600 active ingredients available to farmers globally (Figure 1).

Figure 1: Total number of active ingredients available globally

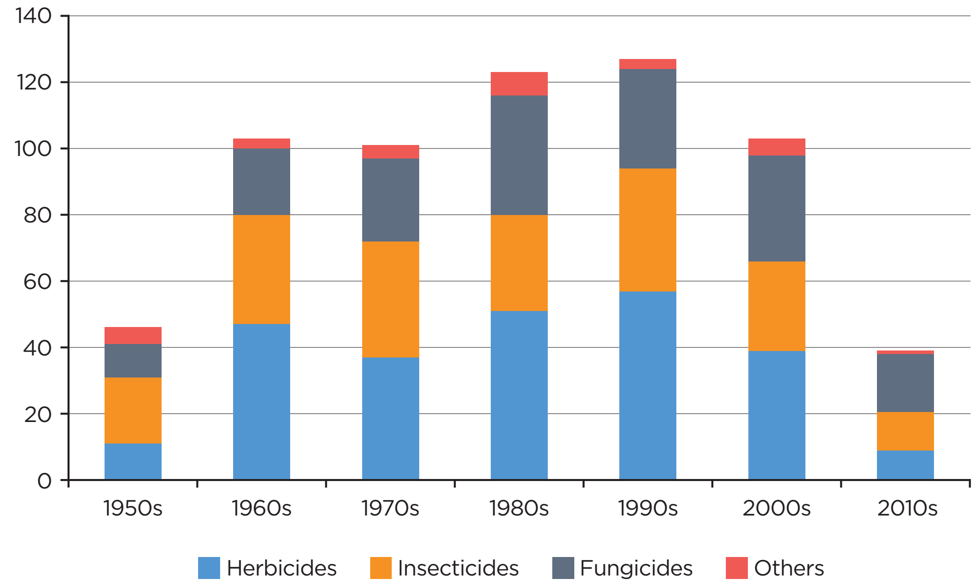


Source: Phillips McDougall Database

Further, in 1960 there were 15 chemical groups on the market, where today's products come from more than 40 different groups. New chemical groups often bring with them new modes of action which are important for addressing problems of resistance, whether to insecticides, fungicides or herbicides.

Although the rate of new product approvals has decreased in recent years (Figure 2), investment remains high and the industry has been able to maintain a decent level of product innovation, alongside other developments such as integrated crop solutions, application technology and precision farming. This reflects a continuous high level of R&D investment compared to other sectors, with the major companies investing 7%-10% of their sales annually over the last 50 years (Phillips McDougall AgriService).

Figure 2: Number of new active ingredients introduced per decade: 1950s to present day



Source: Phillips McDougall Database

To keep up with new safety regulations, many products have been withdrawn from the market over the years, either as a result of being banned, or because they were not supported during a re-registration process. For example, the EPA has a list of over 60 active ingredients no longer available in the US.

The impact this has had on product use in the US is illustrated by comparing the top 10 products used on the major US crops in 1968 with those used in 2016 (Table 1). Six of the top 10 products used in 1968 have now been banned.

Table 1: Top 10 products used in major US crops by volume in 1968 and 2016

Top 10 products in 1968	Top 10 products in 2016
Atrazine	Glyphosate
Toxaphene ***– banned***	Metolachlor
DDT ***– banned****	Pyraclostrobin
2,4-D	Mesotrione
Methyl parathion ***– banned***	Thiamethoxam
Aldrin ***– banned***	Acetochlor
Trifluralin	Azoxystrobin
Propachlor	Atrazine
Dinoseb ***– banned***	Abamectin
Chloramben ***– banned***	Clothianidin

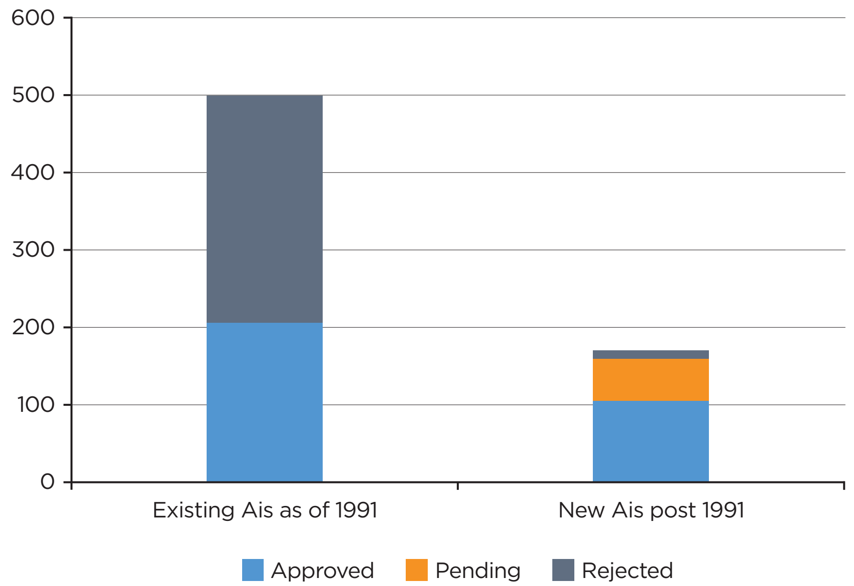
Source: Fernandez-Cornejo et al; Phillips McDougall

*DDT is banned as an agricultural and household pesticide, but it is still allowed for vector control in some countries when locally safe, effective and affordable alternatives are not available.

In the EU, changes to the regulatory regime have imposed more stringent data requirements, the introduction of hazard cut-off criteria and the application of complex technical guidance procedures for risk assessment, resulting in fewer new active substances being registered in the EU and many of those already on the market unlikely to meet the new standards being demanded.

The EU's re-registration process, which took place under the 1991 directive 91/414, has led to the removal of over half of the crop protection active ingredients (293 out of 499) of commercial significance (Figure 3).

Figure 3: Impact of EU re-registration on active ingredients



Source: Phillips McDougall analysis

It is worth noting that while the number of new active ingredients introduced each year for conventional crop protection has declined over the past two decades, there has been a rapid increase in the number of biological products on the market (see chapter below).

It is also important to note, while the crop protection industry has dramatically improved the efficacy and safety profile of new products, the capacity of regulatory systems in low income countries to protect confidential business information related to a new product is often insufficient, jeopardizing the industry's investment, stifling innovation and sometimes leaving farmers without access to new technology.

Biologicals sector

In addition to the 600-odd synthetic crop protection active ingredients there are around 300 biopesticide active substances and organisms (Phillips McDougall analysis). These include naturally occurring substances, products derived from fermentation, microbes and pheromones, predatory insects and mites, fungi and nematodes.

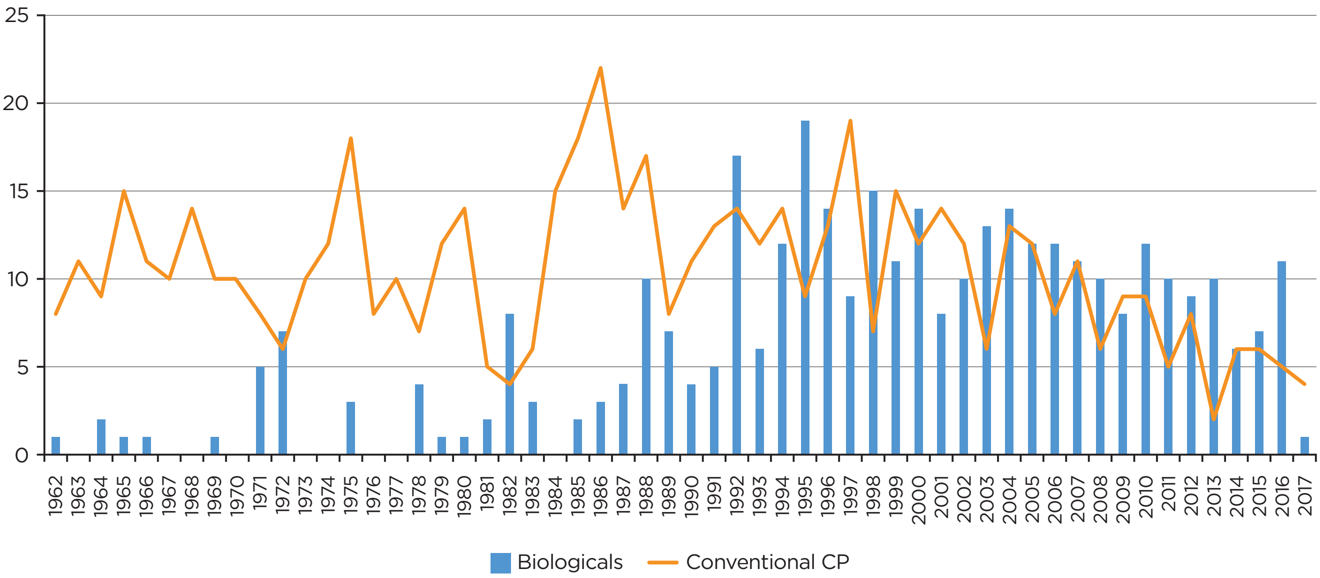
There has been a significant increase in interest in biologicals in recent years from both the larger R&D-based companies and off-patent product manufacturers, as well as many smaller enterprises and start-ups. This trend has been spurred by a less demanding regulatory process faced by biological pesticides, the growth of integrated pest management (IPM) programs and farmers' demand for a more diverse toolbox to deal with pest threats. Biological and synthetic pesticide products are often used together within IPM systems.

The rate of introduction of biological products has grown significantly since 1960 (Figure 4). Between 1960 and 1990 an average of three new biological products were introduced to the global market each year. Between 1990 and 2016 an average of 11 new biologicals have been introduced each year.

Over the last 20 years the rate of new biological product introduction has frequently exceeded that of conventional products and the trend looks set to continue.

In terms of patent activity, 2017 was the first year that there were more patents for biological pesticides than conventional crop protection products: 173 compared with 117.

Figure 4: Annual new product introductions for biologicals and conventional CP



Source: Phillips McDougall database and analysis

Market growth for the biologicals sector has also been greater than for conventional crop protection products, growing by 2900% since the early 1990s, though starting from a very low base (Table 2).

Table 2: Biopesticides market growth versus total crop protection sales

Year	Biopesticides sales: $m	Total crop protection sales: $m	Biopesticides %
1993	100	24307	0.4%
1999	250	29227	0.9%
2005	500	32814	1.5%
2009	1000	40147	2.5%
2012	1500	52617	2.9%
2014	2000	59930	3.3%
2016	3000	53582	5.6%

Source: Phillips McDougall/Dunham Trimmer

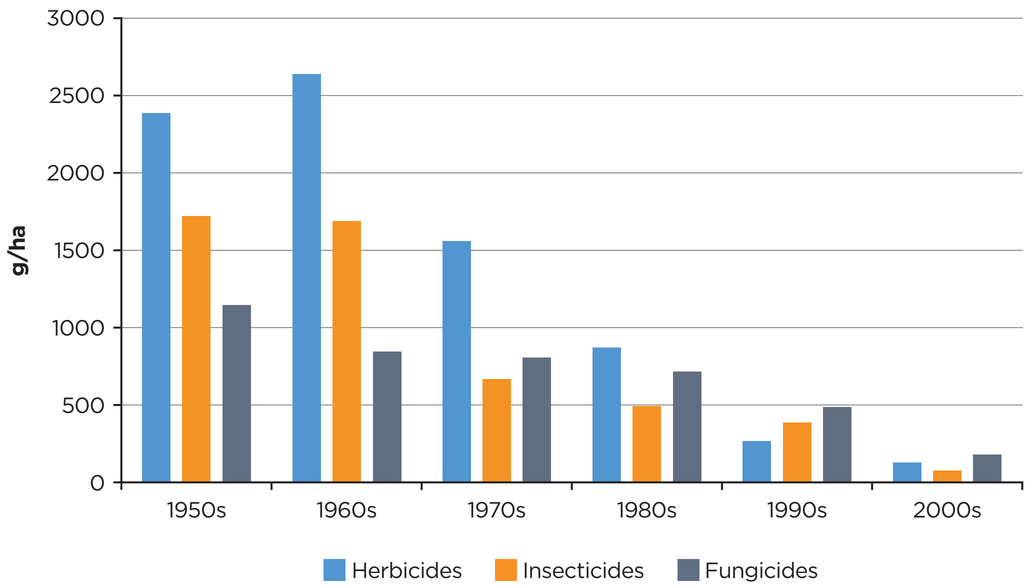
Despite high potential and recent rapid growth, the biologicals market retains a relatively small share, with a total value of less than 10% of the overall crop protection product market. Furthermore, Phillips McDougall estimates that the average annual sales at maturity for a biological product is of the order of $10m, compared with an average of $75m for a conventional crop protection product. For the sector to continue to grow, biological products will need to demonstrate their efficacy over multiple years and at scale.

Product efficacy

Significant investment into crop protection products since the 1950s has led to continued improvements in their effectiveness and efficiency. For example, as products have evolved, there has been a significant reduction in the application rates of a product per hectare – farmers therefore need to apply a lower dose of a crop protection product to achieve the same efficacy (Figure 5).

Average application rates in the 1950s were 1,200, 1,700, and 2,400 grams of active ingredient used per hectare for fungicides, insecticides, and herbicides respectively. By the 2000s the average use rates were reduced to 100, 40, and 75 g/ha. This technology evolution means the amount of active ingredient used by a farmer today is around 95% lower than the rate used in the 1950s.

Figure 5: Average active ingredient application rates over time



Source: Phillips McDougall, 2017

The average application rates for different classes of chemistry introduced over time for herbicides, insecticides and fungicides are shown in Tables 3-5.

Table 3: Chronology and application rate ranges of main fungicide groups

	Dithicarb-amates	Morpholines	Triazoles	Strobilurins	SDHIs
Period of introduction	1943-67	1968-2003	1976-2002	1996-2007	2000s
Average rate: g/ha	2500	590	140	490	100

Source: Phillips McDougall Analysis

Table 4: Chronology and application rate ranges of main insecticide groups

	Organo-phosphates	Organo-chlorines	Carbamates	Pyrethroids	Neonic-otinoids	Diamides
Period of introduction	1940s	1950-1958	1950s	1970s	1990s	2000s
Average rate: g/ha	1500	1100	2500	250	100	35-50

Source: Phillips McDougall Analysis

Table 5: Chronology and application rate ranges of main herbicide groups

	Phen-oxies	Ureas	Tria-zines	Paraquat	Aceta-mides	Dinitro-anilines	Glyph-osate	HPPD	Sulpho-nylureas
Period of introduction	1945-1988	1951-1978	1956-2002	1960	1960-2006	1964-1977	1972	1979-2008	1982-2005
Average rate: g/ha	950	2750	2000	500	2250	1500	1500	270	50-100

Source: Phillips McDougall Analysis

Regulatory costs and requirements

The regulatory standards to which crop protection products must adhere have become ever-more demanding, requiring new and more stringent studies with increased levels of scrutiny and societal expectations. These affect older products during re-registration reviews as well as the introduction of new products.

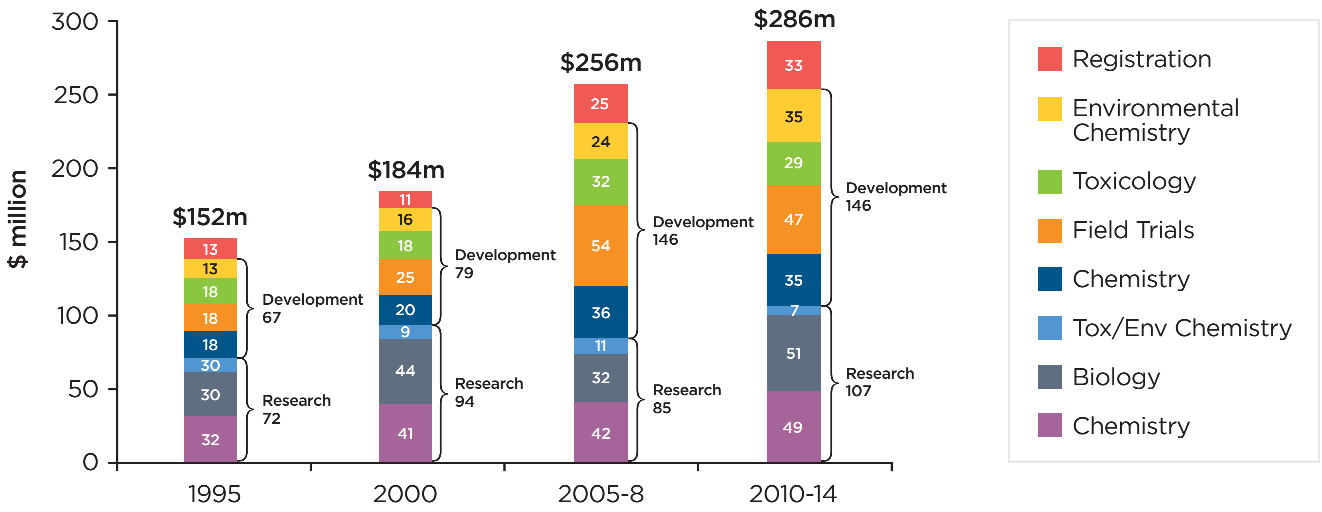
In the 1960s the focus of pesticide product development was to maximize crop yield by achieving the best possible weed, pest and disease control. Since then, statutory requirements to register pesticides have developed so that efficacy is just one of many factors to be considered. Much greater attention has been given to managing the human and environmental risks from agriculture and pesticides, alongside intense scrutiny from stakeholders.

The outcome has been robust, complex regulations which require huge quantities of data from studies to demonstrate the hazard profile and risk assessment of active ingredients and finished products. Typically, more than 150 studies are carried out to register a new active ingredient, and the databases for most older active substances have been substantially updated with new studies, particularly to meet EU, US and other OECD member country requirements. Other countries have also developed more robust regulatory requirements, for example Brazil, China and India. In addition, crop exporting countries have to meet the requirements of the importing nations with regard to the safety of residues in commodities.

Pesticides are now among the most regulated substances in the world, and typically have significantly more data developed than for most chemicals, even for those used daily in household and personal care products. This is particularly true for studies needed to evaluate the potential for environmental and health impacts.

As a result of this, and other factors, the absolute costs of registering new products have increased (Figure 6). The total registration-related costs of developing a new active ingredient[1] has more than doubled in nominal terms between 1995 and 2014 to around $100 million, 34 percent of the total cost of developing a new product.

Figure 6: Discovery and development costs of a new crop protection product



Source: Phillips McDougall, 2016

Over the same period the time to develop and launch a new product has increased from 8.3 years to 11.3 years (Table 6).

Table 6: Time to develop a new crop protection product

	1995	2000	2005-8	2010-15
Number of years between the first synthesis and first sale of product	8.3	9.1	9.8	11.3

Source: Phillips McDougall, 2016

In many OECD countries, products have to undergo periodic reviews in order to be re-registered and to make sure they are in line with the latest scientific knowledge and meet regulatory requirements. Low income countries, that often do not have the regulatory capacity to review products, can use these reviews to guide their own decisions on products.

HAZARD AND RISK-BASED REGULATION

In their regulation of pesticides, most government authorities use risk assessment methodologies that balance the best available science with the political, cultural and economic priorities of their constituents. The science of risk assessment generally includes identification of hazards, measurement and modeling of exposures, and mathematical calculations determining the probability of harmful effects.

The European Union, however, has been criticized for focusing on the hazard potential of a product rather than a realistic analysis of the potential for harm. The adoption of the new regulation for

[1] Registration-related costs are defined as those relating to toxicology, environmental chemistry and registration *per se* (e.g. assembling the registration dossiers)

pesticides in 2009 (1107/2009) has led to the adoption of 'cut-off criteria'. Certain hazard criteria or properties, like environmental persistence or toxicity in a laboratory trial, are invoked to eliminate substances from further consideration as possible tools for agriculture, without consideration of the actual risk of use.

In contrast, the US EPA recognizes that regardless of the hazardous properties a substance may possess, the potential for harm is directly related to exposure, and potential benefits need to be weighed before ruling out any new product. Under this rationale, a substance of high toxicity can only cause harm if sufficient exposures occur and exposures cannot be mitigated to ensure protection of human health and the environment.

An outcome of these different approaches to regulation leads to different availability of tools for farmers, impacting productivity, profitability, and ability to manage pests most effectively. In the EU, for example, a study found the restrictions on neonicotinoids reduced oilseed rape production by 912,000 tonnes and cost the oilseed rape industry €350 million. However, neonicotinoids remain in the toolbox for farmers in the US, where the EPA analyzes the safe use of neonicotinoids in practice, with risk mitigation measures in place.

VOLUNTARY COMMITMENTS

In addition to the requirements to which the crop protection industry is subject from the regulatory authorities there can be other voluntary controls. For example, CropLife International's member companies, representing a large proportion of the crop protection industry, recently completed a voluntary portfolio review, evaluating more than 6,400 crop protection products under real use conditions, including those encountered in low income countries. Any products meeting highly hazardous pesticide hazard criteria, as set out in the International Code of Conduct on Pesticide Management, underwent risk assessment, risk mitigation and, where the risk remained too high, the product was withdrawn from the market.

Product stewardship is another area that has developed markedly in recent decades, with crop protection industry commitments to ensure the safe and environmentally compatible use of a product throughout its lifecycle from discovery through launch, use and ultimate disposal of any waste.

Measures of impact on health, safety and the environment

In order for a crop protection product to pass regulatory requirements and be approved for commercial use, it must prove it can be safely handled and used with minimum risk to human health and the environment.

As explained earlier in this report, the regulatory standards around safety, along with heightened societal expectations, have led to a marked improvement in the human and environmental safety profile of products entering the market today.

Innovation in the R&D process now allows companies to screen potential active ingredients very early in the development process to immediately rule out any product that would be unacceptably toxic or persistent in the environment. In addition, as technology has advanced, the average number of new molecules that are synthesized and subjected to biological research in order to lead to the registration of one new crop protection product has increased from 52,000 in 1995 to 160,000 today.

TOXICITY

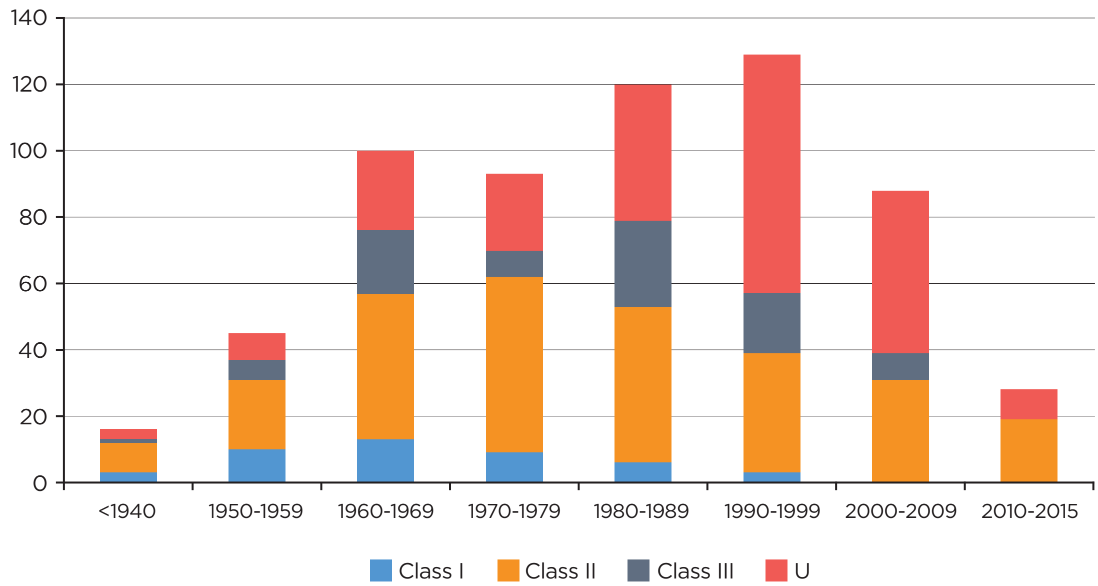
The World Health Organization (WHO) classifies pesticides into four main safety categories:

- Class 1: Extremely (1a) and highly (1b) hazardous
- Class 2: Moderately hazardous
- Class 3: Slightly hazardous
- U: Unlikely to be hazardous

These classifications are determined by 'LD50s', a measurement of acute toxicity of a material – an essential input into a decision on product safety.

The higher the LD50 number, the greater the margin of acute safety to humans. With that in mind it is a positive trend that the average LD50 of active ingredients today is around 3,500 mg/kg compared to an average LD50 in the 1960s of around 2,500 mg/kg – that is to say the acute toxicity has reduced 40%. As a result of these improvements, a lower number of today's new active ingredients fall into the WHO's class 1 and class 2 categories (Figure 7).

Figure 7: Number of active ingredients falling into different safety classifications as a function of the decade in which they were introduced



Source: Phillips McDougall analysis based on 'The Pesticide Manual' (*based on data for 600 active ingredients*)

The increasing LD50 combined with the decreasing application rate of pesticides (as noted earlier in this report) tells a positive story of progress in the crop protection industry where the industry has been able to simultaneously increase product efficacy and reduce acute product toxicity.

Another positive example is provided in a study by Fernandez-Cornejo *et al* (Figure 8), where toxicity in the United States, based on US drinking water standards, has fallen continuously between 1968 and 2008.

The authors note that: "New and better pesticide active ingredients (more effective and less harmful to human health and the environment) have frequently been introduced while other active ingredients have been banned or voluntarily canceled by their manufacturers".

SOIL PERSISTENCE

The impact of crop protection products on the soil is another important factor.

While crop protection products will always have a certain level of persistence to ensure the product is available for sufficient time to be effective against its target pest, and to prevent the need for further crop protection product applications, it is important that crop protection products ultimately degrade into harmless breakdown products in the soil.

The crop protection industry must find the balance between a product that is effective, while posing minimal threat to the environment through persistence.

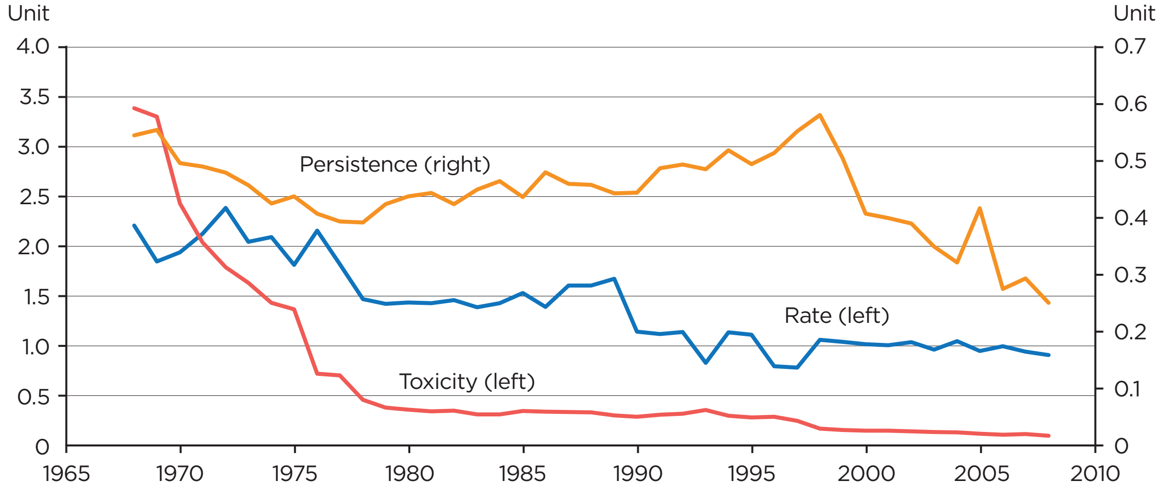
A measure of soil persistence is the DT50 which is the number of days it takes for half of the product to degrade. A higher DT50 value indicates longer persistence. An analysis of DT50s shows that persistence peaked for products introduced in the 1980s at 72 days. New innovations have helped reduce persistence to an average 53 days for those introduced in the 2000s.

Figure 8 shows persistence data in the US using an index developed by Fernandez-Cornejo and Jans (1995). Persistence fell between 1968 and the late 1970s before gradually increasing until the late 1990s and then falling significantly until 2008.

These positive product development trends are underpinned by regulatory policies that have evolved significantly over the past six decades to assess pesticide persistence. Current testing and assessment schemes have been developed to evaluate potential persistence in the context of an environmental risk assessment.

For example, a small amount of a given pesticide may persist into the next growing season, however, a comprehensive environmental risk assessment would be conducted to determine whether that level of persistence would impact the environment, *in situ*, through transport through the soil or in surface water run-off.

Figure 8: Average quality characteristics of pesticides applied to four major US crops, 1968-2008



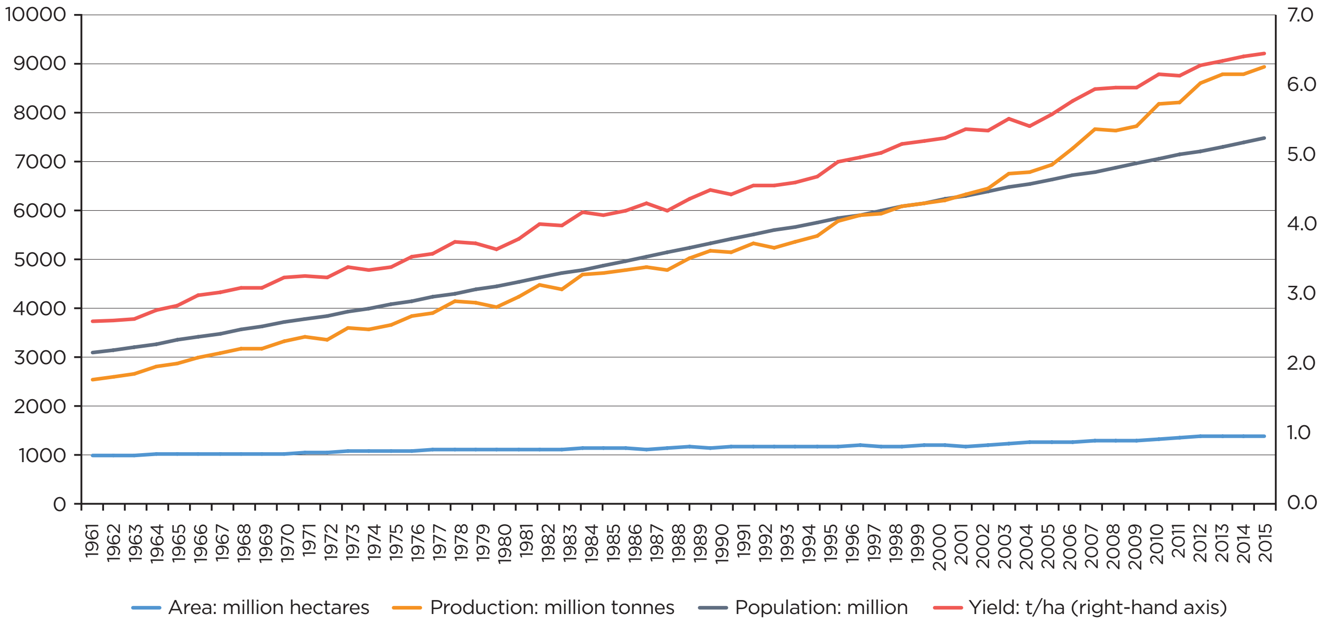
Source: Fernandez-Cornejo *et al.* (2014)

*Notes: **Rate** is pounds of active ingredient applied per acre times the number of applications per year*
*The **toxicity** index is the inverse of the water quality threshold (which measures concentration in in parts per billion) and serves as the environmental risk indicator for humans from drinking water*
*The **persistence** indicator is defined by the share of pesticides with a half-life less than 60 days*

Contribution to crop production and food security

Farmers use crop protection products to help increase their yields and overall production. This helps to feed a growing population and avoids bringing biodiverse land into production. Figure 9 shows how overall yields across all crops have increased from just under 4 t/ha in 1960 to just over 6 t/ha today – an increase of around 60%. This has helped to increase production to meet demand from a growing population without a significant increase in arable land cultivation.

Figure 9: Growth in population, crop production, crop areas and yields 1960-2016



Source: FAOStat and Phillips McDougall analysis

Overall, global crop production has more than tripled since 1960 (Table 7) with most of this attributable to increased crop yields, rather than land-use expansion.

Table 7: Crop production and yield growth 1960-2016

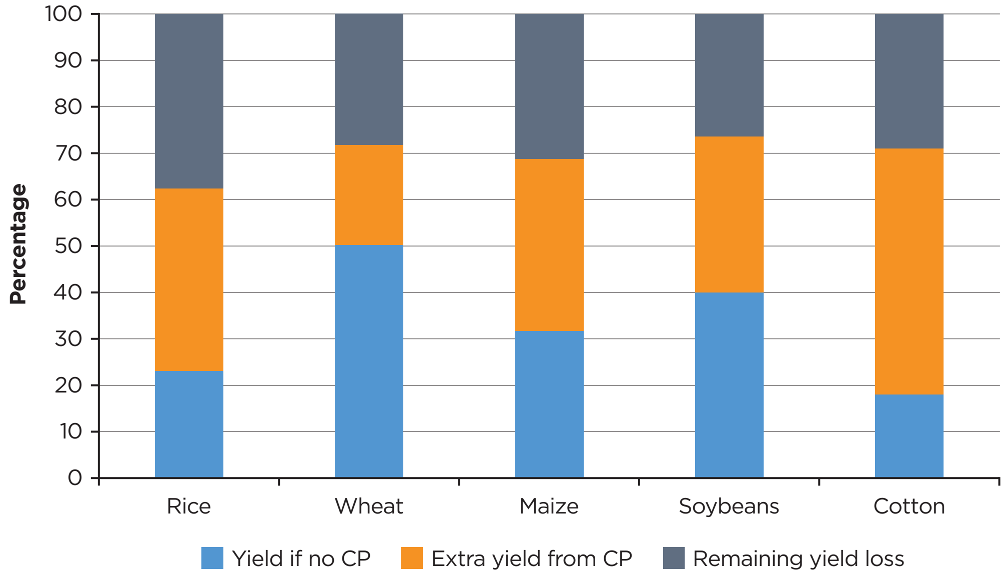
	1960	2016	Factor growth 2016/1960
Total crop production: million tonnes	2588	8923	3.4
Maize yields: t/ha	2.0	5.8	2.9
Wheat yields: t/ha	1.1	3.4	3.1
Rice yields: t/ha	1.9	4.5	2.4

Source: FAOStat; USDA PS&D database

Although only one of three main inputs contributing to increased yields – the others being fertilizer and improved seed – crop protection products play an important role in protecting yields. Without crop protection practices, including pesticides, an FAO/OECD report suggests crop losses could reach between 50 and 80 percent.

Figure 10 provides further evidence to the value of crop protection products to maintain yields. In relation to pesticides, the improvement in crop yields is likely to be derived from a combination of factors relating to improved formulations and application rates, their increasing level of biological activity, and the broadening of the spectrum of activity of products as they control new pests.

Figure 10: Yield losses with and without crop protection products



Source: Oerke, 2006

These yield benefits have been a significant factor in feeding the increasing global population over the period and the increased per capita calorie consumption (Table 8).

Table 8: Population and per capita calorie consumption 1960-2018

	1960	2018
Population: billion	3.1	7.6
Per capita calorie consumption: Kcal/capita/day	2196	~2900

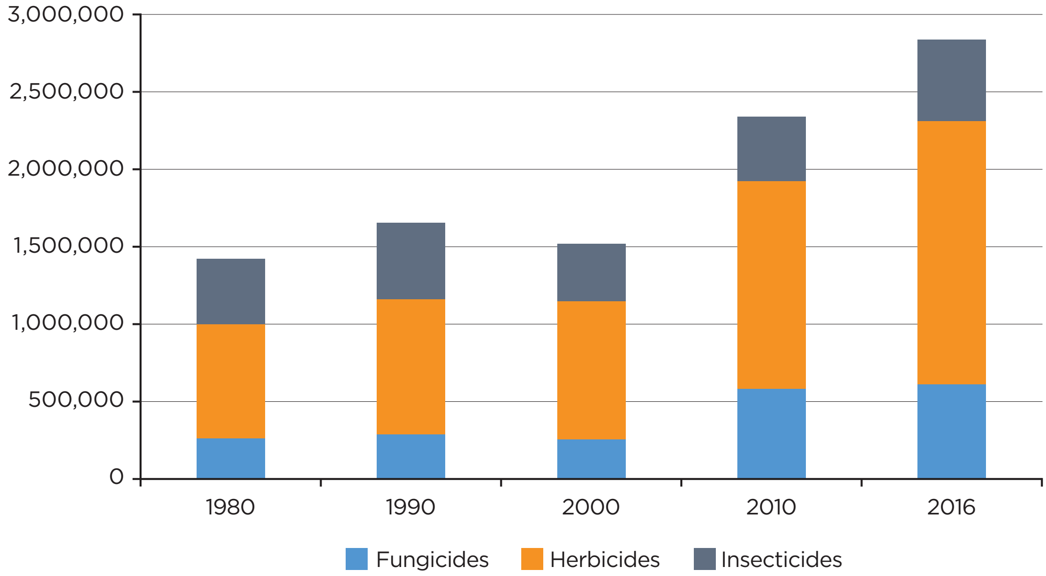
Source: FAO Food Balance Sheets

VOLUMES OF CROP PROTECTION PRODUCTS USED BY FARMERS

Figure 11 shows how the volume of active ingredients used globally between 1980 and the 2000s remained flat, as farmers were able to match the global demand for increased production with no increase in the volumes used.

Since 2008, there has been an increase in volumes used, as more farmers demand a greater range of tools to protect their crops. At the same time the amount of food produced from every tonne of active ingredient has increased by more than 10% from 2,826 tonnes in 1980, to 3,145 tonnes in 2016 (using FAO crop production figures). Overall the volume of active ingredient used per tonne of food produced has gone down since 1980.

Figure 11: Crop protection volume, tonnes of active ingredient



Source: Phillips McDougall, 2017

A number of global trends help to explain the overall volume increase:

- The rapid increase in no-till farming – the practice of planting a new crop directly into the stubble of the previous crop, without ploughing. Intrinsic to the use of no-till is the use of herbicides to control weeds (*see the next chapter for more discussion on no-till*).
- A move to more productive agriculture, and associated access to inputs, in emerging economies. Since 2008 the manufacture of crop protection products has grown 10% in China, 8% in India and 6% in Latin America.
- The 2007-2008 food crisis, which saw a sharp increase in global food prices, global food insecurity and an emphasis on increased production.
- The impact of climate change, where changing conditions present farmers with new pest problems, and demand for new solutions to protect their crops. According to a 2014 study more than one-in-ten pest types can already be found in around half the countries that grow their host crops. If this spread advances at its current rate, scientists fear that a significant proportion of global crop-producing countries will be overwhelmed by pests within the next 30 years. A 2018 study estimated a 2-degree Celsius rise in global mean surface temperatures would result in yield losses due to insects of 31% for corn, 19% for rice and 46% for wheat.

Sustainable agriculture

The UN Food and Agriculture Organization (FAO) estimates that farmers will have to produce significantly more food by 2050 to meet the needs of the world's expected 9-billion-plus population, while also tackling climate change and protecting finite natural resources.

Pesticides are an essential tool in farmers' armory to farm in a sustainable way, meeting growing demand and protecting the environment.

INTEGRATED PEST MANAGEMENT

The global consensus is that integrated pest management (IPM) is the most effective and holistic approach within sustainable farming. IPM focuses on preventing problems from arising using ecological principles. When intervention is needed it focuses on managing insects, weeds and diseases through a combination of cultural, physical, biological and chemical methods that are cost effective, environmentally sound and socially acceptable. This includes the responsible use of crop protection and plant biotech products.

The FAO's definition of IPM notes that pesticides should be used when economically justified and where risks to human health and the environment are minimized. IPM is also a cornerstone of the European Commission's sustainable use of pesticides. It defines IPM as the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms, and only using pesticides when needed.

NO-TILL/CONSERVATION TILLAGE

Another major technique which has an important role in sustainable agriculture is no-till, the practice of planting a new crop directly into the stubble of the previous crop, without ploughing. Intrinsic to the use of no-till is the use of herbicides to control weeds, and the benefits are many:

- It avoids ploughing the soil which is time-, labor- and energy-consuming and damages the soil structure increasing the chances of soil erosion
- It conserves soil moisture
- It reduces water run-off
- It preserves soil biodiversity relative to conventional cultivation
- It leads to lower greenhouse gas (GHG) emissions, both through avoided energy use and disturbance of GHG sequestered in the soil
- It allows more land to be brought into production as there is reduced need for fallow

The main countries which have widely adopted no-till practices are the US, Canada, Brazil, Argentina and Australia which between them account for over 90 percent of global adoption (Table 9). The next largest country is China where the area of conservation tillage has more than doubled between 2011 and 2013 according to the FAO.

Table 9: Leading countries practicing conservation tillage

Country	Conservation tillage area: mha	Latest year for which FAO data available
US	35.6	2009
Brazil	31.8	2012
Argentina	29.2	2013
Canada	18.3	2013
Australia	17.7	2014
China	6.7	2013

Source: FAO

BIODIVERSITY BENEFITS

Another major environmental benefit which can be attributed partly to crop protection products is avoided deforestation and maintenance of biodiversity.

The assumption is often that alternatives to high-yield farming are better for the environment. However, a study published in Nature Sustainability found that a number of high-yield practices were positive, reducing greenhouse gases, water use, soil loss and nitrogen and phosphorus levels. It added that these benefits only worked if the higher yields resulted in land being set aside for nature.

Other biologists, notably Edward O. Wilson of Harvard, have stated that in order to truly preserve global biodiversity, about half of the planet's surface must be set aside for nature. Cutting food loss, waste and over-consumption of foods is one important element, alongside increasing production per area unit (high yield).

Based on FAO production figures between 1975 and 2017, were it not for the yield increases facilitated by crop protection and other farm inputs, more than 370 million hectares more land (equivalent to 60% of the Amazon rainforest) would have had to be used for agriculture.

Conclusion

This report demonstrates that since the 1960s, there have been significant improvements in the benefits and properties of crop protection products.

The number and variety of crop protection products have increased dramatically, providing a more extensive and effective pest control toolbox to farmers. There has been a particularly rapid growth in the development of biological products in recent years.

This has contributed to a major increase in crop production which has met the rapidly growing global demand for food. Most of this demand has been met through improved yields, rather than the cultivation of new, biodiverse land.

At the same time, products have become much more effective, leading to a 95% decrease in active ingredient application rates per hectare. In addition, crop protection products introduced today are less acutely toxic, as manufacturers screen out problematic active ingredients early in the R&D process.

Indeed, the scrutiny of products to ensure environmental and human safety has increased dramatically since the 1960s, with regulatory-related costs doubling between 1995 and 2014. Products are now periodically reviewed by regulatory agencies in many countries to ensure the data packages are up to date with the latest scientific knowledge and comply with the most recent regulatory requirements for safely to humans and the environment.

Overall, global active ingredient product volumes remained more or less the same between 1980 and 2008 but showed some growth thereafter with an increased uptake of no-till agriculture, rapid growth in Asia and Latin America, high commodity prices, and demand from farmers to deal with increased pest threats due to a changing climate. Despite the overall increase in volumes, food production per tonne of active ingredient used has increased by more than 10% since 1980.

If global demand for food is to be met to 2050, while also protecting the environment and meeting the challenges of climate change, farmers need sustainable solutions, with integrated pest management at the heart of their approach. Other farm techniques, such as no-till agriculture with associated benefits of reduced soil erosion and reduced greenhouse emissions, will also be important.

In this context, crop protection products remain of central importance to feed the world sustainably. However, more must be done. The crop protection industry must continue to invest to innovate and the regulatory environment must be receptive to new improved products for farmers that also meet societal expectations.

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