# Analysis

## of the Economic Impact of Restrictions on the Commercialization of Pesticides in the Production of Relevant Crops of the Mexican Agri-Food Market.

PROCCYT

GlobalMind
Nodo de Inteligencia Estratégica S.C.

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PROTECCIÓN DE CULTIVOS, CIENCIA Y TECNOLOGÍA A.C.
WORKING TOGETHER FOR SUSTAINABLE AGRICULTURE

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# Introduction

The purpose of the economic analysis is to generate evidence to support decisions. This analysis is therefore intended to provide information on the relevance of pesticides in the socio-economic field.

A basic premise for analyzing the global increase in the use of pesticides is the growing demand for primary products, caused by an ever-growing population: mainly in countries with deficient food and agricultural raw material supply.

Therefore, it is necessary to emphasize that pesticides are mainly used to create beneficial conditions for human well-being.

Global demographic trends indicate that the world's population is expected to increase by nearly 2 billion people in the next 30 years[1]. The global population could grow to around 8.5 billion in 2030, and add 1.8 billion in the following two decades, reaching 9.7 billion in 2050.

Low-income economies will have the greatest impact on population growth. The United Nations estimates that the population of these territories could double over the next three decades.

[1] *United Nations, Department of Economic and Social Affairs Population Division. World Population Prospects 2022. https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/wpp2022_summary_of_results.pdf Consulted in November 2022.*

The population dynamics show a qualitative and quantitative transition, concentrated in the following megatrends:

a) The age structure of the population is changing; in some countries this is due to the arrival of a young population that will impose their consumption patterns and lifestyles;

b) Increasing urbanization with changes in supply chains for goods and services;

c) Increased international migration of both men and women, mainly to developed economies;

d) Consumption patterns of more dynamic agro-industrial products;

e) Relative decline in the rural population and reduced availability of labor for agricultural work; among the most relevant.

Although demographics will vary across countries, the overall trends over the next 30 years have global implications for agricultural production. For example, food demand could grow by 60%, meat production by almost 70%, aquaculture by 90% and dairy products by 55%, so arable land will be used for different purposes and there will be a constant pressure to increase productivity[2].

Consumption patterns that favour natural products drive the global production of textile fibres and the increase in biofuels. Meanwhile the pet breeding boom is influencing the growth of specialized agricultural supplies[3]. In short, the agricultural frontier faces multiple challenges to meet present and future needs, in an area that is shrinking rather than expanding.

In this context, the use of pesticides use will continue to contribute to agricultural productivity growth and food supply, since they prevent or reduce crop losses; reduce or mitigate diseases spread by pests in plants and animals; contribute to preserving the shelf life of agricultural and forestry products; and are an important input for the safety of feed for various livestock species, among their main contributions

Another driver of pesticide use is global trade in agricultural products. The demand for pathogen-free products determines the increased use of pesticides in their places of origin. Protecting local production requires pest-free imports. Another characteristic of global trade, which goes hand in hand with crop protection, is the degree of sophistication in the quality standards of food products, in particular with regards to their appearance and shelf life (in the case of perishables).

The production and use of pesticides are determined by various actors in the supply chain of the agri-food system and food marketing and processing chains. At the global scale, the industrialized food market has a high economic concentration, which allows large multinational food and beverage companies to influence trends in the quality of their supplies and set the tone for the price/quality ratio of agricultural inputs.

At the other end of global trends is the concentration of agricultural production in multinational companies, based on the intensive use of productive resources: biological, chemical, mechanical, computing resources and artificial intelligence. Here the use of agrochemicals still predominates as a trend in crop protection.

*[2] FAO. 2022. The future of food and agriculture: Drivers and triggers for transformation - Summary version. Rome. https://www.fao.org/3/cc1024en/online/cc1024en.html Consulted in October 2022.*

*[3] FAO, Secretariat of the High-Level Expert Forum. Global Agriculture towards 2050. https://www.fao.org/fileadmin/templates/wsfs/docs/Issues_papers/HLEF2050_Global_Agriculture.pdf Consulted in October 2022.*

# Glossary of Terms[4]

**Agrochemicals:** This term refers to chemical compounds or mixtures thereof used to increase agricultural productivity and quality, including fungicides, insecticides, herbicides, plant hormones, etc.

**Statistical Correlation:** Statistical correlation is a statistical measure that expresses the extent to which two variables are linearly related (meaning they change together at a constant rate).

**Price elasticity of supply:** It is a regression analysis that assesses changes in the volume produced and changes in the average rural price of a product, and is defined as the percentage change in the quantity offered over the percentage change in price.

**Fungicide:** is a chemical agent used to kill fungal mycelium or spores or inhibit their growth.

**Herbicides:** are chemical substances used to destroy or inhibit the growth of plants, such as weeds.

**Agricultural Production Index:** It is an indicator that aims to measure changes in physical volume (in units such as tons or thousands of liters) produced during a defined reference period.

**Active Ingredient:** An active ingredient is any component that provides biologically active or other direct effect in the diagnosis, cure, mitigation, treatment, or prevention of disease.

**Insecticide:** A substance used to control insects. They include ovicides and larvicides used against insect eggs and larvae, respectively.

**Maximum Residue Limit (MRL):** MRL is the maximum concentration of a pesticide residue (expressed as mg/kg), recommended by the Codex Alimentarius Commission to be legally permitted in or on food commodities and animal feeds[5].

**Integrated Pest Management (IPM):** is the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations[6].

**Weeds:** are natural hazards for human interests and activities. They are plants frequently described as harmful to crop production systems and also to industrial and commercial processes.

**Morbidity:** Morbidity is a diseased state, disability, or poor health due to any cause.

**Mortality:** The number of people who die in a given place and time period.

**Index Number:** It is a statistical measure that expresses the relative evolution of the magnitude of crop production and prices, in one or more periods, with respect to a base period or reference year.

**Genetically Modified Organism (GMO):** is an organism whose genetic material has been altered using genetic engineering techniques.

**Food loss:** is the decrease in the quantity or quality of food resulting from decisions and actions by food suppliers in the chain, excluding retailers, food service providers and consumers.

**Potential crop loss:** It includes losses without physical, biological or chemical protection of crops compared to yields of similar crop production in a no-loss scenario.

**Actual crop losses:** They include crop losses that have occurred despite crop protection practices.

**Pest:** Any form of plant or animal life, or any pathogenic agent, injurious or potentially injurious to plants or plant products.

*[4] Barioglio, Carlos Fernando (2011). Diccionario de Las Ciencias Agropecuarias. Editorial Brujas. ISBN 9789872302245; National Pesticide Information Center. http://npic.orst.edu/index.es.html; Instituto Nacional de Estadística y Geografía (INEGI), https://www.inegi.org.mx/*

*[5] FAO. Codex Alimentarius. Glossary of terms. https://www.fao.org/fao-who-codexalimentarius/codex-texts/dbs/pestres/glossary/en/ Consulted in December 2022.*

*[6] FAO. Integrated Pest and Pesticide Management. https://www.fao.org/pest-and-pesticide-management/ipm/integrated-pest-management/en/ Consulted in December 2022.*

**Quarantine pest:** means a pest of potential national economic importance to the country endangered thereby and not yet present there, or present but not widely distributed and being actively controlled.

**Pesticide:** means any substance intended for preventing, destroying, attracting, repelling, or controlling any pest including unwanted species of plants or animals during the production, storage, transport, distribution, and processing of food, agricultural commodities, or animal feeds or which may be administered to animals for the control of ectoparasites[7].

**Gross Domestic Product:** It is the sum of the monetary value of all final goods and services generated by a country or federal state during a specific period of time, usually one year.

**Potential yield:** It is determined by the genetic composition of cultivated plants, current temperature regimes and radiation; it is achieved without any nutrient and water limitations at any stage of development, and without any damage caused by pathogens, animals or weeds[8].

**Attainable yield:** It depends on natural factors, overlapped by a number of yield-limiting factors that are inherent in a given production situation: water and nutrient scarcity at some stages of development, as well as excess water and mineral compounds, which can cause toxicities.

**Actual yield:** The actual yield (Y) is the yield actually harvested: it encompasses the yield-defining factors, the yield-limiting factors, and incorporates the yield-reducing effects of injuries caused by harmful organisms[9].

**Efficacy rate of crop protection practices:** It is the percentage that reflects the loss due to the absence of crop protection products; it is calculated as the difference between the potential and actual percentages.

**Morbidity Rate:** The number of people in a specific geographical location who contracted a particular disease during a specific period of time, usually expressed as the number of cases per 100,000 persons at risk.

**Mortality rate:** is a measure of the number of deaths (in general, or due to a specific cause) in a particular population, scaled to the size of that population, per unit of time. Mortality rate is typically expressed in units of deaths per 1,000 individuals per year;

**Aggregated Value:** The Aggregated Value or Added Value in the agricultural sector consists in the transformation of the raw material into a product in order to give it a higher commercial value, without losing sight of the quality of its origin.

*[7] FAO. Codex Alimentarius. Glossary of terms. https://www.fao.org/fao-who-codexalimentarius/codex-texts/dbs/pestres/glossary . Consulted in December 2022.*
*[8] Savary, S., Ficke, A., Aubertot, JN. et al. Crop losses due to diseases and their implications for global food production losses and food security. Food Sec. 4, 519–537 (2012). https://doi.org/10.1007/s12571-012-0200-5*
*[9] Savary, S., Ficke, A., Aubertot, JN. et al. Crop losses due to diseases and their implications for global food production losses and food security. Food Sec. 4, 519–537 (2012). https://doi.org/10.1007/s12571-012-0200-5*

# BACKGROUND

# Correlation between pesticides and productivity

Pesticides are one of the resources needed to compensate for the demand for food, feed, bioenergy and products for the textile industry with regard to the challenge posed by an ever-growing human population, an increasing livestock production and an agricultural frontier limited or reduced by urbanization, the abandonment of crops or changes in land use.

In the last three decades pesticide use and food production have a direct relationship; this means that any increase in agricultural productivity requires a proportional increase in pesticides use.

Between 2000 and 2020 the growth of the agricultural production index published by FAO[10] grew at average annual rates of 1.6%, while the annual growth of pesticide use was 2.5%.

The agricultural production index is an indicator that aims to measure changes in the physical volume produced during a defined reference period; in this case the index is made by comparing the volumes of food produced each year, with respect to the average observed in the period 2014-2016. The agricultural production index takes into account changes in the type and quality of products and changes in stocks (inventories) of agricultural production.

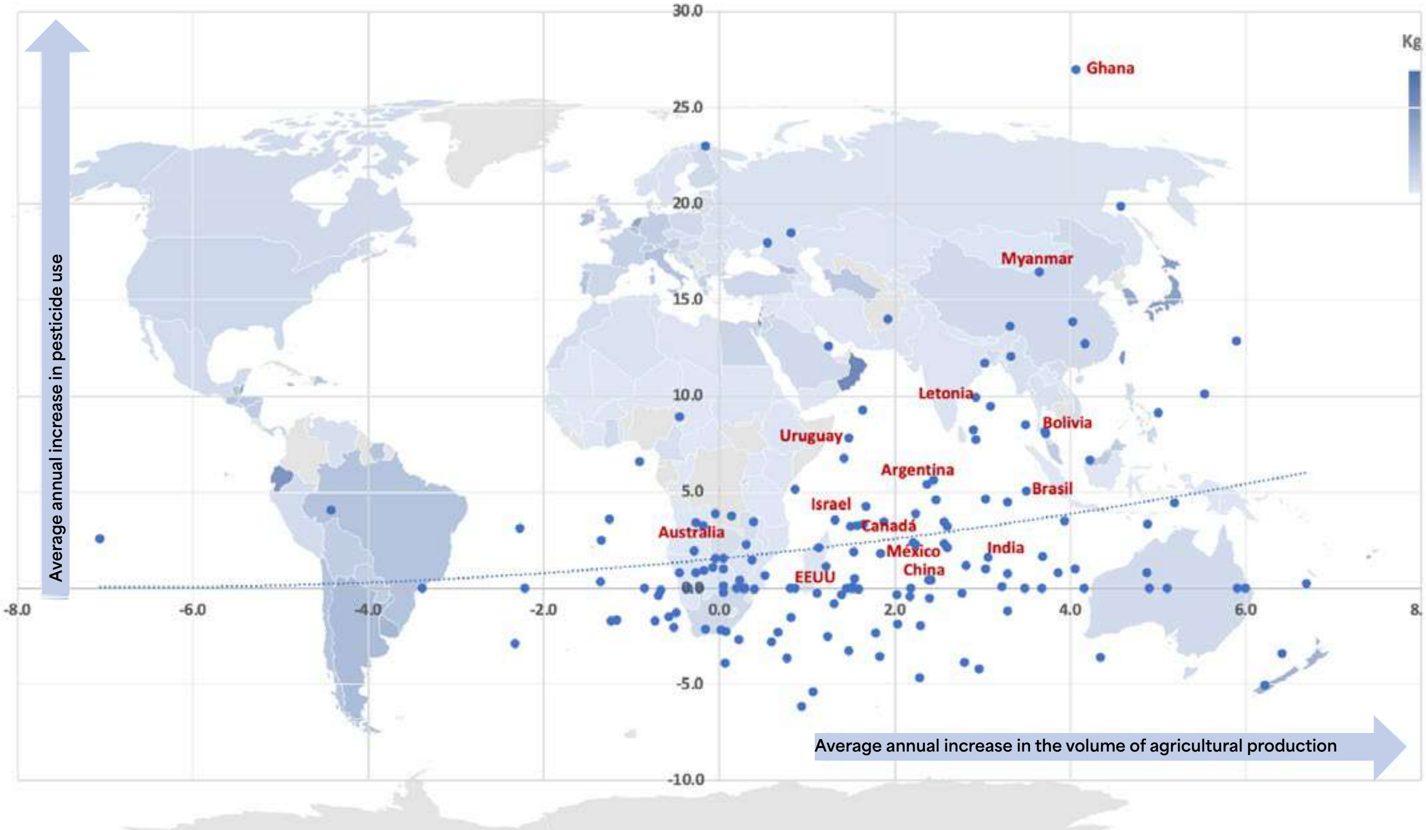
We will now use correlation analysis to show the strength and significance of the relationship between pesticide use and productivity in agriculture. A first conclusion of this analysis for the countries analyzed is that there is a relationship between both variables, both in meaning (when one changes, the other one does it in the same way) and magnitude, which means that the change in one variable corresponds to a similar change in the other variable. It should be noted that this analysis does not consider all other variables of agricultural production since they are not the subject of this study but are nevertheless relevant to production (such as climatic variables, natural resources, use of technical and scientific resources, social, working and political conditions, among others).

To demonstrate the correlation between agricultural production[11] growth and pesticide use, we have taken as a reference six countries that together generate 23% of the world's agricultural production and which are regionally interrelated by trade agreements. They are Argentina (2% of the world's agricultural volume), Brazil (11%), Canada (1%), Chile (0.16%), the United States (7%) and Mexico (1%). Among them, there is a high correlation between the growth of the agricultural production index and the use of pesticides. In the case of Argentina and Brazil the relationship is direct (with correlation coefficients higher than 95% between both variables for the period 1990-2020), which implies that the increase in the physical volume of agricultural production (measured in tons) corresponds to an equal increase in the use of pesticides. The same is true for Canada's agricultural economy (with a correlation coefficient of 93% for the period 1990-2020). Dependence is lower in the United States, Mexico and Chile, and yet, both variables advance in the same direction and at similar rates.

*[10] Food and Agriculture Organization of the United Nations. Gross Production Index Number (2014-2016 = 100). FAOSTAT, FAO Rome. Consulted in October 2022. In the course of the analysis, Index Numbers, which are a statistical measure that allows to study the variations of one or more magnitudes of equal or different nature, in relation to a reference period, should be used. Reference periods (or base years) are periods where conditions are relatively stable. There is a wide range of index numbers; for this analysis Simple Index Numbers will be used. In the case of agricultural production, the United Nations (specifically FAO) refers to the average magnitude (production volume) between 2014 and 2016 as a comparison period. In the case of Mexico's macroeconomic indicators, the System of National Accounts refers to 2013 and, for price indicators both 2018 and 2019 are used as base years for comparison.*

*[11] Food and Agriculture Organization of the United Nations. Crop and livestock statistics (recorded for 278 products). FAOSTAT, FAO Rome. Consulted in October 2022.*

*Figure 1. Selected countries: Correlation between pesticide use and productivity. 2000-2020*

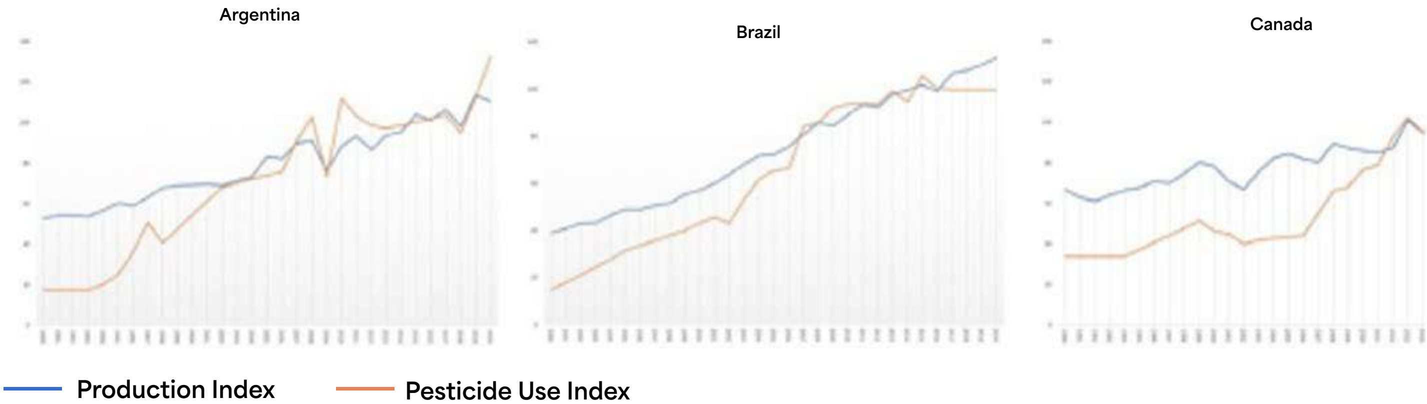



*Average annual growth rate of pesticide use and average annual growth rate of agricultural production: 2000 - 2020. Percentage. Source: Elaborated based on FAO. FAOSTAT. Consulted on 15 October 2022.*

Of all the phytosanitary challenges faced by agricultural production, the most important one is weeds, which explains why 60% of the total volume of plant protection products used worldwide corresponds to herbicides. The increasing use of fungicides is explained by the increased demand for fruits and vegetables and also by the resistance that organisms have developed, in addition to other factors. Meanwhile, insecticide use has decreased as a percentage of total crop protection products. This trend may be related to the increase in the adoption of GMO technologies that incorporate protection against some insects.

For the selected group of countries in the Americas, for each increase in agricultural production, the volume of herbicides increases in virtually the same proportions. Fungicides are used to a lesser extent, and in the case of insecticides, their use is stable or declining.

***Figure 2. Selected countries: Correlation between pesticide use and productivity. 1990-2020***

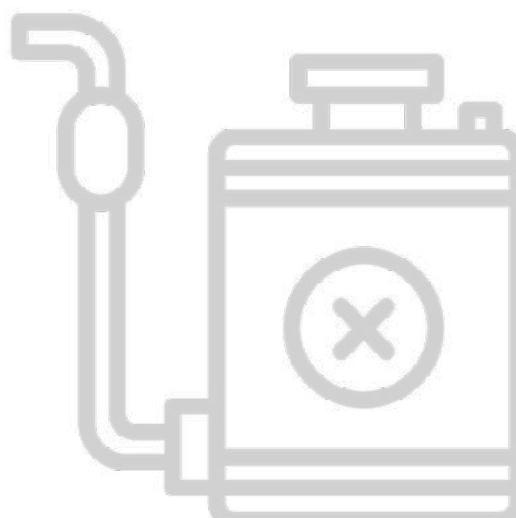



*Production Growth Index and Pesticide Use Index. 2014 - 2016 = 100. Source: Elaborated based on FAO. FAOSTAT. Consulted on 15 October 2022.*

A greater need for pesticide application is associated with climate change. A review of scientific studies promoted by the Food and Agriculture Organization of the United Nations (FAO) concludes that climate change will increase the risk of pests spreading in agricultural and forest ecosystems. There is evidence that specific pests of maize, sorghum and millet have already spread to other latitudes and crops due to warmer climate, as well as pests commonly found in fruit.

Moreover, migratory pests could change their routes and geographical distribution due to climate change. The analysis warns that at least 15 pests with high impact on agricultural and forestry production may spread by the effects of climate change and global trade.

FAO concludes that there is sufficient evidence to say that invasive pests are a growing threat to food security and the environment. Pests that were once endemic are spreading through international transport, to become a regional or global threat. Emerging plant diseases are spreading through global trade and are rooted in the climate; hence, FAO suggests protecting plant health for its multiple positive impacts, always within the framework of international regulations[12].



[12] *Food and Agriculture Organization of the United Nations. IPPC Secretariat. 2021. Scientific review of the impact of climate change on plant pests. A global challenge to prevent and mitigate plant pest risks in agriculture, forestry and ecosystems. Rome. https://www.fao.org/3/cb4769en/online/cb4769en.html*

[13] *Rizzo, DM, Lichtveld, M., Mazet, JAK et al. Plant health and its effects on food safety and security in a One Health framework: four case studies. One Health Outlook 3, 6 (2021). https://onehealthoutlook.biomedcentral.com/articles/10.1186/s42522-021-00038-7*

# INTERNATIONAL CONTEXT

*The metrics of productivity reduction in the absence of agrochemical application have a recent evidence: the abrupt decrease of agrochemicals (mainly fertilizers and pesticides) resulted in a productive crisis with significance in other variables of the national economy; this is the case of Sri Lanka in the period 2021-2022.*

# Sri Lanka: Agrochemicals restrictions, crop loss and food crisis

In 2021, Sri Lanka's agricultural policy adopted a strategy aimed at food production without the supply of agrochemicals and banned the import of pesticides and fertilizers. The measure was based on the grounds that the use of pesticides did not generate an increase in agricultural production and that agrochemicals accelerated soil infertility, low yields and loss of biodiversity.

With the promulgation of a decree, the Sri Lankan government restricted and banned the import of agrochemicals (including insecticides and herbicides) to increase domestic production of organic fertilizers as a substitute[14].

The abrupt breakdown of the supply of chemical inputs for agriculture in 2021 resulted in a food crisis. Maize production declined by 40% a year later, with collateral effects on poultry and livestock production. The decline in the production of vegetables, fruit and export-oriented crops (tea, rubber, coconut and spices) led to a significant decline in export revenues and an inevitable foreign currency shortage to restore the import of agricultural inputs.

The effects on food production experienced an annual drop of at least 30% in rice yields across the country. Rice crop yield fell to 2.92 million tons in 2021-2022, down from 3.39 million last year. The country has not experienced this low level of production since the harvest affected by the drought in 2017[15].

Sri Lanka had been self-sufficient in rice for decades, but due to the production crisis it had to resort to international markets to import that grain after the fertiliser shortage affected availability. In 2022, the country has already contracted to import 424,000 tons (MT). The total cereal import requirement in 2022 is estimated at 2.2 million tons. In the first six months of 2022, more than 930,000 metric tons of cereals were imported, leaving an outstanding import requirement of 1.27 million metric tons. In view of the persistent macroeconomic challenges, there is a high risk that the remaining import requirement will not be met due to foreign exchange constraints.

[14]*USDA. Foreign Agricultural Service. Sri Lanka: Restricting Import of Fertilizers and Agrochemicals. June 3, 2021. https://www.fas.usda.gov/data/sri-lanka-sri-lanka-restricts-and-bans-import-fertilizers-and-agrochemicals Consulted in November 2022.*

[15]*Devjyot Ghoshal. Sri Lanka faces looming food crisis with stunted rice crop. En Reuters. August 16, 2022. https://www.reuters.com/world/asia-pacific/sri-lanka-faces-looming-food-crisis-with-stunted-rice-crop-2022-08-16/ Consulted in November 2022.*

According to data from November, and data provided by the World Food Programme (WFP), most food prices had a year-on-year inflation rate of 70% and it is estimated that 37% of the population are food insecure. Animal protein, diary and fruit are consumed less than three days a week by the average household. Consumption of diary has halved since June and continues to be the lowest-consumed food group[16].

The WFP report notes that pests and diseases, erratic rainfall and extreme weather are issues that farmers are anticipating, so for the 2022/2023 period only 48% of farmers plan to cultivate the same area of rice (main staple food of the country) that they did during the previous season. Among the main challenges to restore agricultural production is the presence of crop pests and diseases: one out of five farmers in Sri Lanka anticipates that the presence of pests would be a constraint to restoring agricultural productivity.

[16] *United Nations. World Food Program. Sri Lanka, Food Security Monitoring, November 2022. https://docs.wfp.org/api/documents/WFP-0000145643/download/?_ga=2.25620920.407229744.1675774438-458050933.1675774438*

# Non-tariff barriers to pesticide use

The trend of food-importing countries to tighten their food safety and quality standards, affects the use of pesticides in producer countries. Specifically, the European Union has imposed trade barriers on agriculture imports by changing its quality standards, particularly by minimising maximum pesticide residue limits (MRLs) in ranges below international agreements such as the provisions of the Agreement on Sanitary and Phytosanitary Measures of the World Trade Organisation.[17]

This trend has already been replicated in other food-importing countries such as the United Arab Emirates, which normally adopt FAO's CODEX Alimentarius standards, although in the absence of an established Codex MRL, European Union MRLs may be applied[18].

[17] *Iyengar, Suresh P. EU uses pesticide residue norms as trade barrier on agri-imports. The Business Line. October 2022. https://www.thehindubusinessline.com/economy/agri-business/eu-uses-pesticide-residue-norms-as-trade-barrier-on-agri-imports/article66060336.ece*

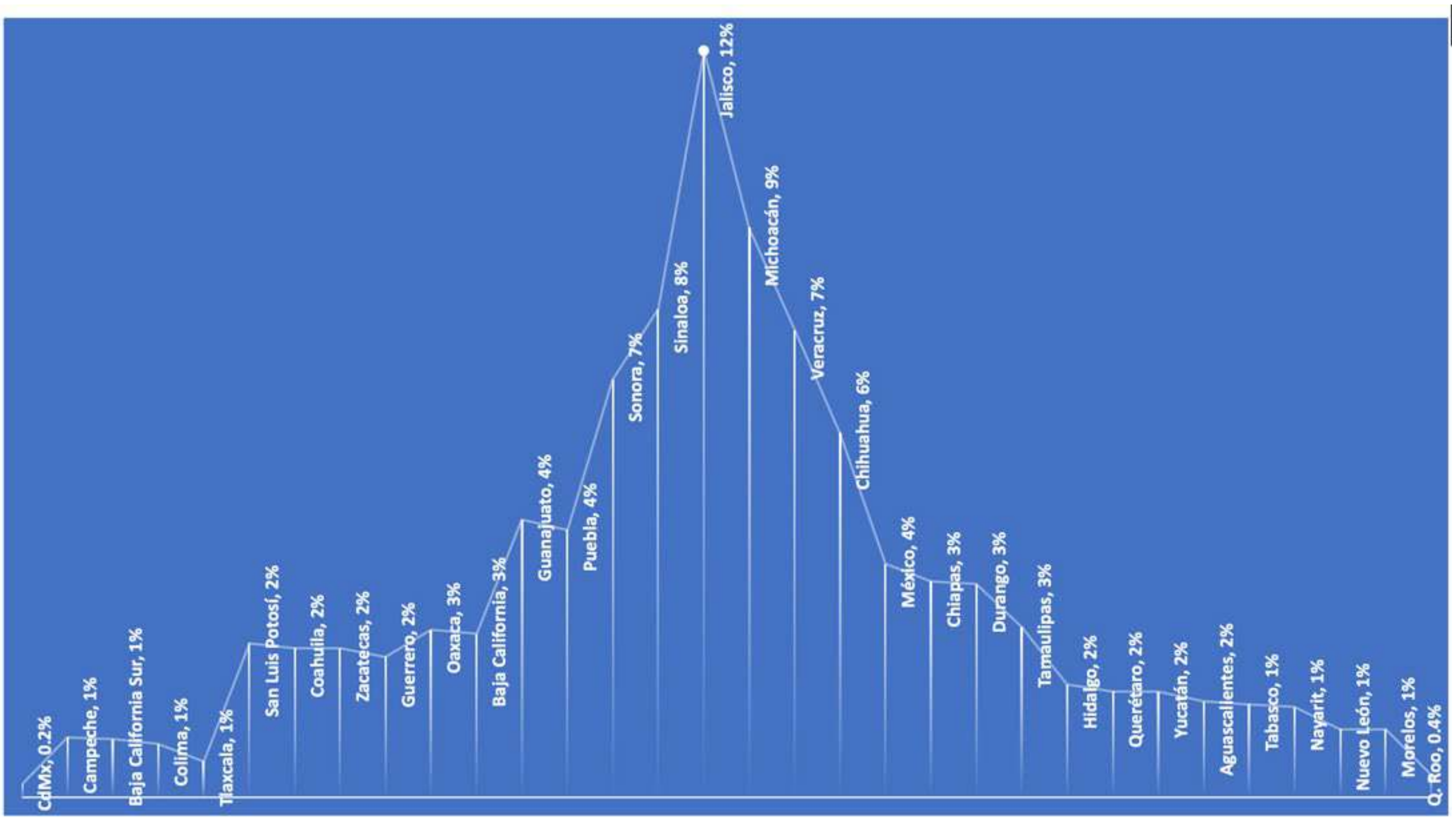
[18] *Northwest Horticultural Council. Export Manual United Arab Emirates. https://nwhort.org/export-manual/countries-toc/united-arab-emirates/*

# AGRICULTURAL ECONOMY IN MEXICO

# Gross Domestic Product

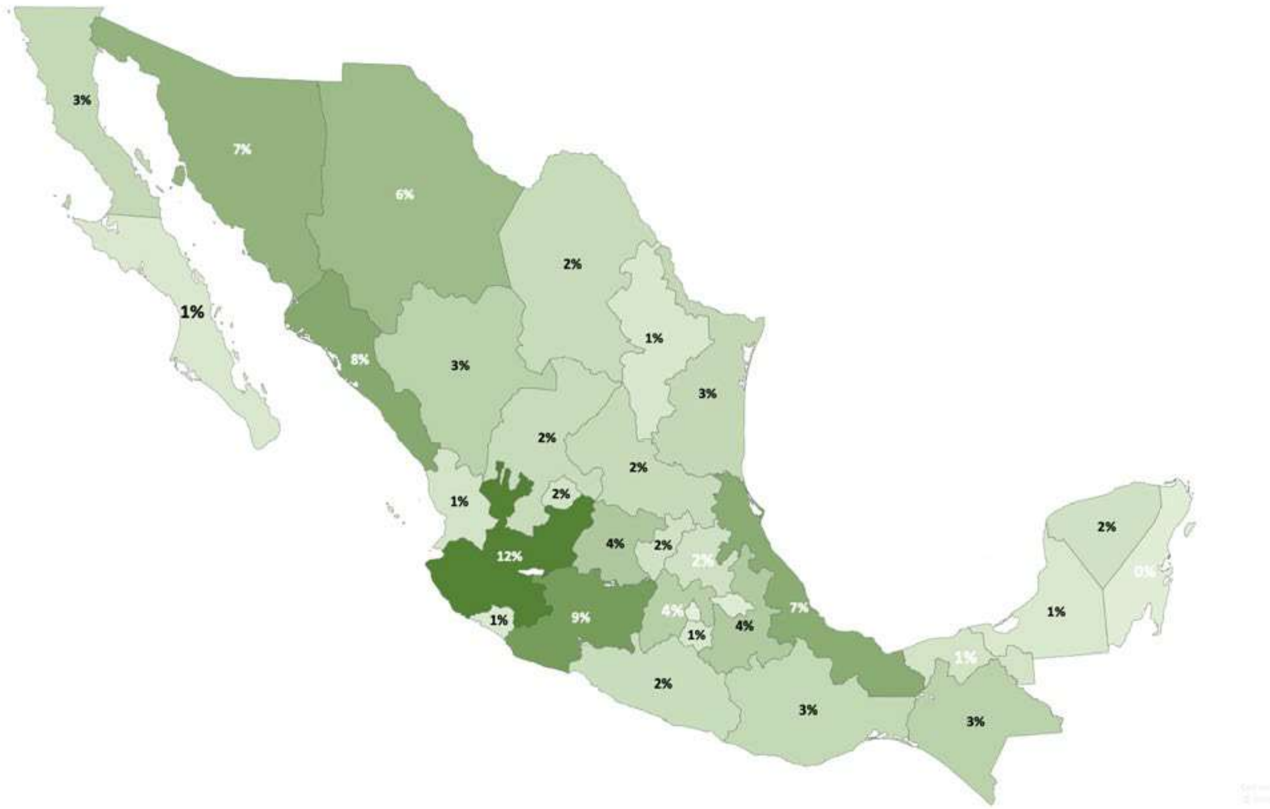
In Mexico, the primary activities include the role of agriculture, which currently accounts for 3.4% of the national gross domestic product. The level of concentration of agricultural GDP is average, while six states concentrate half the added value of this sector (Jalisco, Michoacán, Sinaloa, Veracruz, Sonora and Chihuahua). This level of concentration of agricultural added value makes it possible to balance the degree of regional influence and not necessarily depend on a state or a small group of them.

***Figure 3. Mexico: State concentration of agriculture gross domestic product, 2015 - 2021 (Normal Distribution)***




*Percentages of the average agricultural GDP from 2015 to 2021. Source: INEGI, System of National Accounts, Gross Domestic Product by state, 2013. https://www.inegi.org.mx*

***Figure 4. Mexico: State concentration of agriculture gross domestic product, 2015 - 2021, (Map)***




*Percentages of the average agricultural GDP from 2015 to 2021. Source: INEGI, System of National Accounts, Gross Domestic Product by state, 2013. https://www.inegi.org.mx*

In recent decades, Michoacán has been the most dynamic agricultural economy, mainly due to its contribution to the maize harvest, in addition to higher value-added products (avocado, blackberries, strawberries, raspberries, mangoes, agaves and vegetables). Although Michoacán is the second state in terms of the size of agricultural GDP, it has the greatest dynamism in the recent decade (5% real growth, annual average).

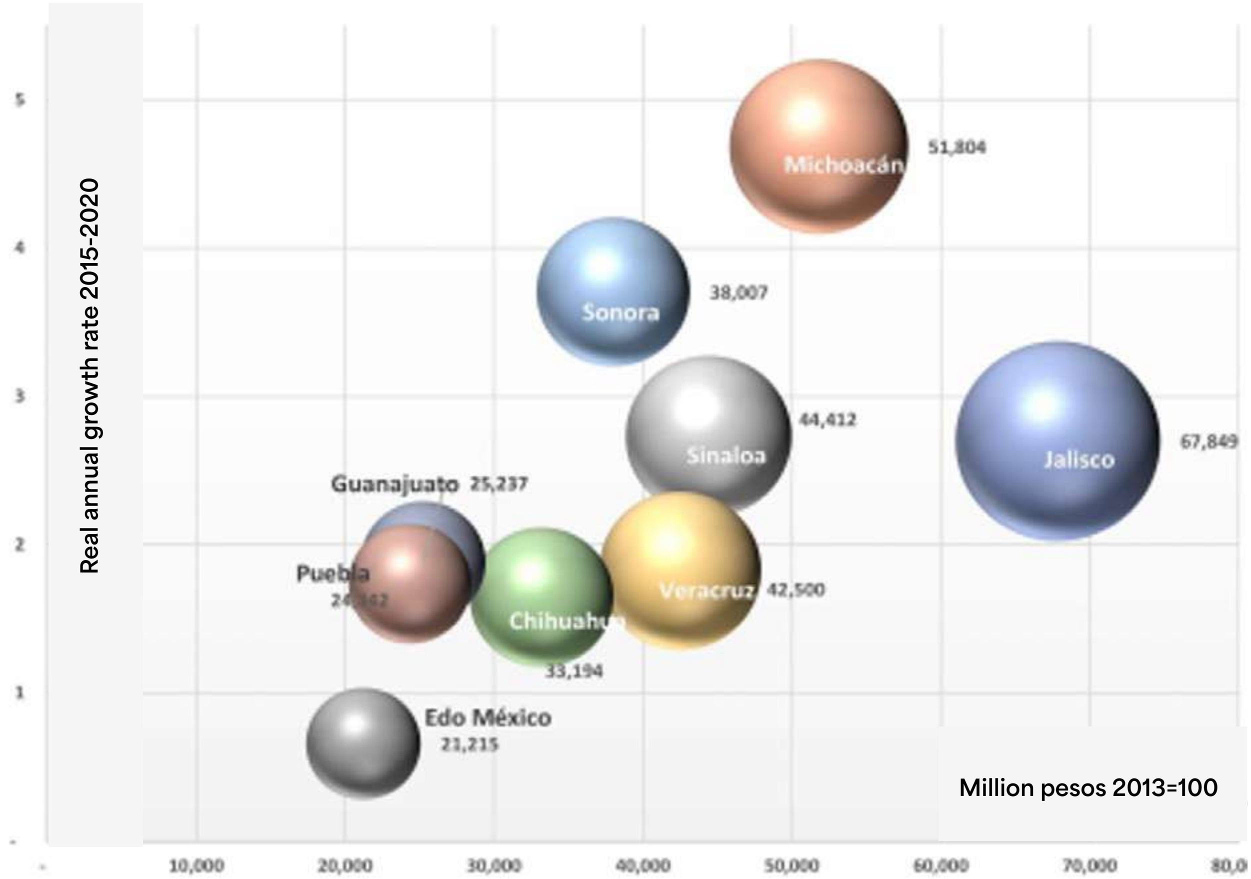
Jalisco is the second state that contributes to the growth of agricultural GDP. Its most representative crops are agave, maize, sugar cane, avocado and vegetables. Over the past 10 years, its average annual growth rate has been close to 3%.

Sonora is the third engine of growth for the Mexican agricultural economy, ranking 5th in size, but its growth in the recent decade is one of the most important; its average annual growth rate is close to 4%. Its contributions come mainly from the cultivation of grapes, asparagus, wheat, potatoes, maize, vegetables and nuts.

Sinaloa accounts for 8% of the national agricultural GDP and its real growth rate over the last decade is 3% per year. The crops that drive its growth are maize, vegetables (mainly tomato and chili), potatoes, beans, mango and sorghum.

In the case of Veracruz, it represents 7% of the national agricultural GDP, with a real annual growth rate of 2%. The most representative crops are sugar cane, citrus, maize, pineapples, potatoes, coffee and bananas. Chihuahua accounts for 6% of agricultural GDP and its average annual growth rate has been 2% per year in real terms. It is distinguished by the production value of nuts, cotton, apples, maize, alfalfa, vegetables, beans and fodder oats.

***Figure 5. Mexico: Growth and size of main states in the agriculture gross domestic product.***




*Value of agricultural GDP from 2015 to 2020 (billions of pesos 2013=100) and average real annual growth rate. Source: INEGI, System of National Accounts, 2013. https://www.inegi.org.mx/*

# GDP of pesticide production and sales

The manufacture and sale of pesticides as specific activities are listed in the recent 2013 and 2018 Economic Censuses. They include the advance of economic units that are formally registered. In 2013, about 6 thousand units were listed, employing 33,360 people and representing 0.18% of the national added value. Employed personnel is a variant of employment, which considers both the population that works in an economic unit and does not receive remuneration (self-employment, family employment, among others), as well as those who are employees (formal and informal) and receive income from the activity.

In 2018, the economic units were 7,160 (129 manufacturing units and 7,031 marketing units). The total employed personnel were 37,208 and its share in the national GDP was accounted for 0.18%.

The table below shows the percentage of personnel employed in the manufacture and sale of pesticides with respect to the national total. The percentage of employed personnel is concentrated in marketing and increased between 2013 and 2018 (latest economic census available).

Where applicable, the Added Value can be understood as the value of the production that is added during the work process (in the case of marketing) or processing (in the case of the manufacture of pesticides). Gross Census Value Added (VACB) results from subtracting intermediate consumption from total gross output (without taking into account the depreciation of fixed investment). For our analysis, it highlights the growth of this indicator, since it is a concrete contribution to the growth of the national economy.

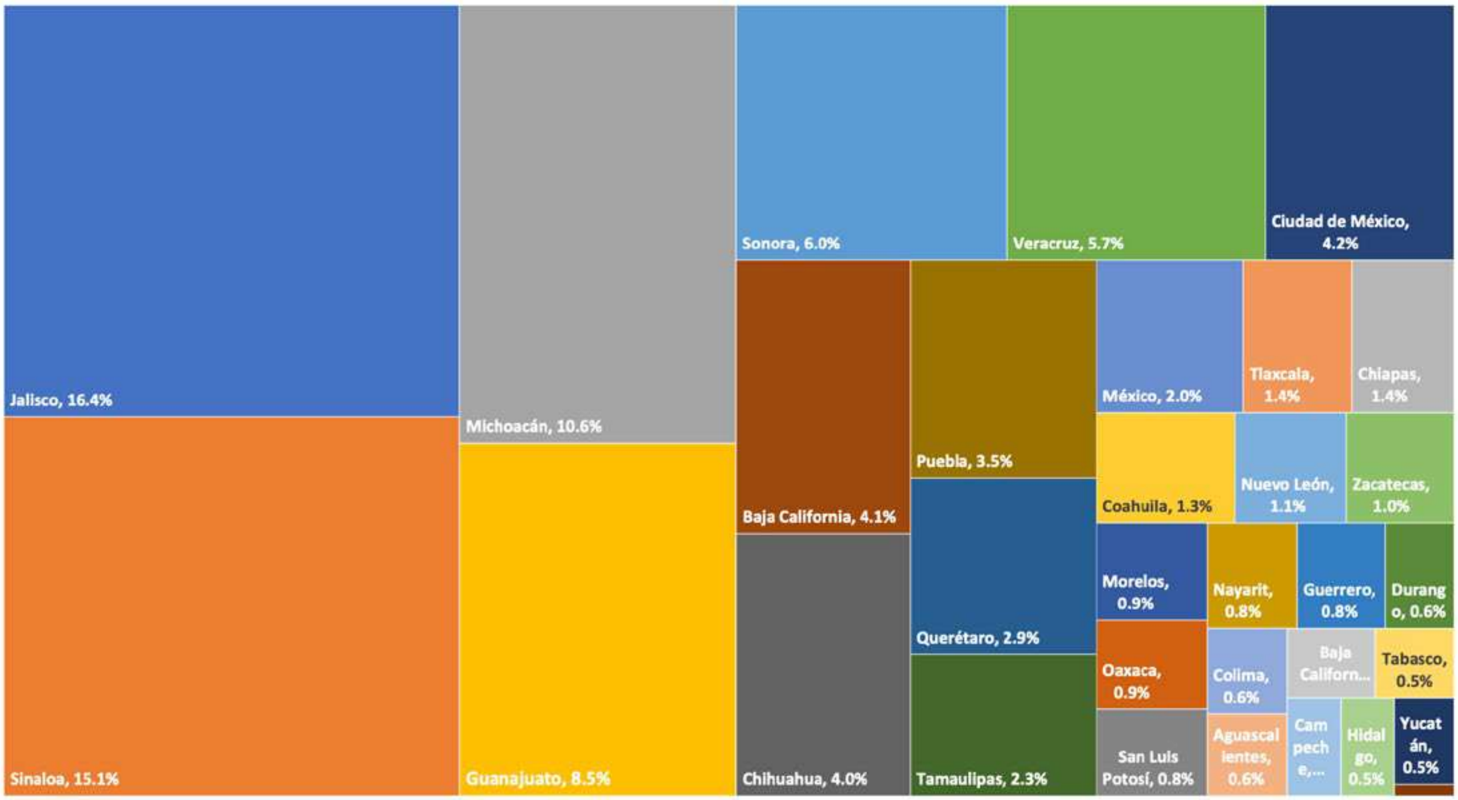
***Table 1. Mexico: Employed personnel and Gross Added Value in the manufacture and sale of pesticides, 2013 and 2018.***

| Concept | Total employed personnel (%) | Gross census added value. (%) |
|---|---|---|
| **2013** | | |
| Manufacture of pesticides and other agrochemicals, except fertilizers. | 0.02% | 0.04% |
| Wholesale trade of fertilizers, pesticides, and seeds for sowing. | 0.13% | 0.14% |
| **Manufacture and trade of pesticides and agrochemicals.** | **0.15%** | **0.18%** |
| **2018** | | |
| **Manufacture of pesticides and other agrochemicals, except fertilizers.** | 0.02% | 0.07% |
| Wholesale trade of fertilizers, pesticides, and seeds for sowing. | 0.14% | 0.17% |
| **Manufacture and trade of pesticides and agrochemicals.** | **0.16%** | **0.24%** |

*Percentage of national total. Source: INEGI, Economic Censuses. Automated Census Information System (ACIS). Years 2013 and 2018.*

The value generated in the states of Mexico is a good approximation of sales by each state, as it is census information referred to geographically. The states that account for 80% of the national added value are: Jalisco (16.4%), Sinaloa (15.1%), Michoacán (10.6%), Guanajuato (8.5%), Sonora (6.0%), Veracruz (5.7%), Mexico City (4.2%), Baja California (4.1%), Chihuahua (4.0%), Puebla (3.5%) and Querétaro (2.9%).

***Figure 6. Mexico: Distribution of Added Value in Pesticides and Fertilizers Trade.***




*Percentages. Source: INEGI, Economic Censuses. Automated Census Information System (ACIS). Years 2013 and 2018.*

# Direct and indirect employment in agricultural activities

Employment in the primary sector amounted to 6.7 million jobs, according to the National Occupancy and Employment Survey (ENOE).[19] More specifically, employment in agriculture is estimated at 5.8 million. Crops that consolidate two thirds of the personnel employed in agricultural activity are grass, maize, alfalfa, sugar cane, beans and sorghum.

***Table 2. Mexico: Personnel employed in agricultural activity by crop, 2019.***

| CROP | Jobs | CROP | Jobs |
|---|---|---|---|
| Grass | 1,517, 488 | Food crops in greenhouses | 33,807 |
| Maize (grain) | 1,111,164 | Avocado | 31,756 |
| Alfalfa | 407,148 | Watermelon | 31,119 |
| Sugar cane | 372,132 | Floriculture in open fields | 29,805 |
| Bean (grain) | 256,687 | Potato | 29,242 |
| Sorghum (grain) | 231,898 | Banana | 26,923 |
| Non-food crops in greenhouses and nurseries | 151,921 | Grape | 25,805 |
| Mango | 141,277 | Soybean | 23,410 |
| Coconut | 137,871 | Chickpea (grain) | 22,934 |
| Other vegetables | 98,732 | Other oilseeds | 21,438 |
| Fodder oats | 95,756 | Melon | 20,122 |
| Other crops | 89,931 | Other cereals | 19,949 |
| Coffee | 81,222 | Agave (for the production of spirits) | 18,190 |
| Chili | 76,125 | Other pulses | 16,224 |
| Fodder corn | 76,057 | Apple | 14,736 |
| Non-citrus fruit trees and nuts | 74,086 | Peanut | 13,932 |
| Green tomato | 72,917 | Oats (grain) | 12,381 |
| Wheat | 63,691 | Other citrus | 11,277 |
| Onion | 57,422 | Pumpkin | 10,424 |
| Orange | 55,050 | Rice | 5,315 |
| Cocoa | 53,849 | Tobacco | 5,109 |
| Tomato | 50,932 | Safflower | 3,716 |
| Barley (grain) | 38,553 | Floriculture in greenhouses | 2,217 |
| Cotton | 37,310 | Sunflower | 790 |
| Fodder sorghum | 36,758 | Trees | 62 |
| Lemon | 35,074 | **Total agricultural employment** | **5,851,734** |

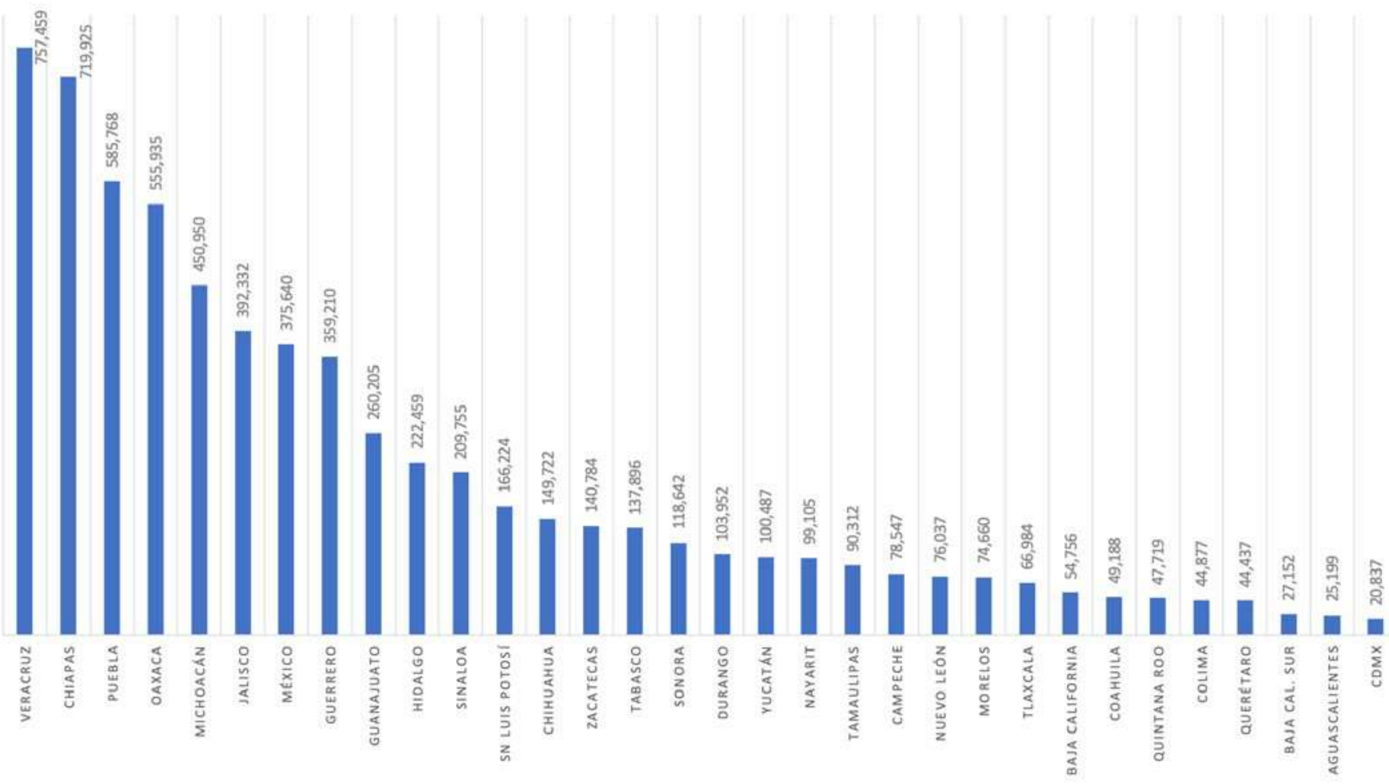
*Jobs. Source: INEGI. System of National Accounts. Input-Output Matrix. 2019.*

*[19] INEGI. National Occupancy and Employment Survey (ENOE). In the System of National Accounts. Input-Output Matrix, 2019, occupations are estimated by crop.*

The geographical distribution of rural employment, which includes other activities such as livestock, forestry and fishing, provides an approximation of the states where the occupation related to agricultural activity is concentrated. However, one of the most important challenges for agriculture is the demographic aspect, mainly international migration.

Demographic estimates by the National Population Council of Mexico (CONAPO) indicate that from 2025 to 2030, international migration will continue with an annual flow of more than 300,000 people, where the origin of that population will come mainly from Guanajuato (12.0%), Michoacán (8.4%), Puebla (7.7%), Jalisco (7.2%), Oaxaca (6.9%), Mexico (6.6%), Veracruz (6.0%) and Guerrero (4.7%). Of every one hundred international migrants expected to leave the country in the coming years, at least 6 of them will come from the country's main agricultural states,[20] in such a way that the pressure on the need for labor force for rural activities will increase. In turn, the impact on agricultural workers' salaries will also increase due to this population dynamics. Pesticides are an input that helps mitigate labor shortages in agriculture and maintain crop productivity rates. Just like mechanization, the use of pesticides is essential in order to meet food security objectives.

***Figure 7. Mexico: Personnel employed in agricultural activity by state, 2022.***




*Jobs. Source: INEGI. Quarterly National Occupancy and Employment Survey. Comparative data. 2022.*

On the other hand, crop production is indirectly linked to 860,000 jobs that are distributed in 197 branches of economic activity (one out of every four branches of activity), most of them involved in food production. The estimate is based on calculating the level of importance of agriculture in the supply chain of each of the economic activities and assuming that this proportion is the same in the number of employees in each activity. The branches of economic activity and the supply relationships are taken from the most recent Input-Output Matrix, published by INEGI[21].

[20] *National Population Council. Projections of the Population of Mexico and the Federative Entities, 2016-2050. International Migration. http://indicadores.conapo.gob.mx/Proyecciones.html*

[21] *INEGI. System of National Accounts. Input-Output Matrix, 2019.*

Approximately
**7 million jobs**
are generated, both directly and indirectly, by agricultural activities.

This represents
**about 11 %**
of the country's economically active population.

***Table 3. Mexico: Indirect jobs related to agricultural activity by main branches of activity, 2019.***

| Economic activity | Indirect jobs | | Economic activity | Indirect jobs |
|---|---|---|---|---|
| Corn tortilla preparation and nixtamal grinding | 216,619 | | Manufacture of wide width woven fabrics | 8,212 |
| Bovine use for joint milk/beef production | 107,704 | | Freezing of fruits and vegetables | 8,135 |
| Bovine use for milk production | 94,022 | | Restaurants with appetizer preparation service | 6,987 |
| Bovine use for beef production | 91,529 | | Restaurants with tacos and tortas preparation service | 6,672 |
| Farming of equids | 62,755 | | Animal feed production | 6,616 |
| Restaurants with à la carte food or quick meals ("comida corrida") preparation service | 29,139 | | Preparation and spinning of natural soft fibres | 6,484 |
| Cane sugar processing | 28,219 | | Restaurants with pizzas, burgers, hot dogs and roast chicken preparation service (take-away) | 6,350 |
| Pig farming (on-farm) | 19,467 | | Rabbit breeding and fine-fur animals farming | 5,921 |
| Hen farming for table egg production | 17,483 | | Benefit of agricultural products | 5,771 |
| Fruit and vegetable preservation by processes other than freezing and dehydration | 11,942 | | Manufacture of distilled agave beverages | 5,259 |
| Snack production | 11,069 | | Cotton ginning | 4,837 |
| Goat farming | 9,597 | | Other activities | 89,234 |
| | | | **Indirect jobs in 197 national activities** | **860,025** |

*Jobs. Source: Own calculations based on INEGI's data. System of National Accounts. Input-Output Matrix. 2019.*

# Foreign Currency Generation

Mexico is among the world's major economies, based on data from UN COMTRADE, in 2021, Mexican exports of farming products exceeded 43 billion dollars or 9% of the total value of exports.

In the group of edible vegetables, plants, roots and tubers, the value of Mexican production for export ranks third, after exports from China and Spain. In 2021, the value of vegetable exports was 8,6 billion dollars and the most representative products in international sales were fresh or chilled tomatoes, chilies or peppers, asparagus, zucchini, cucumbers and cabbages.

The second most important item in Mexico's agricultural exports is fruits, citrus fruits, melons and watermelons. In 2021, it totalled USD 8.2 billion and that value depends essentially on the sale of avocados, strawberries, blackberries, raspberries and blueberries.

Exports of coffee and other stimulants were close to USD 600 million in 2021, with a trend towards recovery in the last four years.

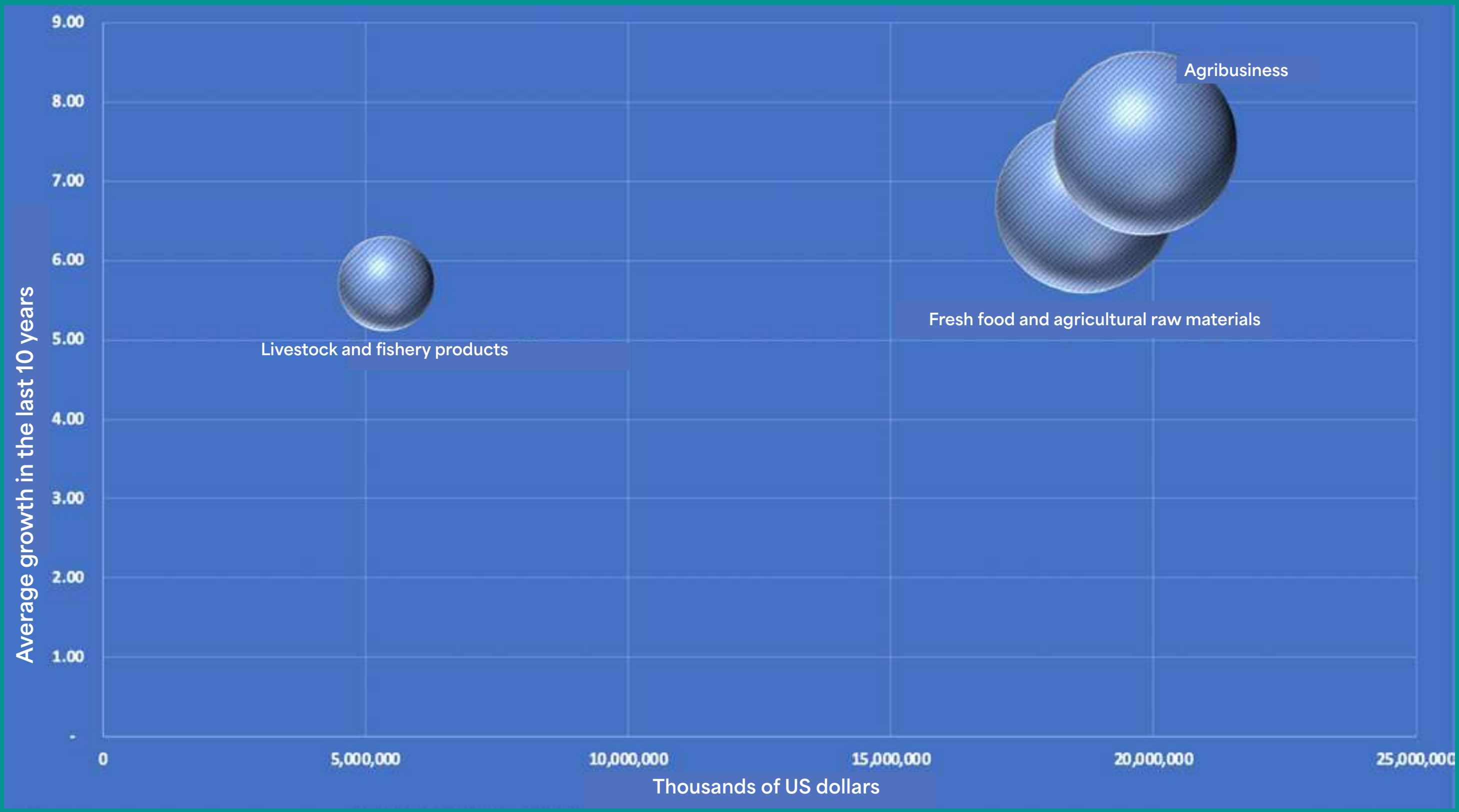
As far as cereal exports are concerned, the value is 400 million dollars, where wheat exports stand out.

Vegetable flours are another resource that generates foreign currency for USD 250 million annually. The increasing share of corn flour exports, mainly to the United States, is noteworthy.
Oilseeds and oilseed products are another emerging product group. The most recent data indicate an export value of USD 229 million. This also happens in the segment of gums, resins and other vegetable saps and extracts, totalling an export value of USD146 million in 2021. Live plants are also a growing export resource: in 2018, a value of USD 82.5 million was exported; by 2021 the export value was USD 128 million. In 2021, domestic exports of live plants were among the 25 most important economies in this sector.

In terms of exports, the National Service of Agri-food Health, Safety and Quality (SENASICA), notes that 'compliance with phytosanitary standards allows to open up new market opportunities for Mexican products and to position the country in terms of agricultural exports. The phytosanitary requirements established by each of the countries with which there are trade agreements are a condition for exports.'[22] It highlights the importance of pesticides in the control of quarantine pests and the impact these pests have on entering international markets.

[22] *National Service of Agrifood Health, Safety and Quality (SENASICA). National Plant Protection Organizations (NPPOs). https://www.gob.mx/senasica/acciones-y-programas/exportacion-de-productos-agricolas-149565*

*Figure 8. Mexico: Value and Export Growth by Product Group 2012-2021*




*Average growth rates of exported value and value of exports in 2021 in thousands of dollars. Source: Elaborated based on UN COMTRADE Database. Consulted in October 2022.*
**/Agri-business refers to industrially processed agricultural products such as coffee, sugar and sugar products; flour; prepared foods, among others.*

# TRENDS IN AGRICULTURE AND FOOD SECURITY

# TRENDS IN AGRICULTURE AND FOOD SECURITY

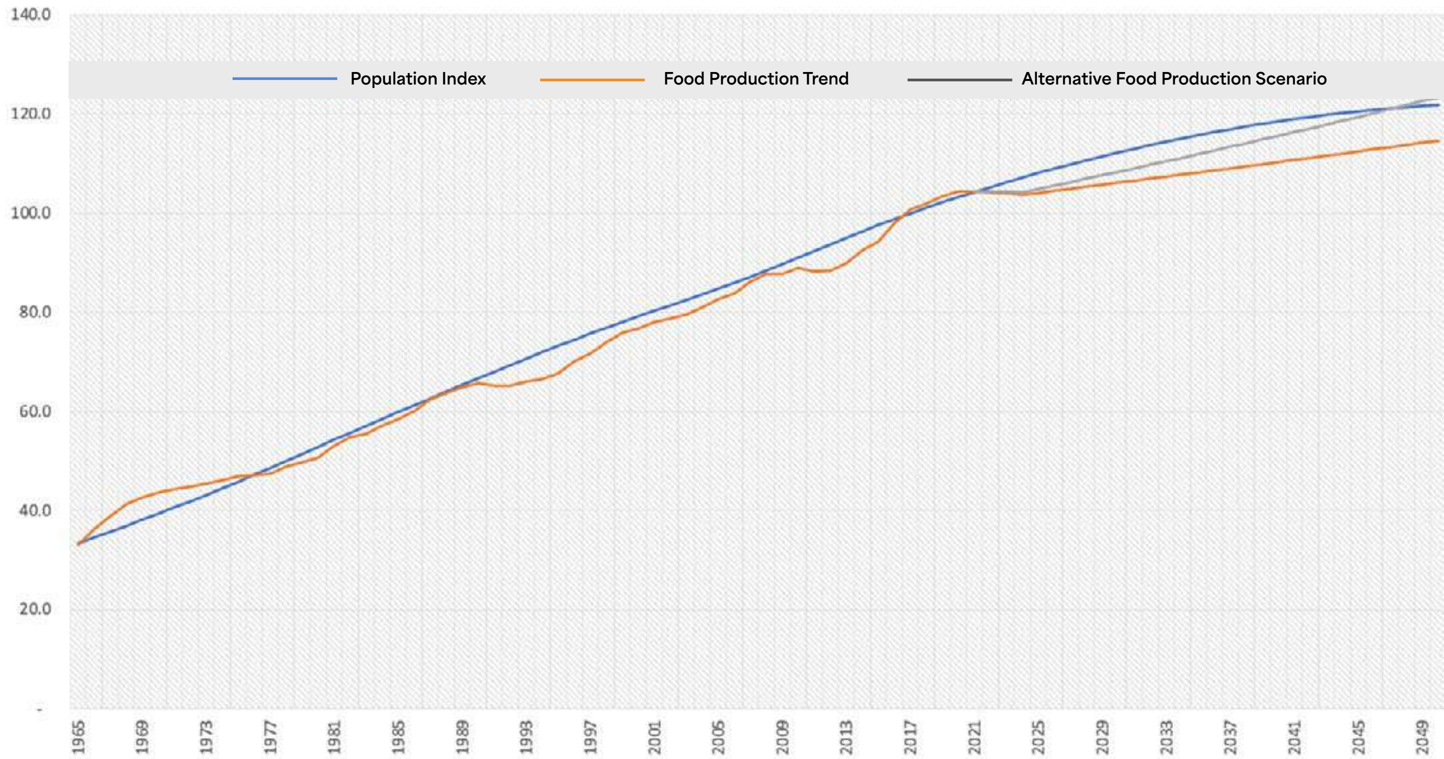
Mexico's agricultural economy faces the challenge of providing the national diet with an increasing amount of food. According to the projections of the National Population Council, the national population will increase by an average of one million Mexicans each year over the next eight years, and with a limited arable land, food supply must come from productivity that advances at rates similar to or higher than population growth (1% per year). On the other hand, the enduring trend of national and international migration will continue to be a key factor in local labor shortage for primary activities, in addition to climatic factors that are conditioning temporary changes that affect water availability, climate variability, among other effects of climate change.

The global trend shows that increases in agricultural yields are interdependent on the use of agrochemicals, biotechnology and food production. Essentially, with regards to agrochemicals, it is observed that any increase in food production mainly requires an increased use of pesticides and fertilizers.

In the case of Mexico, the long-term trend confirms the complementary relationship between fertilizers and pesticides, and the direct relationship between food production and the growing demand for agrochemicals. In the last 25 years it can be seen that when the economy has periods of exchange rate crises, pesticide consumption is affected more than fertilizer demand. The production and consumption projections for agricultural products for the period 2016-2030 pose an adverse scenario for national food security, since -according to the demographic projections of the National Population Council- demand could reach 139 million people and exceed the supply resulting from domestic production. In another sense, we must consider the constant loss of arable land in recent years, which increases the pressure to achieve higher crop yields per unit area.

If the current technological model is maintained, agrochemical requirements will grow, mainly in products such as insecticides, herbicides and fungicides, in order to increase the productivity of Mexican agriculture. It is worth noting that there are new innovative technological trends for crop protection, such as geomatics (remote, local sensing and other sensors linked to precision agriculture), whose use is expected to increase. Nonetheless, deficiencies in agri-food inputs will be covered by an increasing rate of imports. In turn, it is relevant to consider consumers' expectations in terms of quality, who demand greater access to safe, affordable and quality food throughout the year. Meeting quality conditions requires crop protection to ensure farmers' livelihoods.

*Figure 9. Mexico: Demographic Pressure and Food Needs, 1965 - 2050*

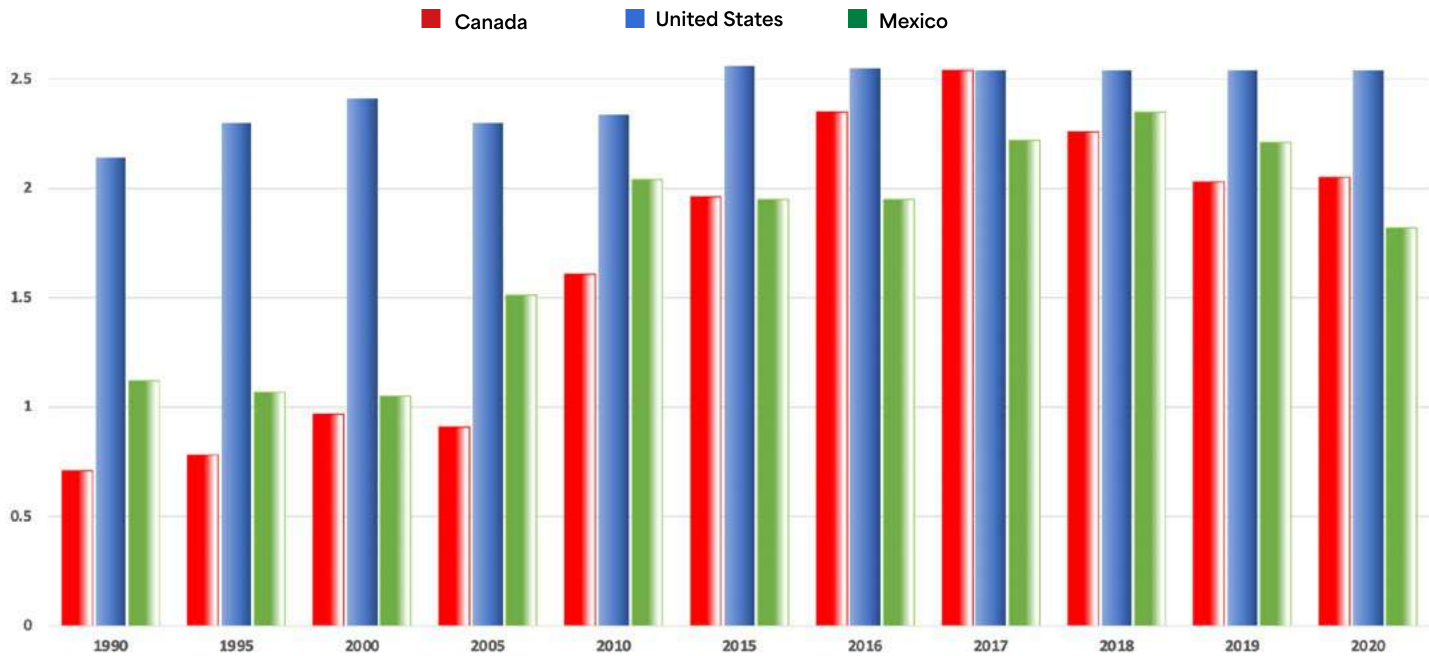



*Food Production Indices, Population Index and Alternative Food Production Scenario, (2014-2016=100). 5-year moving averages. Source: Elaborated based on information from the National Population Council (CONAPO), Food and Agriculture Organization of the United Nations. FAOSTAT. Consulted on 15th October 2022*

There is literature that refers to the use of pesticides using the gross volume of annual consumption. Using this type of gross indicators results in an overwhelming amount, particularly for economies such as Mexican economy, that needs to protect almost 25 million hectares of crops. A more appropriate measure to know whether pesticide application is moderate or excessive is the relative use of pesticides compared to the area under cultivation. Furthermore, it is necessary to compare this indicator with other economies with outstanding agricultural performance, such as the North American countries (United States and Canada). When comparing the use of pesticides per cultivated hectare in Mexico, the United States and Canada, it can be seen that the use of pesticides in Mexico is lower than in the other countries and that, in the last three years reported by FAO, there has been a downward trend in this indicator.

Thus, for example, between 2017 and 2019 -on average- 2.3 kilograms (or its equivalent in liters) were used per cultivated hectare. By 2020, pesticide use continued to decline to 1.7 kg per hectare. In contrast, the chart below shows that in the United States the proportion of pesticides used per hectare has averaged 2.5 kg over the last five years.

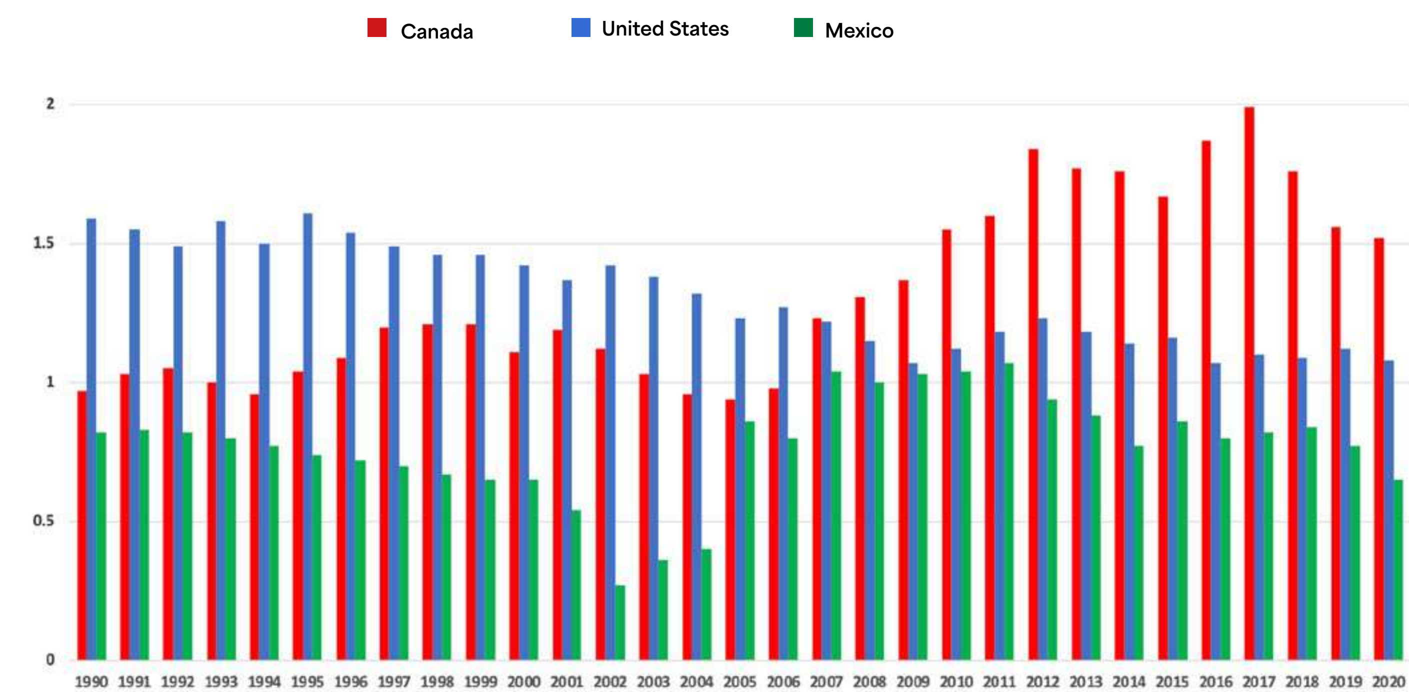
*Figure 10. Countries of the United States-Mexico-Canada Agreement (USMCA): Pesticide use per area of cropland, 1990-2020*




*Kilograms per hectare (kg/ha). Source: Authors' elaboration based on FAO. FAOSTAT. Consulted on 15 October 2022*

The efficiency of pesticides in Mexico stands out when comparing the amount used per thousand dollars of cultivated products. When contrasting this indicator with the USMCA economies, it shows that domestic agri-food products are incorporated into high value-added goods and that fewer agrochemicals are needed to generate the same production value.

*Figure 11. Countries of the United States-Mexico-Canada Agreement (USMCA): Pesticide use by produced value. 1990 - 2020*




*Kilograms applied per $1,000 of value produced (kg / $1000). Source: Authors' elaboration based on FAO. FAOSTAT. Consulted on 15 October 2022*

# CROP LOSSES TO PESTS AND PATHOGENS

# Crop Losses to Pests and Pathogens

Crop loss involves multiple factors. It is not a deliberate act of producers and is influenced by various components of the agricultural system that are beyond human control, such as epidemics and climate, among other factors.

Based on multiple analyses, it has been estimated that the lack of crop protection has an impact on the loss of productivity of essential foodstuffs for the human diet.

On-farm food losses can occur before, after or during harvest; in some cases, crops may be left unharvested. The causes of on-farm losses are numerous and context-specific; factors such as weather conditions, seed quality, crop variety and cultivation practices, pest infestations, and plant diseases all play a role.

In 2019, the Food and Agriculture Organization (FAO), conducted a research based on meta-analysis (a method for synthesizing results from different studies), on food loss and waste that includes publications and reports from sources such as governments, universities, and international governmental and non-governmental organizations. The meta-analysis presents useful insights into the extent and causes of loss and waste across different stages in the food supply chain.[23]

Since the publication of FAO in 2019 to present, the largest number of food loss and waste research is contained in the Food Loss and Waste Database, which contains information from open access databases, reports and studies that measure food loss and waste across food commodities, stages of the value chain and geographic areas.[24] The analyses detail losses during production and throughout the supply chain, excluding the retail stage. The data repository compiles findings from studies that analyze food losses as a percentage of national production at different stages in the supply chain.

The analyses referred by the database show the percentages of food loss and waste in general. Between 2000 and 2021, about 28,000 analyses were compiled, of which 61 documents refer to the estimations made for Mexico, prepared on the one hand by the FAO (Technical Assistance Project) and, on the other hand, by the National Council for the Evaluation of Social Development Policy (CONEVAL) in 2013, specifically by the Technical Group of Food Loss and Waste, of the National Crusade Against Hunger, which developed the Food Waste Index in Mexico, which estimates that 37% of the food produced throughout the supply chain is lost in the country, without specifying the losses during production, nor the causes that provoke them.[25]

[23] *FAO. 2019. The State of Food and Agriculture. Moving Forward on Food Loss and Waste Reduction. Rome. https://www.fao.org/3/ca6030en/ca6030en.pdf*

[24] *FAO. Food Loss and Waste Database https://www.fao.org/platform-food-loss-waste/flw-data/en/ Consulted in January 2023*

[25] *Ministry of Welfare. Reducing food losses, objective of the National Crusade Against Hunger. 23 December 2013. https://www.gob.mx/bienestar/prensa/reducir-perdidas-de-alimentos-objetivo-de-la-cruzada-nacional-contra-el-hambre. Consulted in January 2023.*

*Table 4. Mexico: Food loss and waste throughout the supply chain, 2013. (Percentage).*

| Crop | Loss and waste (%) |
|---|---:|
| Aubergines | 49.1 |
| Rice | 46.9 |
| Grapes | 45.5 |
| Pepper | 45.5 |
| Chilies and dried peppers | 44.1 |
| Melons | 41.2 |
| Potatoes | 37.1 |
| Lemons and limes | 33.4 |
| Pineapples | 32.8 |
| Onions | 32.1 |
| Red tomatoes | 28.9 |
| Beans | 25.0 |
| Oranges | 23.2 |
| Papayas | 22.8 |
| Garlic | 21.4 |
| Carrots | 19.0 |
| Tomatoes | 17.8 |
| Pumpkins | 14.7 |

*Source: Food Loss and Waste Database https://www.fao.org/platform-food-loss-waste/flw-data/en/ Consulted in January 2023.*

# Global estimates

In 2012, an analysis carried out by the Organisation for Economic Cooperation and Development (OECD) and FAO indicated that "between 26% and 40% of the world's potential crop production is lost annually because of weeds, pests and diseases, and these losses could double without the use of crop protection practices. (...). Crop protection products also play an important role in water conservation by efficiently controlling invasive plants that threaten scarce water sources. (...) Herbicides have also enabled conservation practices that require less land cultivation, maintaining soil moisture and topsoil in the field, rather than losing it due to evaporation, or wind and water erosion."[26]

The range of production losses due to unprotected crops cited in the FAO analyses coincides with Serge Savary's studies and models for estimating crop losses due to pest influence.[27]

Savary says crop protection against plant diseases is essential to meet the growing demand for food quality and quantity. "Roughly, direct yield losses caused by pathogens, animals, and weeds are altogether responsible for losses ranging between 20 and 40% of global agricultural productivity. Crop losses due to pests and pathogens are direct, as well as indirect; they have a number of facets, some with short-, and others with long-term consequences."

Crop protection goes beyond yield losses caused by diseases; it also includes post-harvest quality losses and the potential accumulation of toxins during and after the growing season. The role of crop protection in food security and food safety is underappreciated, even ignored. Crop loss assessment is a necessary step that benefits societies, the environment, consumers and farmers in the most effective way; it is the scientific domain of plant pathology, although it transcends into various fields of knowledge and public policy management.

Crop health depends on their own and induced levels of protection. The impact depends on the severity of epidemics ranging from those that occur regularly in large areas where they cause relatively low crop losses; through epidemics that cause acute crop losses, which occur infrequently, in restricted areas, sometimes causing very high crop losses; and emerging epidemics that affect large areas and can cause large crop losses. The risk of crop damage depends on the probability of the occurrence of a pandemic associated with the levels of impact described above and its consequent environmental, agro-ecological and socio-economic attrition in the short, medium and long term.[28]

Accurate knowledge of crop losses is at play in decision-making for crop health management, as well as the search of an economic balance between the cost of disease management options and the benefit of their implementation in light of the plant disease risk. Disease management efforts are mostly devoted to minimize the likelihood of epidemics occurring, reduce crop loss, and harvest quality losses and toxin accumulation.[29]

There are models that assess agricultural impacts due to global warming and consider crop losses due to insects; these pests substantially reduce yields of three staple grains: rice, maize and wheat. A correlation analysis explored the relationships between temperature, population growth and metabolic rates of insects to estimate how and where climate warming will augment losses of staple grains. As a result of the research, global yield losses of these grains are projected to increase by 10 to 25% per degree of global mean surface warming. Crop losses will be most acute in areas where warming increases both population growth and metabolic rates of insects. These conditions are centered primarily in temperate regions, where most grain is produced.[30]

*[26] OECD/FAO (2013), OCDE-FAO Agricultural Outlook 2012, OECD Publishing, Paris, https://www.oecd-ilibrary.org/agriculture-and-food/oecd-fao-agricultural-outlook-2012_agr_outlook-2012-en (emphasis by authors).*

*[27] Savary, S., Ficke, A., Aubertot, JN. et al. Crop losses due to diseases and their implications for global food production losses and food security. Food Sec. 4, 519–537 (2012). https://doi.org/10.1007/s12571-012-0200-5*

*[28] Savary, S. Op. Cit.*

*[29] Savary, S. Op. Cit.*

The most referenced analysis for estimating crop losses due to pests and pathogens was conducted in 19 regions of the world, with observations from 2001 to 2003; in this research, potential and actual losses per crop were estimated.[31] The research, by author E. Oerke, indicates that crop protection has been developed for the prevention and control of crop losses due to pests in the field and during storage. However, the analysis focuses on measuring losses due to pests and pathogens during crop production in the field.

Crop losses can be quantitative and/or qualitative; the former result from reduced productivity, while qualitative losses focus on reducing the quality demanded by the market, affecting aesthetic characteristics, damage caused by storage, or due to contamination of the harvested product with pests, pest parts or toxic pest products. Oerke's analysis focuses on quantitative losses and distinguishes two crop loss rates: the potential loss rate and the actual loss rate -also referred to as the current loss rate. Potential loss due to pests includes losses without physical, biological or chemical crop protection compared to yields of similar crop production in a no-loss scenario. Actual losses include, where appropriate, crop losses recorded despite crop protection practices.

Where applicable, the effective protection rate or effectiveness rate of crop protection practices is the percentage that reflects the loss due to the absence of crop protection products and it is calculated as the difference between the potential and actual percentages.

Estimates suggest that the potential rate of crop loss to pests and pathogens could range from 50% for wheat to 82% loss for cotton.

The total overall actual or current loss due to pests was estimated at around 28% in wheat and up to 29% in cotton production; losses were between 26% and 29% for soybeans and wheat, and 31%, 37%, and 40% for maize, rice, and potatoes, respectively.

In the case of effective pesticide protection, it was estimated on average at 37%, with a variation of 21.6% for the wheat crop, up to 53.2% for the cotton crop. In the scenario of a restriction on the use of pesticides of all types, the effective protection rate of pesticides would be the equivalent of the crop losses that could be observed.

*[30]Curtis A. Deutsch et al. Increase in crop losses to insect pests in a warming climate. Science 361, 2018. https://web.archive.org/web/20200218145349id_/ https://science.sciencemag.org/content/sci/361/6405/916.full.pdf*

*[31]Oerke, E. Crop losses to pests. The Journal of Agricultural Science, Cambridge University Press: 09 December 2005. 144(1), 31-43. doi:10.1017/S0021859605005708. https://www.cambridge.org/core/journals/journal-of-agricultural-science/article/abs/crop-losses-to-pests/AD61661AD6D503577B3E73F2787FE7B2*

### *Table 5. World: Estimated potential loss to weeds, animal pests, pathogens and viruses; actual losses and effective pesticide protection in six global strategic crops. 2001- 2003 (1) (Percentages)*

| Crop | Weeds | | Animal Pests | | Pathogens | | Viruses | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Potential | Current | Potential | Current | Potential | Current | Potential | Current | Potential | Current | **Effective protection** |
| Wheat | 23.0 (18-29) | 7.7 (3-13) | 8.7 (7-10) | 7-9 (5-10) | 15.6 (12-20) | 10.2 (5-14) | 2.5 (2-3) | 2.4 (2-4) | 49.8 (44-54) | 28.2 (14-40) | **21.6** |
| Rice | 37.1 (34-47) | 10.2 (6-16) | 24.7 (13-26) | 15.1 (7-18) | 13.5 (10-15) | 10.8 (7-16) | 1.7 (1-2) | 1.4 (1-3) | 77.0 (64-80) | 37.4 (22-51) | **39.6** |
| Maize | 40.3 (37-44) | 10.5 (5-19) | 15.9 (12-19) | 9.6 (6-19) | 9.4 (8-13) | 8.5 (4-14) | 2.9 (2-6) | 2.7 (2-6) | 68.5 (58-75) | 31.2 (18-58) | **37.3** |
| Potatoes | 30.2 (29-33) | 8.3 (4-14) | 15.3 (14-20) | 10.9 (7-13) | 21.2 (20-23) | 14.5 (7-24) | 8.1 (7-10) | 6.6 (5-9) | 74.9 (73-80) | 40.3 (24-59) | **34.6** |
| Soybean | 37.0 (35-40) | 7.5 (5-16) | 10.7 (4-16) | 8.8 (3-16) | 11.0 (7-16) | 8.9 (3-16) | 1.4 (0-2) | 1.2 (0-2) | 60.0 (49-69) | 26.3 (11-49) | **33.7** |
| Cotton | 35.9 (35-39) | 8.6 (3-13) | 36.8 (35-41) | 12.3 (5-22) | 8.5 (7-10) | 7.2 (5-13) | 0.8 (0-2) | 0.7 (0-2) | 82.0 (76-85) | 28.8 (12-48) | **53.2** |

In addition to the estimates noted above, other estimates of crop losses due to pests, diseases and weeds have been made. Estimates of crop losses show great variability, depending on the type of crop, geographic area, agronomic and environmental factors, estimation methods used, and baselines selected for crop damage. The most recent reviews, in which different methods were used, indicate crop losses of 20% to 40% of potential yields, directly associated with field losses due to the presence of pests and diseases.

Available studies identify regional differences in crop losses. Crop losses appear to be more significant in food-insecure regions than in regions with surplus production. Such regional variations are partly explained by environmental differences, but also by differences in the efficiency of crop health management practices.

More recent analyses (2017), based on documented observations in Asian countries (mainly in India), indicate that at least one third to half of global agricultural production or potential production is lost due to pests, diseases, weeds, and waste. Arthropod pests destroy approximately 18%-20% of annual production worldwide and in the particular case of India, this type of loss annually is around 16%.[32] Depending on the organism or pest analyzed, impacts have been documented by crop type, with an emphasis on crop losses due to insects.

[32] *Smriti Sharma, Rubaljot Kooner, and Ramesh Arora. Insect Pests and Crop Losses. Springer Nature Singapore Pte Ltd. 2017. http://agri. ckcest.cn/ass/8cc97a38-304e-4987-98f2-9af742facb6e.pdf*

### *Table 6. India: Estimates of crop losses due to insect pests, 2010 - 2015. (Percentage)*

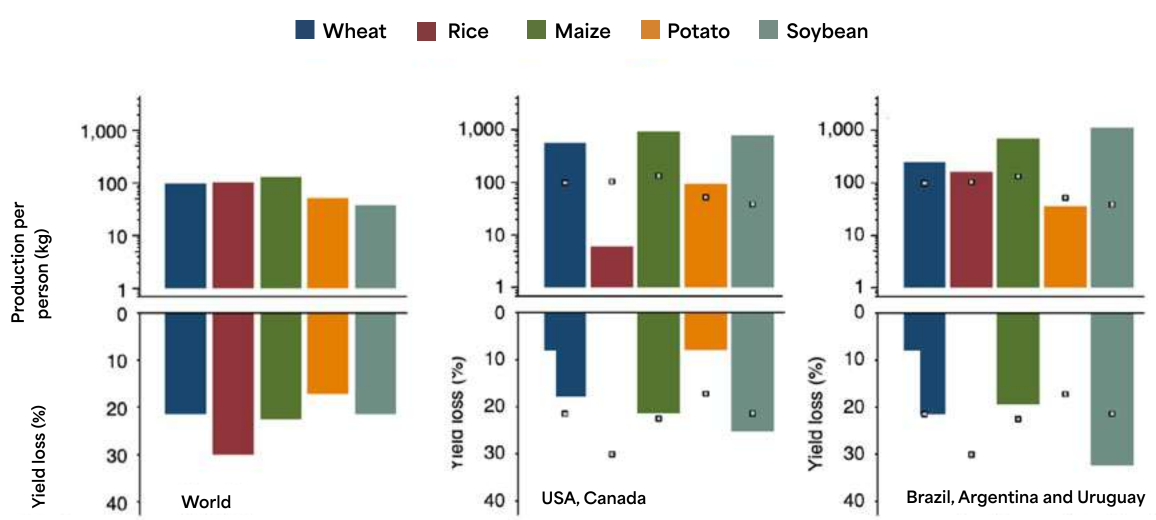
| Crop | 2010 | 2015 |
|---|---|---|
| Cotton | 30 | 30 |
| Rice | 25 | 25 |
| Oilseeds | 15 | 20 |
| Pulses | 15 | 15 |
| Peanuts | 15 | 15 |
| Maize | 25 | 18 |
| Sugar cane | 20 | 20 |

*Source: Dhaliwal GS, Jindal V, Dhawan AK (2010) Insect pest problems and crop losses: Changing trends. Indian J Ecol 74:1-7. Dhaliwal GS, Jindal V, Mohindru B (2015) Crop losses due to insect pests: Global and Indian scenario. Indian J Ecol 77:165-168.*

Another 2019 analysis addresses crop losses due to pests and pathogens for the five most important crops in the world's diet (wheat, rice, maize, potatoes, and soybean), estimates yield losses caused by 137 pests and pathogens (P&P). It concludes that global crop losses caused by P&Ps range from 17% to 23% for all five crops except rice, for which the estimate is 30%.[33] These estimates are within the same range as the global estimates of P&P losses cited in the above-mentioned studies.

This suggests that the range of 20% to 40% is indicative to represent global P&P crop losses. Pathogens and pests are causing yield losses at a global scale. In the case of wheat global losses were estimated at 21.5% (in a range of 10.1% to 28.1%), rice 30.0% (in a range of 24.6% to 40.9%), maize 22.5% (in a range of 19.5% to 41.1%), potato 17.2% (in

### *Figure 12. World and Regions of the Americas: Crop Losses due to Pests and Pathogens, 2017 (Production per person and Percentages).*




*Source: Serge Savary , Laetitia Willocquet et al. The global burden of pathogens and pests on major food crops. On Nature Ecology & Evolution. 2017. Note: Production per person is expressed on a logarithmic scale.*

*[33] Savary, S., Willocquet, L., Pethybridge, S.J. et al. The global burden of pathogens and pests on major food crops. Nat Ecol Evol 3, 430–439 (2019). https://www.nature.com/articles/s41559-018-0793-y -The crops analyzed are highly representative in that they provide about 50% of the global human calorie intake. The analysis was conducted using data from 67 countries that grow 84% of the world's production of the five crops.*

# Food loss

On the other hand, in addition to field losses, it is necessary to consider losses caused by stored grain pests and post-harvest losses of fruits and vegetables. FAO defines losses of agricultural products as those lost through waste during storage and transport; statistics published by FAO exclude pre-harvest and harvest losses.[34]

On a global scale, agricultural production losses during transport and storage are also due to the presence of pests and product handling. The most significant losses are in fruits, starches, vegetables, nuts and sugar crops. No less important is the decline in the grain harvest.

In this case, it highlights the importance of crop protection during transport and storage, since in this phase -depending on the type of crop- from 4.5% to almost 10% of agricultural production is lost, giving on average a loss of 6.2% in the post-harvest phase.

***Table 7. World: Post-Harvest Losses by Product Group, 2019. (Thousands of tons)***

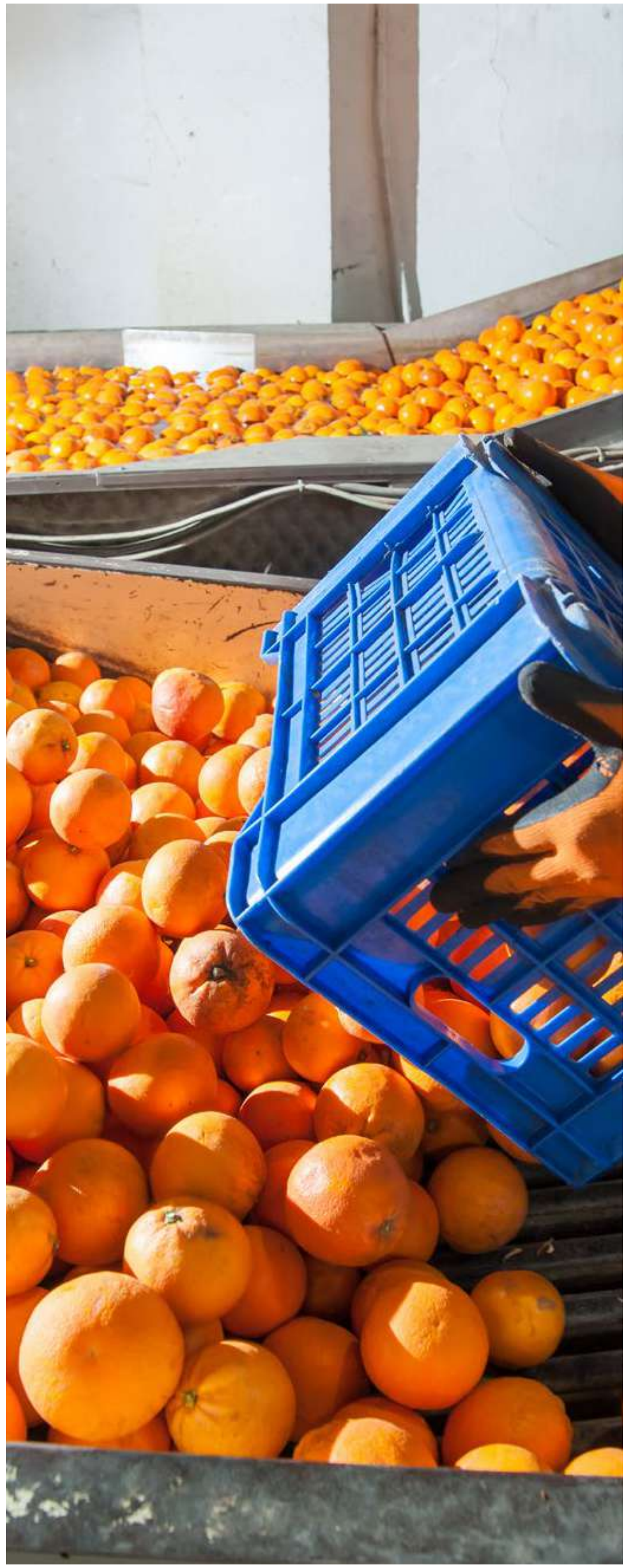
| Product Group | Production | Losses | Loss percentage |
|---|---|---|---|
| Cereals | 2,977,573 | 133,893 | 4.5% |
| Sugar crops | 2,234,864 | 132,841 | 5.9% |
| Vegetables | 1,256,965 | 110,002 | 8.8% |
| Oilseeds | 1,071,830 | 40,269 | 3.8% |
| Starches | 860,922 | 78,797 | 9.2% |
| Fruits | 758,096 | 73,196 | 9.7% |
| Dried beans | 85,252 | 4,684 | 5.5% |
| Stimulants | 23,153 | 1,062 | 4.6% |
| Nuts | 19,594 | 1,190 | 6.1% |
| Spices | 14,384 | 771 | 5.4% |
| Total | 9,302,633 | 576,705 | 6.2% |

*FAO. Faostat. Food Balances. Consulted in December 2022.*

*[34] FAO. Faostat. Food Balances. Consulted in December 2022. https://www.fao.org/faostat/es/#data/FBS. 1986. Definition taken from The ICS users' manual. Interlinked computer storage and processing system of food and agricultural commodity data. Rome.*

In 2019, the Food and Agriculture Organization of the United Nations (FAO), in the "The State of Food and Agriculture" report, elaborated on methodologies for assessing food loss and waste along the food supply chain. In FAO's analysis, food loss and waste is understood as the decrease in quantity or quality of food along the food supply chain.[35] Food loss will result from the decisions and actions of suppliers, while food waste is the result of purchasing decisions by consumers, or decisions by retailers and food service providers that affect consumer behaviour.

With information from the Swedish Institute for Food and Biotechnology, FAO states that roughly one-third of edible parts of food produced for human consumption globally was lost or wasted, which represented in 2011 about 1.3 billion tons of food (agricultural, livestock and industrial) per year. The estimate covered all stages of the food supply chain and encompassed all sectors of food production. Of that one-third, around 14% of all food from post-harvest up to, but excluding, retail is lost.[36]



[35] *FAO. 2019. The State of Food and Agriculture. Moving Forward on Food Loss and Waste Reduction. Rome. License: CC BY-NC-SA 3.0 IGO. https://www.fao.org/3/ca6030en/ca6030en.pdf*

[36] *FAO. 2019. The State of Food and Agriculture.. Op Cit. Pages 39 and 50.*

# IMPACT OF PESTICIDE RESTRICTION AND LOSS OF RELEVANT CROPS IN THE MEXICAN MARKET

# METHODOLOGY AND RESULTS

Food security is one of the greatest global challenges generated by a growing human population, which will have to produce more under changing climatic conditions while facing unpredictable pest threats that disrupt plant health and cause crop production losses.[37]

The movement of pests as a result of human activities has been intensified by increased trade and tourism; the result is an unexpected global relocation of pests and at an unforeseen rate.

In order to assess the impact of the absence of pesticides on Mexican agricultural productivity, the analytical references that point to the determination of crop losses published in the scientific analyses cited in the previous section are taken up. Such research considers expert opinions and yield comparisons conducted over the years through formal experimentation in crop loss assessment.

The aim of these scientific analyses is to measure crop losses in the absence of crop protection in agriculture; this mission, rather than academic, is a public issue of food security and economic stability, especially in the world's most important agricultural economies.

Crop losses have a multidimensional approach, especially because they go beyond the impact of production and the finances of individual production units; the purpose is to assess the widespread impact of epidemics under increasingly complex scenarios of uncertainty.

According to specialists, "the consequences of harmful effects go far beyond the simple direct reduction in yields. The consequences include critical indirect effects along economic fabric and food chains. Plant diseases, in particular, are often not major yield reducers, but their impacts on crop quality (food processing) and safety (toxins) are very serious in many crops and environments around the world. These indirect effects, particularly of diseases, are so poorly documented that one may assume they are greatly underestimated, as several recent studies suggest".[38] The impact of crop loss includes at least the following scopes:

•Food shortages. Crop yield loss due to disease means a reduced market volume for buyers of agricultural products.

• Financial losses due to yield reduction. They are calculated by comparing actual returns with estimates of potential returns, and are used to quantify the impact of supply reductions and their impact on product markets and financial and stock markets.

• Loss of food safety. Deterioration in food security that affects the economic value and/or food safety; in addition to the loss of life and human health resulting from exposure to contaminated food.[39]

•Unused installed capacity. The reduction in the physical volume of agricultural production impacts transport and storage companies, with the consequent increase in operating costs.

*[37] Giovani, B., Blümel, S., Lopian, R. et al. Science diplomacy for plant health. Nat. Plants 6, 902–905 (2020). https://www.nature.com/articles/s41477-020-0744-x*

*[38] Savary, S., Ficke, A., Aubertot, JN. et al. Crop losses due to diseases and their implications for global food production losses and food security. Food Sec. 4, 519–537 (2012). https://link.springer.com/article/10.1007/s12571-012-0200-5*

*[39] Vivian Hoffmann, Samuel K. Mutiga, Jagger W. Harvey, Rebecca J. Nelson, Michael G. Milgroom, Observability of food safety losses in maize: Evidence from Kenya, Food Policy, Volume 98, 2021, 101895, ISSN 0306-9192, https://doi.org/10.1016/j.foodpol.2020.101895.*

- Alteration of the agri-food trade balance. Trade with other nations is compromised by a local reduction of products, or imports make up for deficiencies in local production.

- Phytosanitary barriers to foreign trade. Temporary or permanent blocking of exports of products with risk of spreading epidemics in other countries.

If we look at crop protection from another perspective, we can associate it with measuring the outcomes to project what the yield gains generated by plant protection could be in these contexts.[40] Thus, we can calculate the management efficiencies, i.e., the gains, in relation to current yield levels, that could be obtained from improved crop health management.

Crop health is a matter of public interest for all nations, since, as stated by the FAO,[41] plants make up 80% of the food we eat and produce 98% of the oxygen we breathe. This UN agency estimates that agricultural production must rise about 60% by 2050 in order to feed a larger population, although it faces the challenge of controlling plant pests, which are responsible for losses of up 40% of food crops globally, and for trade losses in agricultural products worth over USD 220 billion each year.

Climate change threatens to reduce both the amount of crops -by reducing harvests- and their nutritional value. Rising temperatures imply the early appearance of a greater number of plant pests in places where they had not been seen before.

In the case of domestic crop production, crop protection is essential to maintain the national food supply and to ensure the continuity of food and raw material exports.

The analysis in the following section is aimed at assessing the impact of crop losses on the food supply and the effects it could have on prices.

*[40] Willocquet, L., Elazegui, F. A., Castilla, N. P., Fernandez, L., Fischer, K. S., Peng, S. B., Teng, P. S., Srivastava, R. K., Singh, H. M., Zhu, D. F., & Savary, S. (2004). Research priorities for rice pest management in tropical Asia: a simulation analysis of yield losses and management efficiencies. Phytopathology, 94, 672-682.*

*[41] IPPC Secretariat. 2021. International Year of Plant Health - Final Report. Protecting plants, protecting life. Rome, FAO on behalf of the Secretariat of the International Plant Protection Convention. https://doi.org/10.4060/cb7056en Consulted in January 2023*

# 1. Impact of crop loss on food production. Total ban scenario:
## Percentage change in price.

International analyses of crop losses due to pests and pathogens conclude that, in general, the decrease in yields is between 26% and 40%, as already endorsed by FAO[42] in various publications. In line with this estimate of crop damage, the federal government's agricultural insurance company, AGROASEMEX, indicates that pests reduce agricultural production[43] and deteriorate crop quality, which is why, in the event of possible damage caused by pests, agricultural insurance supports part of the production. According to data from the Mexican Association of Insurance Companies, between 2016 and 2020, the losses occurred attributable to pests and predators, were 697 on average per year.[44] In order to approach the damage of the most important crops in the Mexican diet, we will henceforth take up the conclusions of scientific analyses detailing the damage caused by pests and diseases in 15 important crops. The objective is to establish what the loss rate of each crop could be if the crops were not protected; for this purpose, the effective protection rates estimated by Oerke are used:

***Table 8. World: Strategic Crops: Crop Loss to Pests and Pathogens in the Absence of Crop Protection (Percentage).***

| Crops/Source | % Loss in absence of crop protection |
|---|---|
| Maize | 37.3% |
| Avocado | 49% |
| Sugar cane | 49% |
| Tomato | 49% |
| Green chili | 49% |
| Agave | 49% |
| Sorghum (grain) | 49% |
| Alfalfa | 49% |
| Bean | 49% |
| Lemon | 49% |
| Wheat (grain) | 21.6% |
| Potato | 34.6% |
| Cotton | 53.2% |
| Asparagus | 49% |
| Orange | 49% |

*Source: Prepared by authors based on data from E.C. Oerke. Crop losses to pests. Cambridge University Press: 09 December 2005.*

*[42] V. Gr. OECD/FAO (2013), OECD-FAO Agricultural Outlook 2012, OECD Publishing. Op. Cit. In addition to IPPC Secretariat. 2021. International Year of Plant Health - Final report. Op. Cit.*

*[43] AGROASEMEX. Pests cause losses of up to 40% in agricultural production, FAO study reveals. April 12, 2019. https://www.gob.mx/agroasemex/articulos/las-plagas-producen-perdidas-de-hasta-un-40-por-ciento-en-la-produccion-agrico-la-revela-estudio-de-la-fao. Consulted in January 2023.*

*[44] Mexican Association of Insurance Companies. Statistical System of the Agricultural and Animal Insurance Sector from 2016 to 2020. https://centroestadisticoamis.mx/ Consulted in January 2023.*

**If this scenario were to be repeated in Mexican agriculture, it would imply annual losses per product as shown in the table below:**

***Table 9. Mexico: Probable crop loss due to pests and pathogens in the absence of crop protection products (Tons).***

| Crops/Source | Loss in absence of crop protection (%) | Average annual production 2015-2021 (tons) | Probable losses per year (tons) |
|---|---|---|---|
| Maize | 37.3% | 27,147,565 | 10,126,041.7 |
| Avocado | 49% | 2,316,057 | 1,134,867.93 |
| Sugar cane | 49% | 56,166,666 | 27,521,666 |
| Tomato | 49% | 3,385,087 | 1,658,692.63 |
| Green chili | 49% | 2,705,288 | 1,325,591.12 |
| Agave | 49% | 1,821,502 | 892,535.98 |
| Sorghum (grain) | 49% | 4,535,683 | 2,222,484.67 |
| Alfalfa | 49% | 23,730,763 | 11,628,073.9 |
| Bean | 49% | 1,093,294 | 535,714.06 |
| Lemon | 49% | 2,768,683 | 1,356,654.67 |
| Wheat (grain) | 21.6% | 3,362,136 | 726,221.38 |
| Potato | 34.6% | 1,816,831 | 628,623.53 |
| Cotton | 53.2% | 808,245 | 429,986.34 |
| Asparagus | 49% | 291,159 | 142,667.9 |
| Orange | 49% | 4,654,651 | 2,280,778.99 |

*Source: Own estimates based on data by E.C. Oerke. Crop losses to pests. Cambridge University Press: 09 December 2005.*

# Impact on the Price Level

As noted by the Food and Agriculture Organization of the United Nations (FAO), the effects of pests and diseases on production can be accompanied by variations in prices, which are determined by supply and demand. Depending on the market for the affected agricultural products, an infestation or outbreak can lead to higher prices if most production is domestically consumed. The relative effects of the production shortfall on producers and consumers will depend on the relative elasticity of demand and supply (in other words, the responsiveness of demand and supply to price changes). Negative price effects can also occur where consumer health concerns lead to reductions in demand.[45]

In the case of Mexico, the impact of crop loss due to pests and pathogens is directly associated with the level of producer and consumer prices, due to the effects of food shortages in rural areas.

This relationship is determined on the basis of the price elasticity method of supply, which is a regression analysis that assesses changes in the volume produced and changes in the average rural price of a product, and is defined as the percentage change in the quantity offered over the percentage change in price. The equation used for this is:

$$\varepsilon = \frac{\Delta Q_i^t}{Q_i^0} \Big/ \frac{\Delta P_i^t}{P_i^0}$$

Where **ε** is the price elasticity of supply;

ΔQ_i^t is the quantity of product i, at time t;

Q_i^0 is the quantity of product i, in the reference (base) period;

ΔP_i^t is the real average rural price of product i, at time t; and P_i^0 is the real average rural price of product i, in the reference (base) period.

[45] *Food and Agriculture Organization of the United Nations (FAO). The State of Food and Agriculture, Rome, 2001. https://www.fao.org/3/x9800e/x9800e00.htm*

[46] *National Institute of Statistics and Geography. INEGI. Producer Price Indexes for Primary Activities. Base year 2019=100. https://www.inegi.org.mx/app/indicadores/?tm=0 NCPI generics by object of expenditure. 24/08/2018. https://www.dof.gob.mx/nota_detalle.php?codigo=5535871&fecha=24/08/2018#gsc.tab=0*

Production and price data from 2000 to 2021, estimated by the Agrifood and Fisheries Information Service, are used for calculation purposes. The price values of the rural environment or producer prices are deflated with the Producer Price Index of Rural Activities, published by the National Institute of Statistics and Geography,[46] to establish the Real Rural Average Prices 2019=100, whose purpose is to deduct inflation from the environment and to measure the objective variations of the crop analyzed.

The crops analyzed are representative of the national food basket, based on the weight given to them by the National Survey of Household Income and Expenditure (ENIGH).[47]

For the calculation of the price elasticity of supply, the absolute values of the quantity produced, and the real prices are transformed into Index Numbers, in order to be able to represent them in homogeneous scales. An index number is a statistical measure that expresses the relative evolution of the magnitude of crop production and prices, in one or more periods, with respect to a base period or reference year.

The price elasticity of supply will be a coefficient estimated according to the method described above. The relationship between the two variables indicates the impacts that inflation of each crop can have on reduced availability of food.

As an example, if the price elasticity of supply of a crop has a value of 0.5 (calculated with historical observations), it would imply that for every 10% of possible production loss, prices would rise 20%.

*[47]NCPI generic consumer concepts by object of expenditure. 24/08/2018. https://www.dof.gob.mx/nota_detalle.php?codigo=5535871&fecha=24/08/2018#gsc.tab=0*

# EXAMPLES

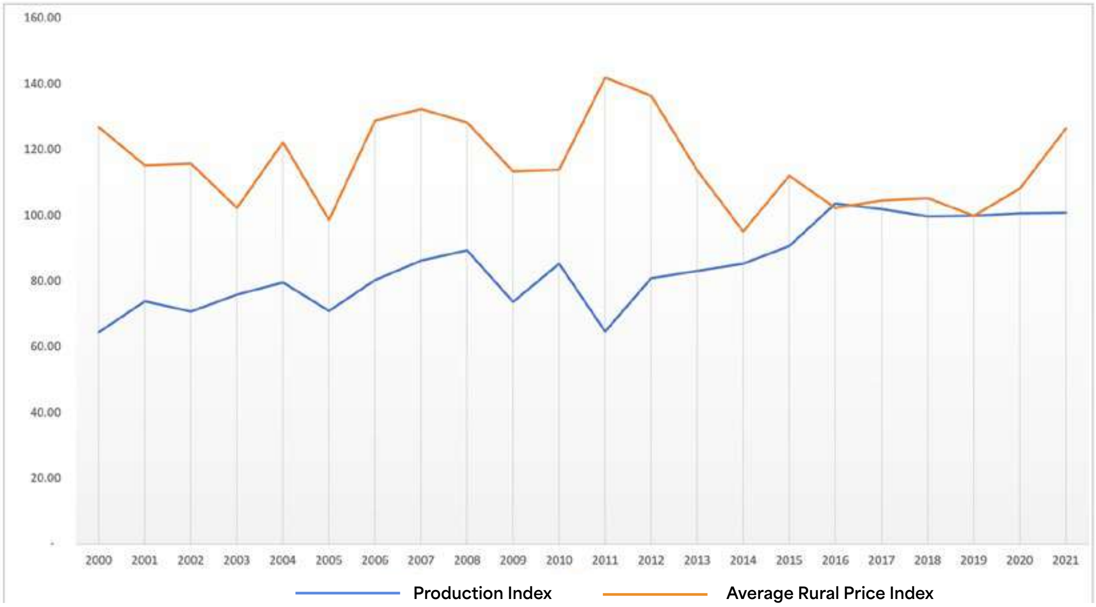
# MAIZE

In the case of maize cultivation, the estimated loss due to pests and pathogens is 37.3%. With the trends of rural average prices and total national production, we create the price elasticity of supply coefficient, which results in a value of 0.44. Hence, with a loss of 37.3% in potential maize yields, prices would increase by 84.77%.

***Table 10. Mexico: Impact indicators on maize price.***

| Crop | Maize |
|---|---|
| Loss of productivity due to pests and pathogens | -37.3% |
| Probable price increase | 84.77% |
| *Source: Prepared by authors based on data provided by SADER. Agrifood and Fisheries Information Service, Statistical Yearbook of Agricultural Production, 2021. Consulted in November 2022.* | |

***Figure 13. Mexico: Maize Production Volume Indices and changes in real average rural price. 2000-2021 (Indices: 2019=100)***




*Source: Authors' elaboration based on data provided by SADER. Agri-food and Fisheries Information Service, Statistical Yearbook of Agricultural Production, 2021. Consulted in November 2022*

# WHEAT

In the case of wheat cultivation, the estimated loss due to pests and pathogens is 22%. With the trends of average rural prices and total national production, we create the price elasticity of supply coefficient, which results in a value of 0.63. Hence, with a loss of 22% in potential wheat yields, prices would increase by 34.9%.

***Table 11. Mexico: Impact indicators on wheat price.***

| Crop | Wheat |
|---|---|
| Loss of productivity due to pests and pathogens | -22% |
| Probable price increase | 34.9% |

*Source: Authors' elaboration based on data provided by SADER. Agri-food and Fisheries Information Service, Statistical Yearbook of Agricultural Production, 2021. Consulted in November 2022.*

***Figure 14. Mexico: Wheat Production Volume Indices and changes in real average rural price. 2000-2021 (Indices: 2019=100)***


*Source: Authors' elaboration based on data provided by SADER. Agri-food and Fisheries Information Service, Statistical Yearbook of Agricultural Production, 2021. Consulted in November 2022.*

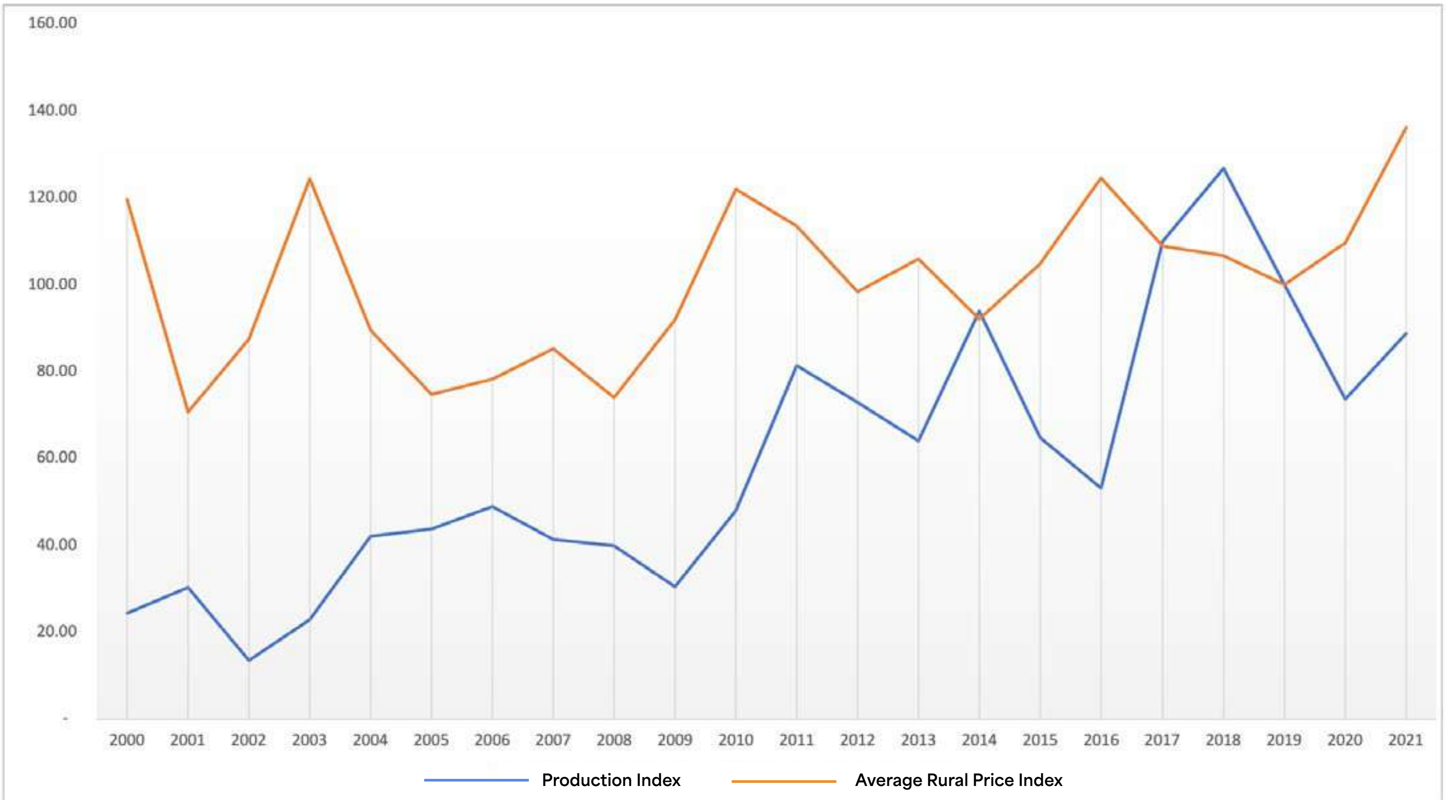
# COTTON

In the case of cotton cultivation, the estimated loss due to pests and pathogens is 53.2%. With the trends of average rural prices and total national production, we create the price elasticity of supply coefficient, which results in a value of 1.66. Hence, with a loss of 53.2% in potential cotton yields, prices would increase by 32%.

### *Table 12. Mexico: Impact indicators on cotton price.*

| Crop | Cotton |
|---|---|
| Loss of productivity due to pests and pathogens | -53.2% |
| Probable price increase | 32% |

*Source: Authors' elaboration based on data provided by SADER. Agri-food and Fisheries Information Service, Statistical Yearbook of Agricultural Production, 2021. Consulted in November 2022.*




*Source: Authors' elaboration based on data provided by SADER. Agri-food and Fisheries Information Service, Statistical Yearbook of Agri-cultural Production, 2021. Consulted in November 2022.*

# SUGAR CANE

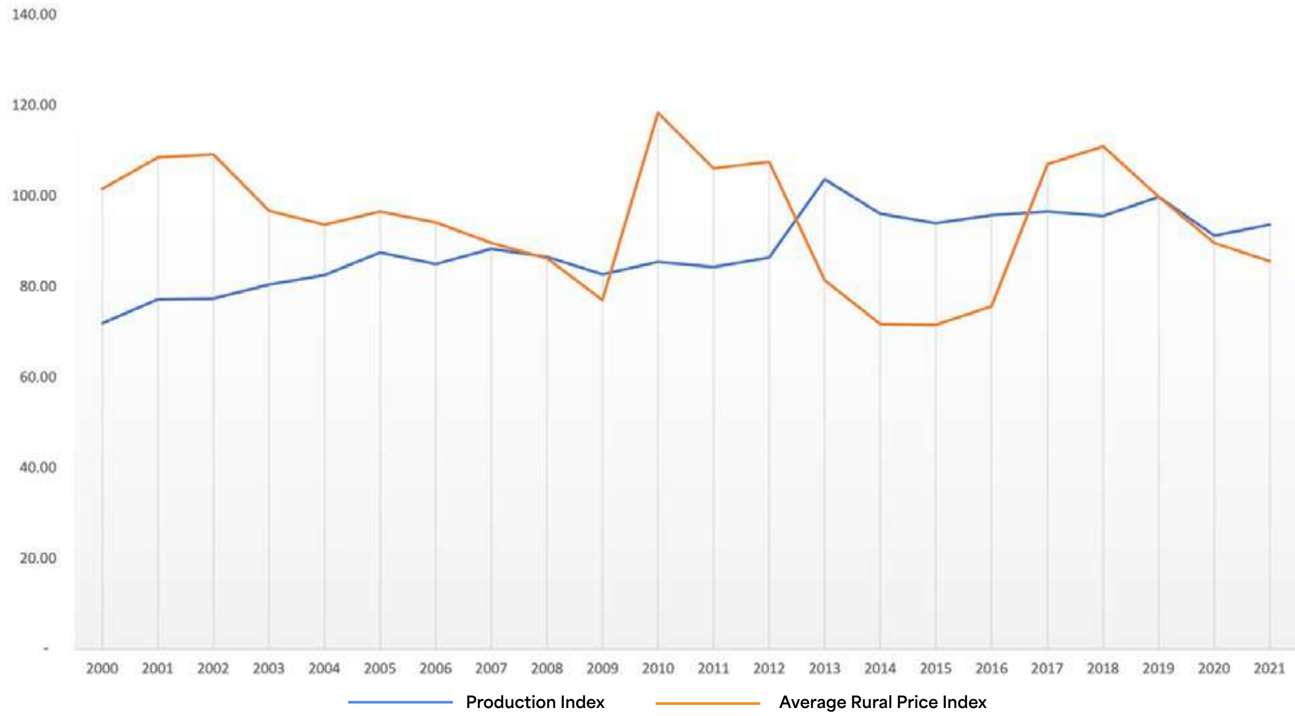
In the case of sugar cane cultivation, losses due to the presence of pests and diseases amount to 49% of the total harvest. To determinate its effect on prices, we calculated the price elasticity of supply factor, which is 0.8, implying that in the face of a 49 % decrease in supply, average prices in rural areas would increase by 61%.

***Table 13. Mexico: Indicators of Sugar cane Production. 2015-2021***

| Crop | Sugar cane |
|---|---|
| Loss of productivity due to pests and pathogens | -49% |
| Probable price increase | 61% |

*Source: Authors' elaboration based on data provided by SADER. Agri-food and Fisheries Information Service, Statistical Yearbook of Agricultural Production, 2021. Consulted in November 2022.*

***Figure 16. Mexico: Sugar cane production volume indices and changes in real average rural price. 2003-2021 (Indices: 2019=100)***




*Source: Authors' elaboration based on data provided by SADER. Agri-food and Fisheries Information Service, Statistical Yearbook of Agricultural Production, 2021. Consulted in November 2022.*

# BEANS

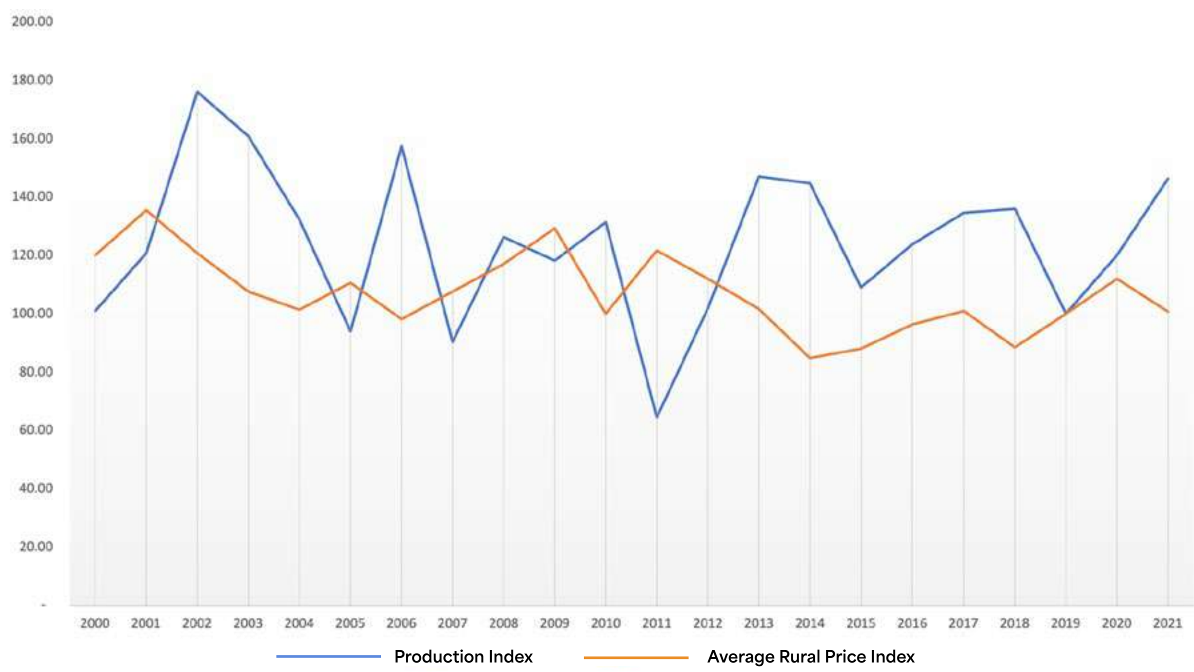
In the case of bean cultivation, losses due to the presence of pests and diseases amount to 49% of the total harvest. To determine its effect on prices, we calculated the price elasticity of supply factor, which is 1.37, implying that in the face of a 49% decrease in supply, average prices in rural areas would increase by 35.8%.

***Table 14. Mexico: Indicators of Bean Production. 2015-2021***

| Crop | Beans |
|---|---|
| Loss of productivity due to pests and pathogens | -49% |
| Probable price increase | 35.8% |

*Source: Authors' elaboration based on data provided by SADER. Agri-food and Fisheries Information Service, Statistical Yearbook of Agricultural Production, 2021. Consulted in November 2022.*

***Figure 17. Mexico: Beans Production Volume Indices and changes in real average rural price. 2000-2021 (Indices: 2019=100)***




*Source: Authors' elaboration based on data provided by SADER. Agri-food and Fisheries Information Service, Statistical Yearbook of Agricultural Production, 2021. Consulted in November 2022.*

# POTATOES

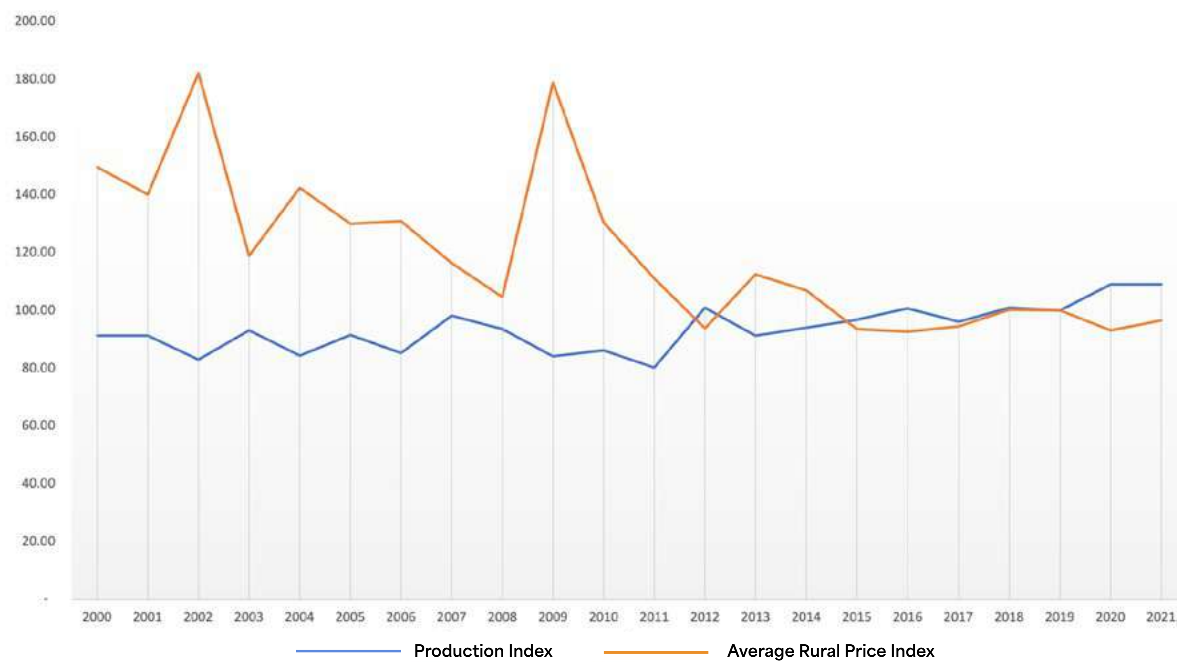
In the case of potato cultivation, losses due to the presence of pests and diseases amount to 34.6% of the total harvest. To determine its effect on prices, we calculated the price elasticity of supply factor, which is 0.77, implying that in the face of a 34.6% decrease in supply, average prices in rural areas would increase by 44.9%.

***Table 15. Mexico: Indicators of Potato Production. 2015-2021***

| Crop | Potato |
|---|---|
| Loss of productivity due to pests and pathogens | -34.6% |
| Probable price increase | 44.9% |

*Source: Authors' elaboration based on data provided by SADER. Agri-food and Fisheries Information Service, Statistical Yearbook of Agricultural Production, 2021. Consulted in November 2022.*

***Figure 18. Mexico: Potato Production Volume Indices and changes in real average rural price. 2000-2021 (Indices: 2019=100)***




*Source: Authors' elaboration based on data provided by SADER. Agri-food and Fisheries Information Service, Statistical Yearbook of Agricultural Production, 2021. Consulted in November 2022.*

# Analysis

The most direct effect of crop pests and diseases the loss of or reduced efficiency of production, which reduces farm income and puts pressure on market conditions due to food shortages and food prices in rural areas and consumer markets. When the regional economy is dependent on one or a few vulnerable commodities, the burden will be severe and will affect the economic circuits of local economies.

FAO[48] indicates that the impacts of reduced productivity on crops or animals can be long-lasting, while pest infestations can impair fertilization rates or seed recovery and can have long-lasting effects on livestock output which often exceed the losses associated with epidemics.

The effects on production are accompanied by variations in prices, determined by the effects of pests and diseases on supply and demand.

***Table 16. Mexico: Simulation of crop loss impact due to pests on average rural food prices***

| Crop | Price elasticity of supply | Crop loss due to P&P in the absence of crop protection | Price increase |
|---|---|---|---|
| Maize | 0.44 | 37.3% | 84.8% |
| Avocado | 0.56 | 49% | 87.5% |
| Sugar cane | 0.80 | 49% | 61.0% |
| Tomato | 0.11 | 49% | 445.5% |
| Green chili | 0.55 | 49% | 89.1% |
| Agave | 0.2 | 49% | 245.0% |
| Sorghum (grain) | 0.34 | 49% | 144.1% |
| Alfalfa | 0.28 | 49% | 175.0% |
| Bean | 1.37 | 49% | 35.8% |
| Lemon | 0.61 | 49% | 80.3% |
| Wheat | 0.63 | 21.6% | 34.3% |
| Potato | 0.77 | 34.6% | 44.9% |
| Cotton | 1.66 | 53.2% | 32.0% |
| Asparagus | 0.3 | 49% | 163.3% |
| Orange | 0.08 | 49% | 612.5% |

*Source: Authors' elaboration based on E.C. Oerke. Crop losses to pests. Cambridge University Press: 09 December 2005.*

*[48] Food and Agriculture Organization of the United Nations (FAO). The State of Food and Agriculture, Rome, 2001. Op. Cit. "III. Economic impacts of transboundary pests and diseases."*

# II. Estimating the impact of crop protection on agri-costs

The analytical basis for establishing the impact on the availability of pesticides in Mexico is the Sigma-Kynetec marketing database. This dataset shows the catalogue of pesticides marketed in Mexico, the target crop, the sector (or pesticide category), the active ingredient (AI), the volume of product marketed, its commercial value and the cost of the product per hectare (USD/ha). These data have been processed and published for 2021.

On the other hand, 182 active ingredients have been registered, which are being considered for a potential ban in the Mexican market. The correlation between these and market products allows us to draw important conclusions: one of them is that the potential ban would affect 58% of the value of current sales.

***Table 17. Mexico: Impact of the ban of 182 active ingredients on the pesticide market, 2021.***

| *Active ingredient and formulation* | Growth regulators | Seed treatment | Insecticides | Fungicides | Herbicides | Grand total |
|---|---|---|---|---|---|---|
| *Under discussion* | | 41 | 2,193 | 859 | 683 | 3,776 |
| *Current* | 186 | 34 | 663 | 1,341 | 459 | 2,683 |
| *Grand total* | 186 | 75 | 2,856 | 2,200 | 1,142 | 6,459 |

*Source: Authors' elaboration based on Sigma-Kynetec. Market Insights for crop protection & seed. Consulted in November 2022.*

Of the 182 active ingredients, a purge was made of those that are not recognized in the Mexican market and therefore are not registered in the database. The analysis identified 84 molecules outside the market register, probably because they have non-agricultural uses (pesticides for urban or industrial use), or because they are no longer in use or have a low market share. The remaining set of 98 Active Ingredients were related to each of the nearly 6,500 commercial pesticides offered in Mexico, in order to have the list of those that under a ban scenario would be available in the market and the effects it would have on the cost of production. The ban scenario is defined as a formal market condition, where there is no access to the products or their active ingredient formulations.

In line with the previous section, we began by developing two scenarios: the first one ("the current scenario"), characterized by the whole world of molecules that are currently available to the market, by crop type and average cost per hectare related to crop protection. Secondly, we developed the "alternative" scenario, which is defined by the set of molecules that would not be under restriction, with which we proceeded to estimate the cost that their use would imply, in order to contrast both scenarios.

Two charts are presented in the course of this analysis. The first chart separates, on the one hand, the active ingredients that could be excluded from the current market by government resolutions and places them in what we call “Current Scenario” where the cost of the pesticide measured in US dollars (USD) per hectare is expressed. Data estimated directly by the cited source of information. This same chart groups together the active ingredients that, faced with a prohibition scenario, would be present in the Mexican pesticide market and is called “Alternative Scenario”; in this subset are represented both the “permitted” active ingredients and their cost of application, measured in USD per hectare.

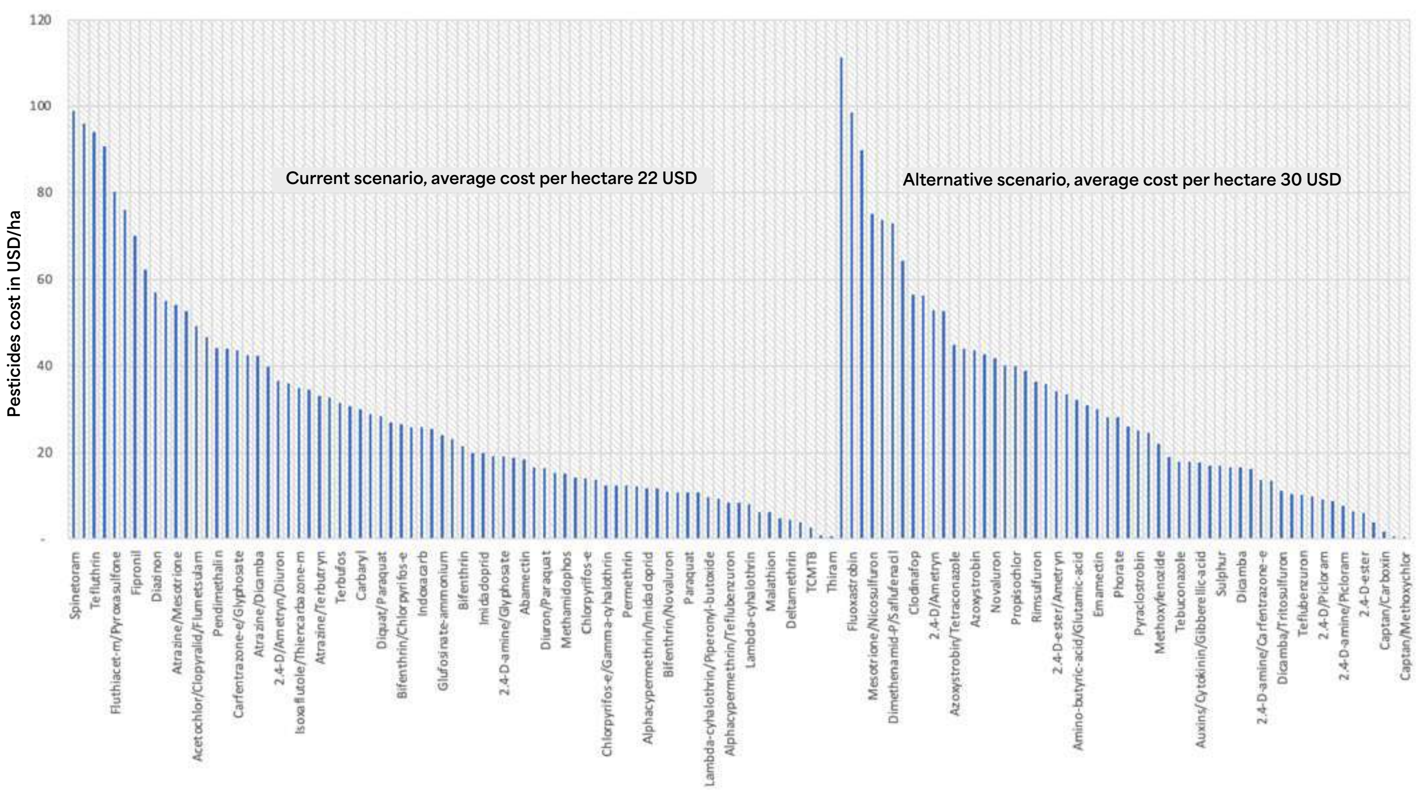
The results are then expressed in terms of the active ingredients that could be excluded under the restriction scenario and the average cost that would result from having only those active ingredients that are not currently questioned by the draft legislative initiatives for reforms to various laws (mainly health and ecology).

Finally, the cost of pesticide application by crop is expressed separately, by category of Active Ingredients (whether in the form of insecticides, fungicides or herbicides) and differences in the cost of applying them in the “Current” and “Alternative” scenarios, measured in US dollars per hectare.

# MAIZE

Our first approach to the cost comparison is directed to maize cultivation, which is the most widespread in Mexico. The comparison of both scenarios shows the exclusion of 260 commercial products out of a total of 371, exclusively for maize. There are 156 insecticides, 92 herbicides and 12 fungicides among the set of products under discussion.

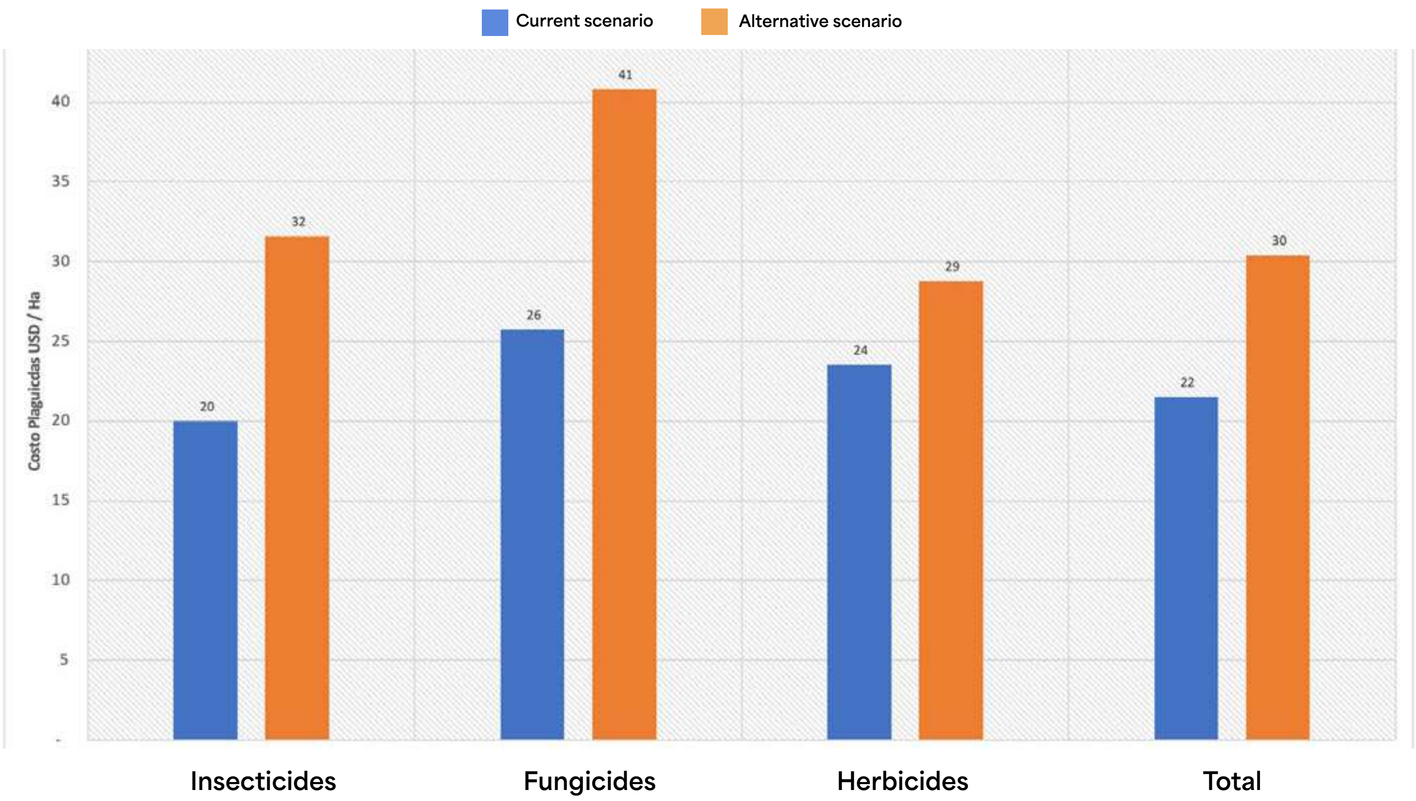
***Figure 19. Mexico: Cost of pesticide application in maize, according to Active Ingredient Status. 2021 (Cost in USD per hectare)***




*Source: Authors' elaboration based on Sigma-Kynetec. Market Insights for crop protection & seed. 2022*

The increase in crop protection costs for maize could be 41%, while the cost per hectare could rise from USD22 to USD30 per hectare. The most evident cost was for fungicides with an increase of 59%.

*Figure 20. Mexico: Cost of pesticide application in maize, by category of active ingredients. 2021 (Cost in USD per hectare)*

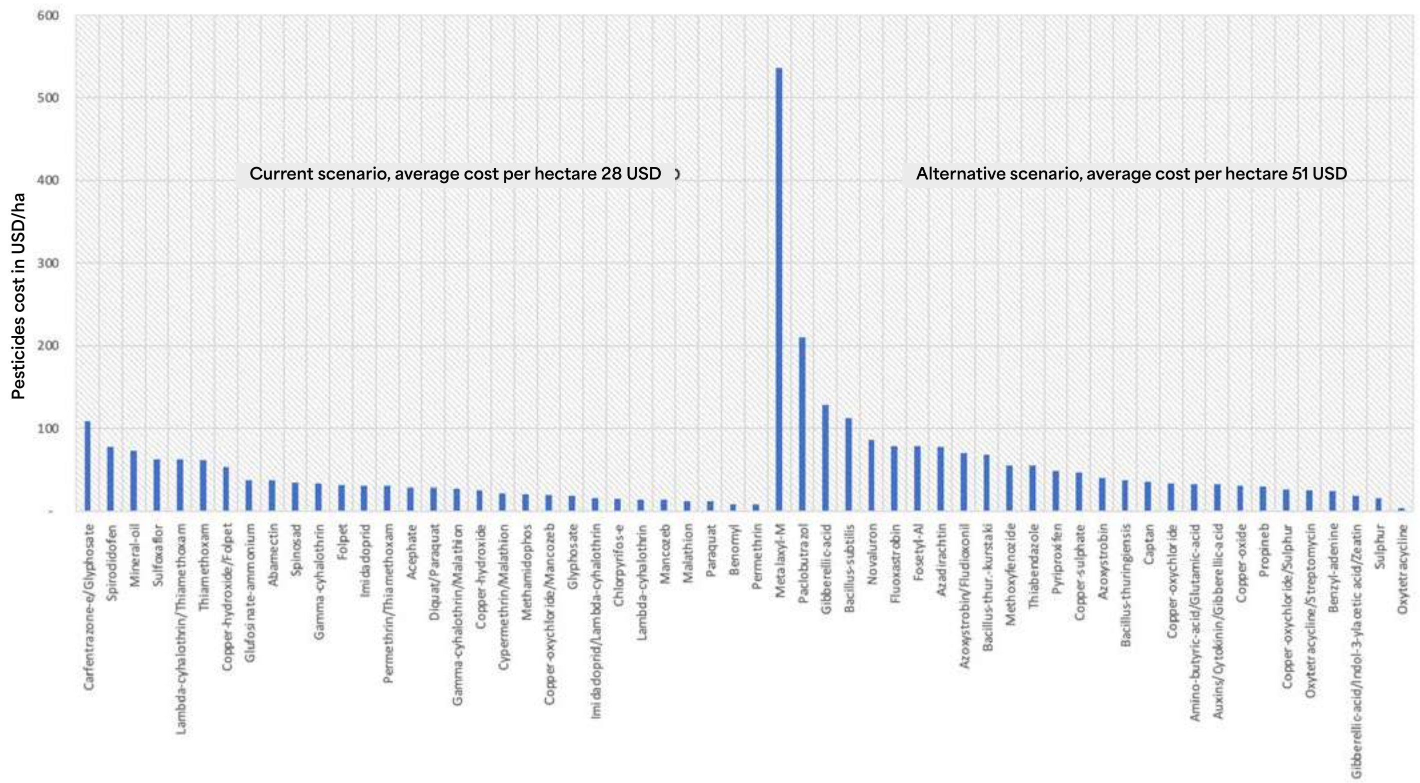



*Source: Authors' elaboration based on Sigma-Kynetec. Market Insights for crop protection & seed. 2022*

# AVOCADO

Another representative case of the impact of the exclusion process currently under discussion in Mexico is the cultivation of avocado.

***Figure 21. Mexico: Cost of pesticide application in avocados, according to Active Ingredient Status. 2021 (Cost in USD per hectare)***




*Source: Authors' elaboration based on Sigma-Kynetec. Market Insights for crop protection & seed. 2022*

Of 183 products currently available in the market, 119 would be excluded under a restrictive scenario, virtually cancelling all avocado-specific herbicides. The increase in cost would be 84% and fungicides would have the greatest impact on production costs with an increase of 122%.

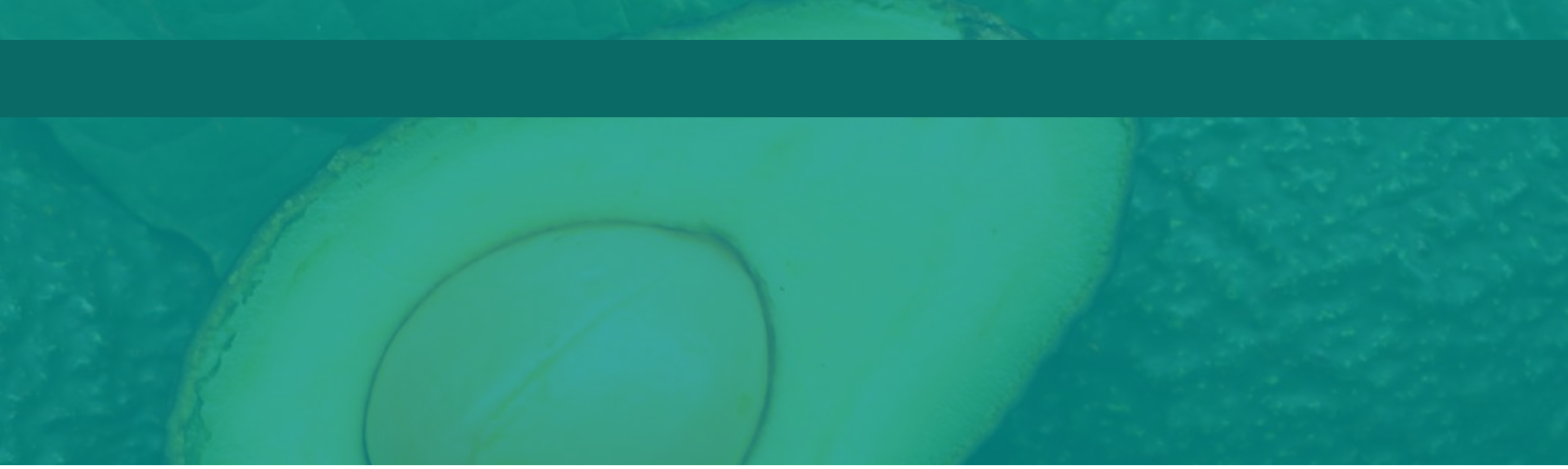
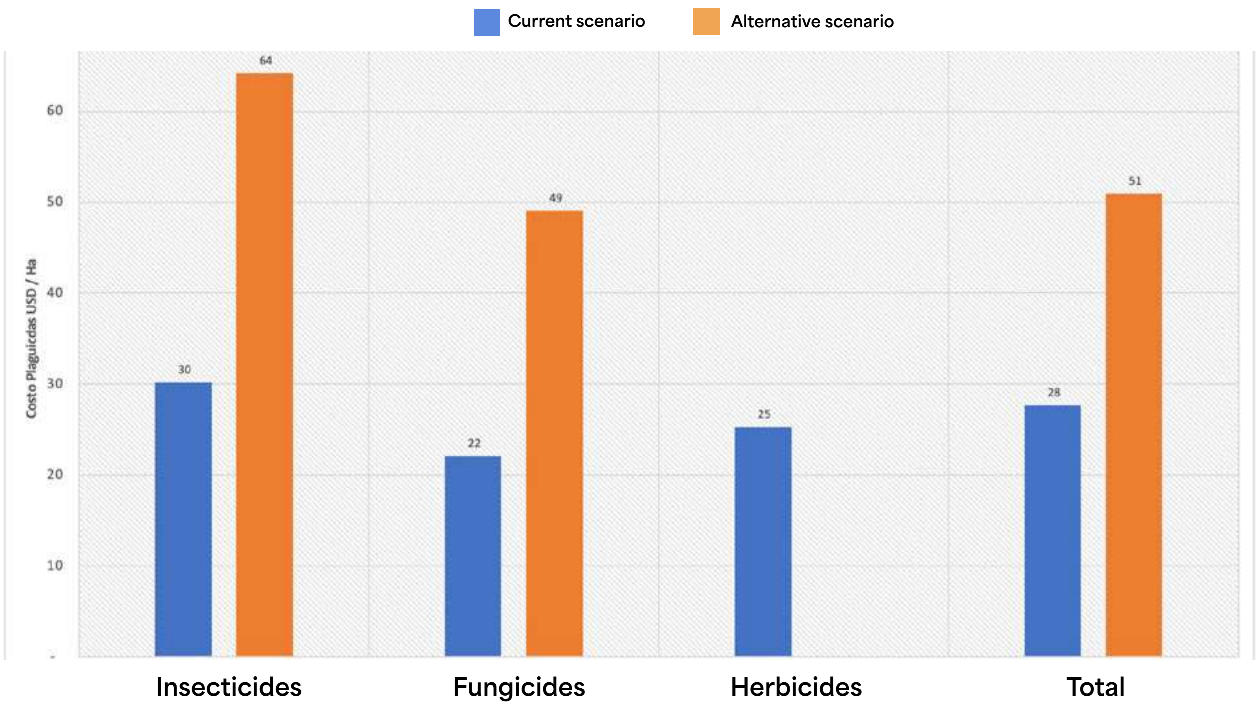


*Figure 22. Mexico: Cost of pesticide application in avocados, by category of active ingredients. 2021 (Cost in USD per hectare)*

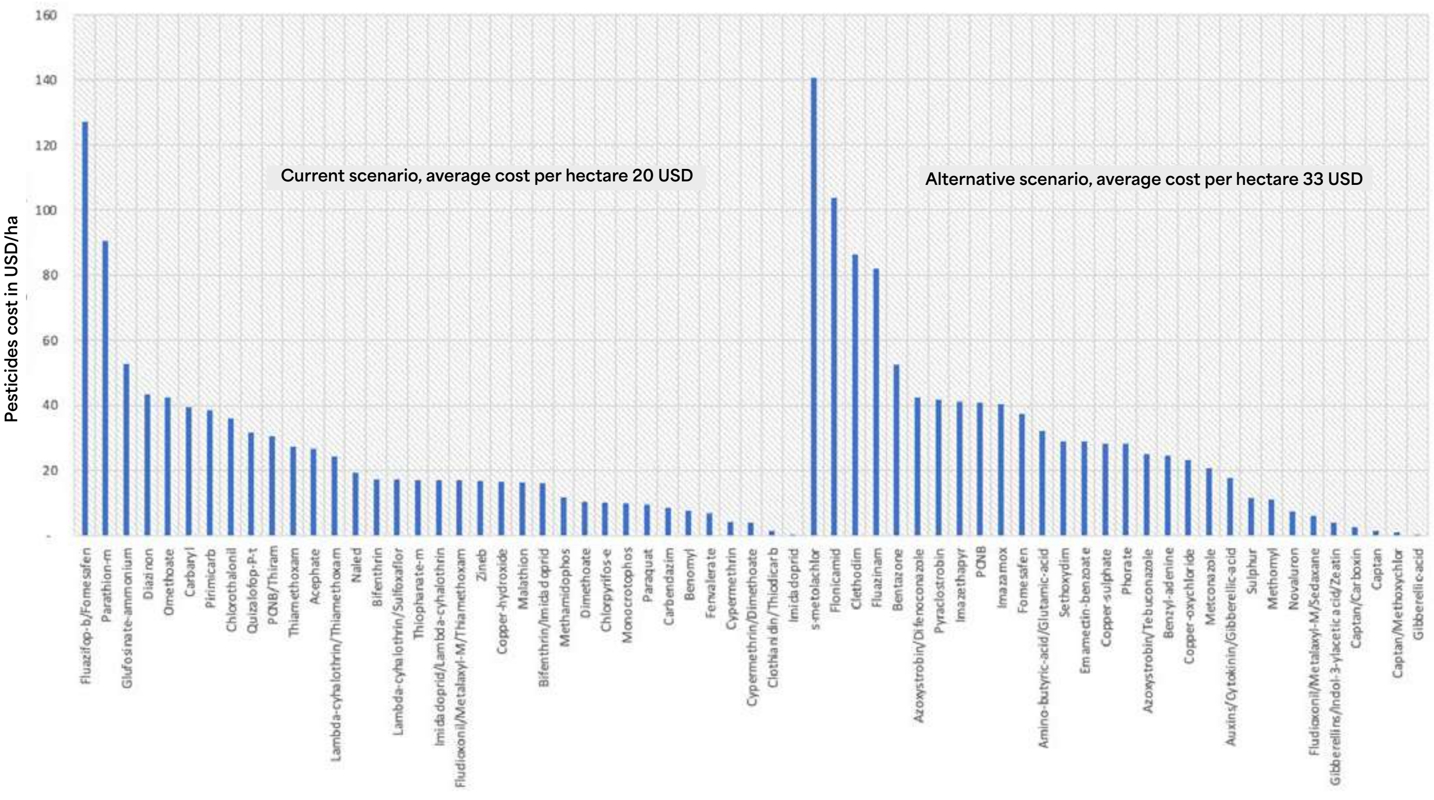



*Source: Authors' elaboration based on Sigma-Kynetec. Market Insights for crop protection & seed. 2022*

# BEANS

Another crop that would see an increase in its cost of production for its protection is beans. With the application of access restrictions to active ingredients and their formulations, the overall cost per hectare would increase from USD20 to USD33 per hectare.

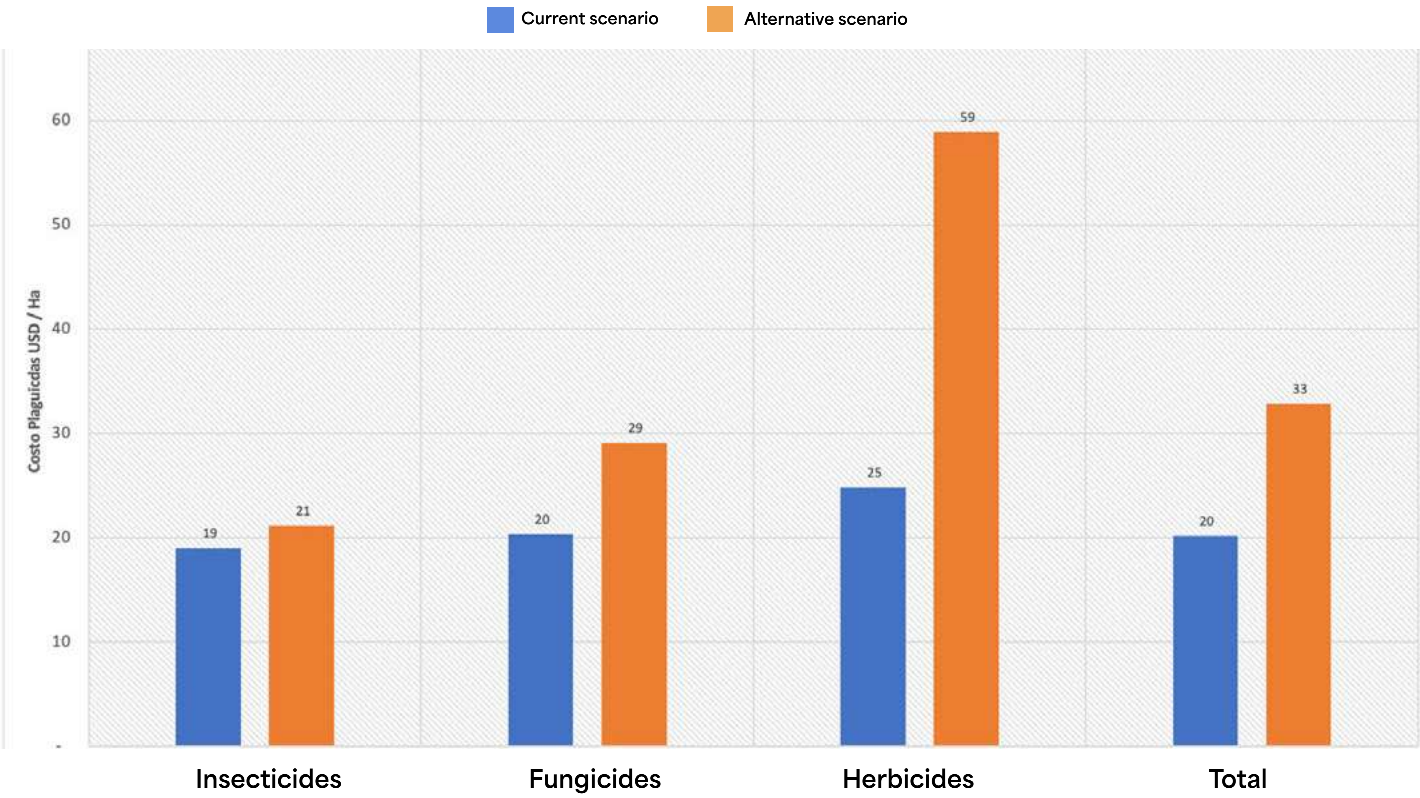
***Figure 23. Mexico: Cost of pesticide application in beans, according to Active Ingredient Status. 2021 (Cost in USD per hectare)***




*Source: Authors' elaboration based on Sigma-Kynetec. Market Insights for crop protection & seed. 2022*

The most representative cost increase by product category would be observed in herbicides, with a cost increase of 137%.

*Figure 24. Mexico: Cost of pesticide application in beans, by category of active ingredients. 2021*
*(Cost in USD per hectare)*

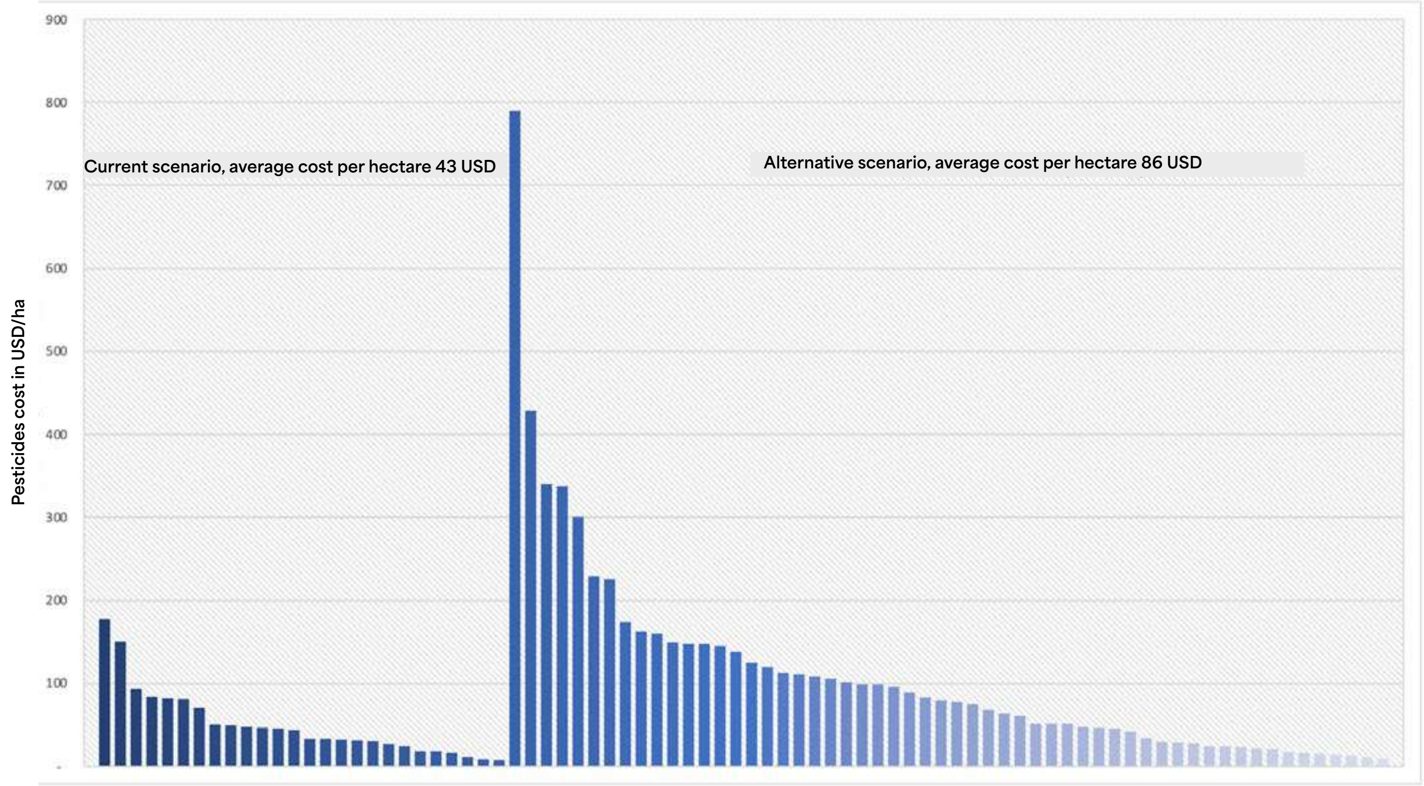



*Source: Authors' elaboration based on Sigma-Kynetec. Market Insights for crop protection & seed. 2022*

# BERRIES

As far as berries protection is concerned, restricting access to products available in the current market would represent a 100% increase.

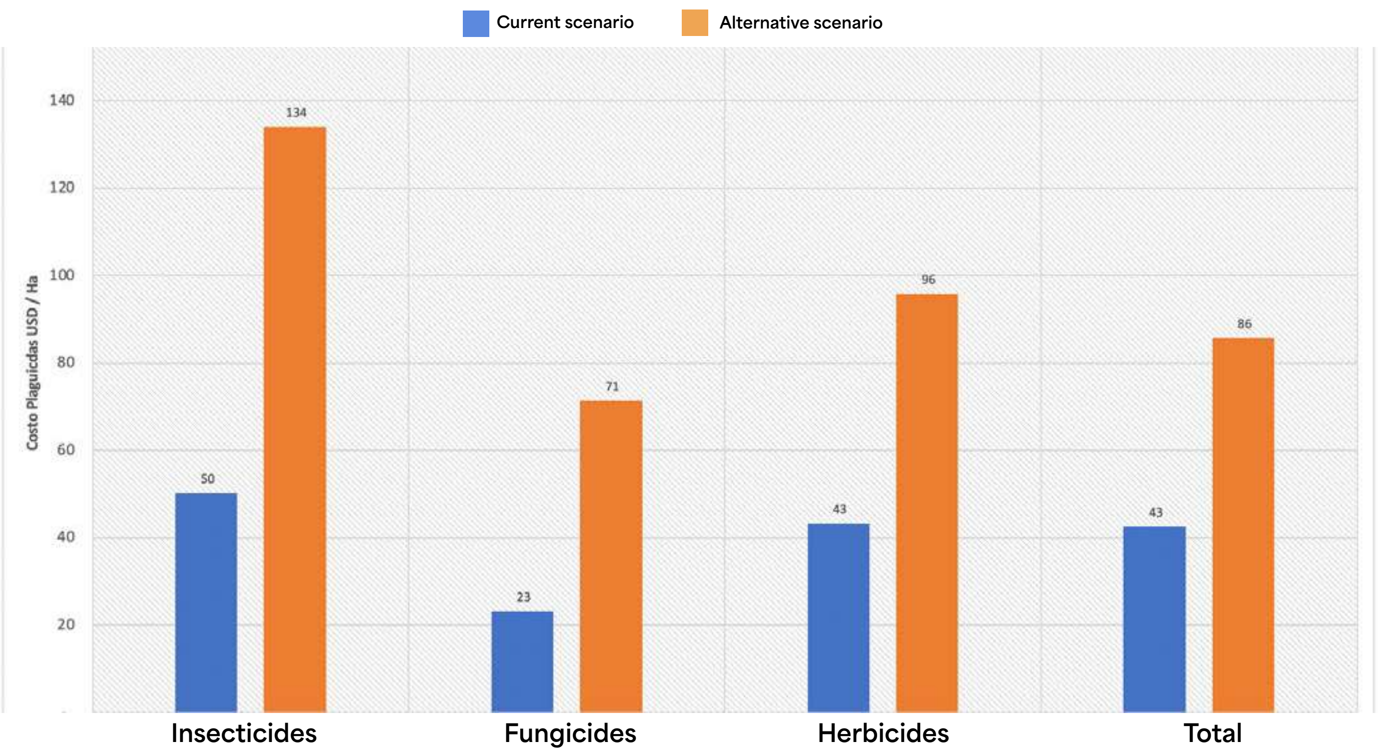
***Figure 25. Mexico: Cost of pesticide application in berries, according to Active Ingredient Status. 2021 (Cost in USD per hectare)***




*Source: Authors' elaboration based on Sigma-Kynetec. Market Insights for crop protection & seed. 2022*

The most representative cost increase by product category would be observed in fungicides with a cost increase of 208%; insecticides in the alternative scenario would also exert pressure on the cost with a potential increase of 166%, and herbicides with an increase of 121%.

*Figure 26. Mexico: Cost of pesticide application in berries, by category of active ingredients. 2021 (Cost in USD per hectare)*

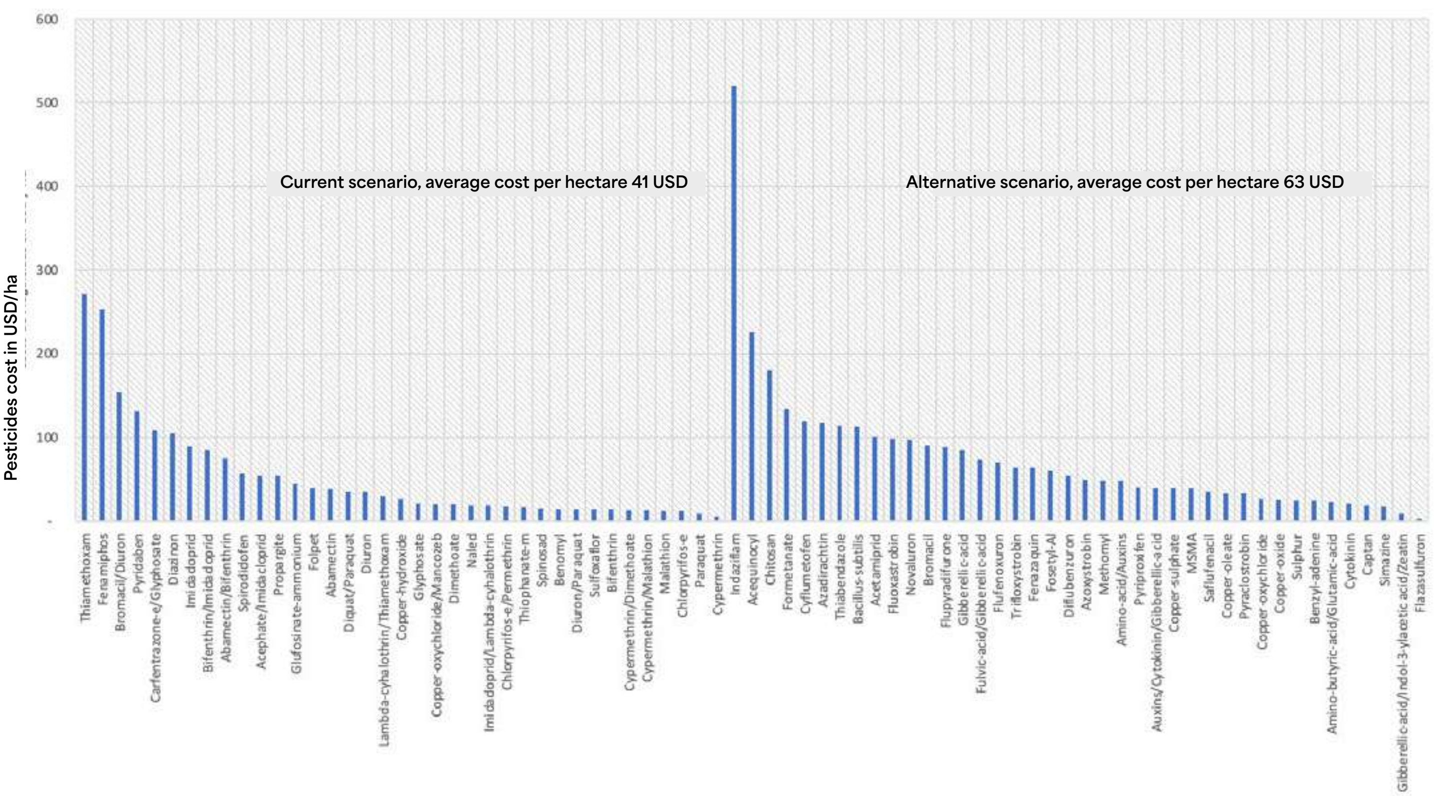



*Source: Authors' elaboration based on Sigma-Kynetec. Market Insights for crop protection & seed. 2022*

# CITRUS FRUITS

As far as citrus fruits protection is concerned, restricting access to products available in the current market would represent an increase of 52.5%.

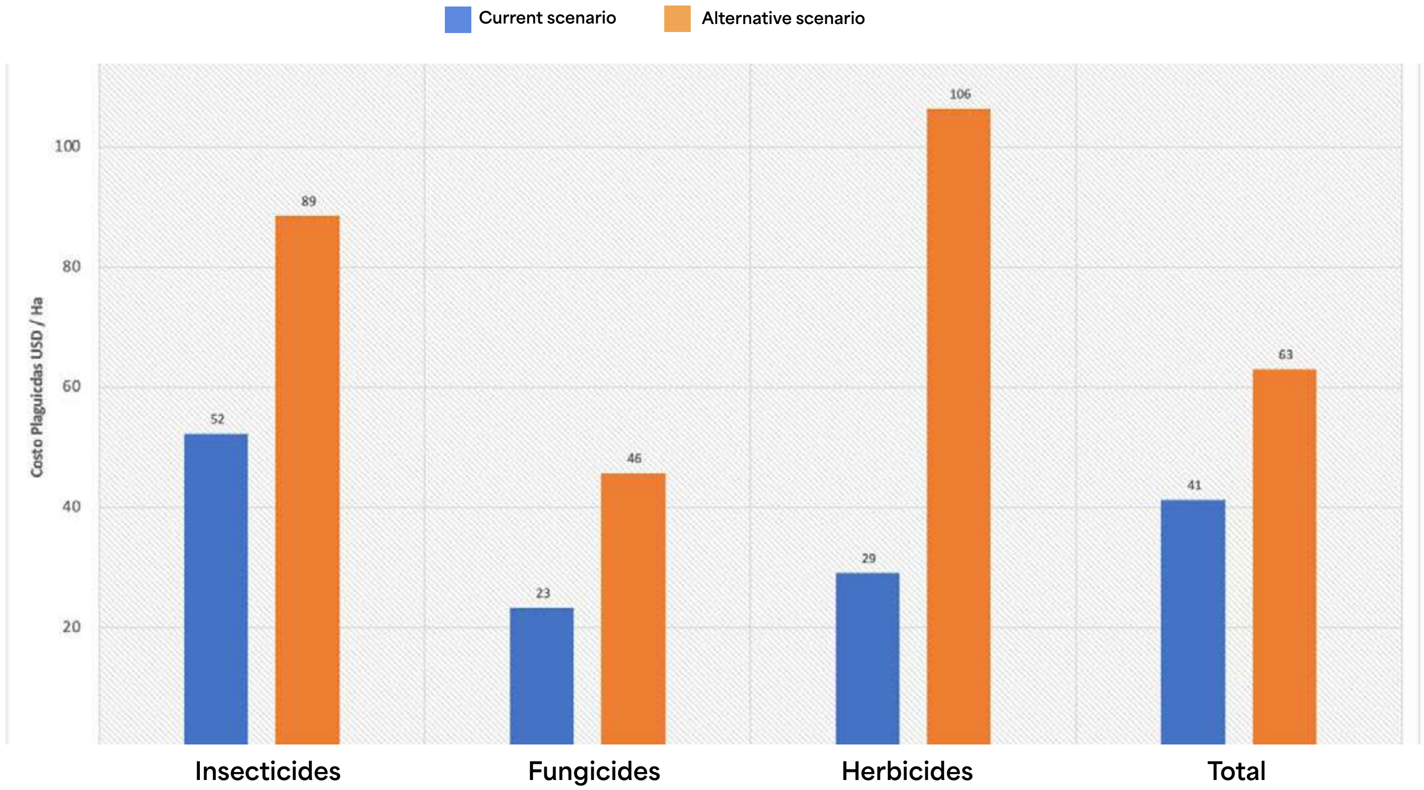
***Figure 27. Mexico: Cost of pesticide application in citrus fruits, according to Active Ingredient Status. 2021 (Cost in USD per hectare)***




*Source: Authors' elaboration based on Sigma-Kynetec. Market Insights for crop protection & seed. 2022*

The relevant increase in costs by product category would be in herbicides with 265%.

*Figure 28. Mexico: Cost of pesticide application in citrus fruits, by category of active ingredients. 2021 (Cost in USD per hectare)*

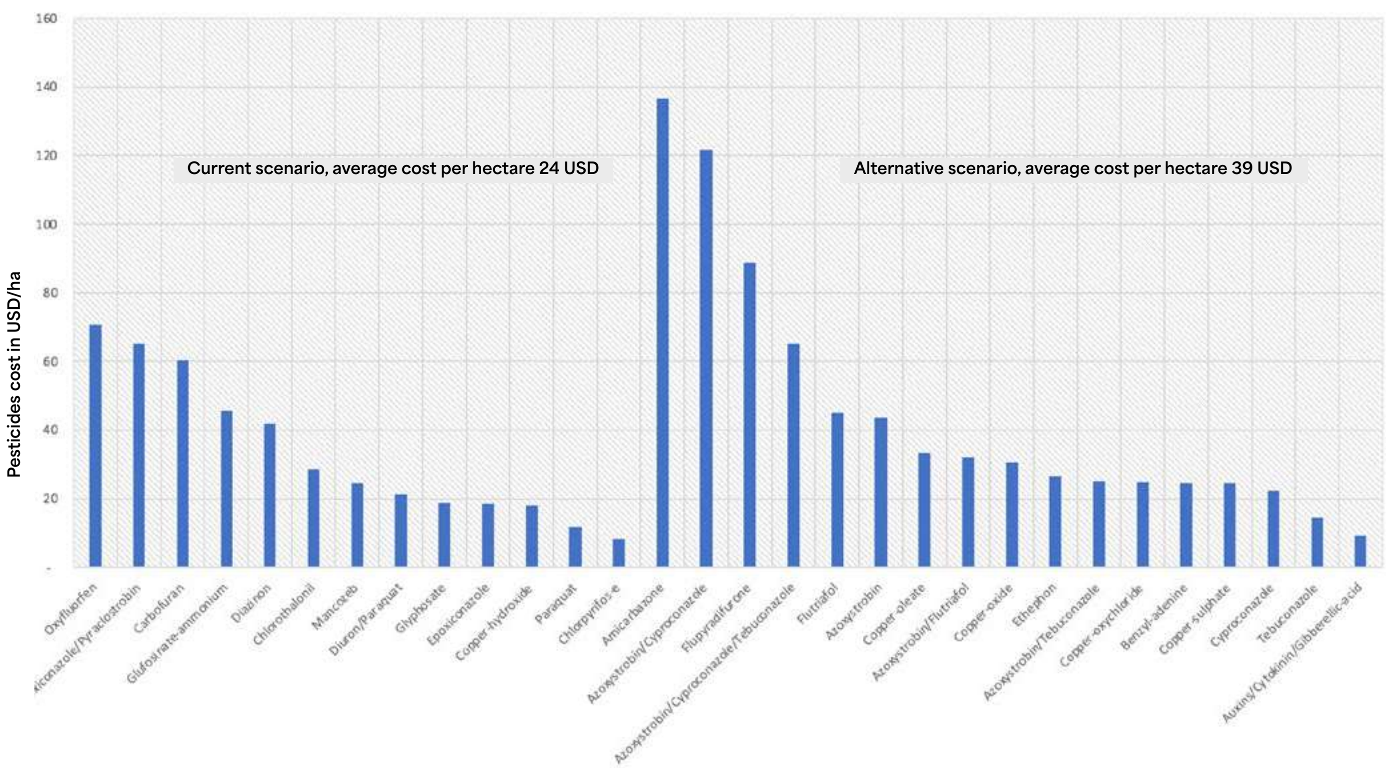



*Source: Authors' elaboration based on Sigma-Kynetec. Market Insights for crop protection & seed. 2022*

# COFFEE

As far as coffee protection is concerned, restricting access to products available in the current market would represent an increase of 63.6%.

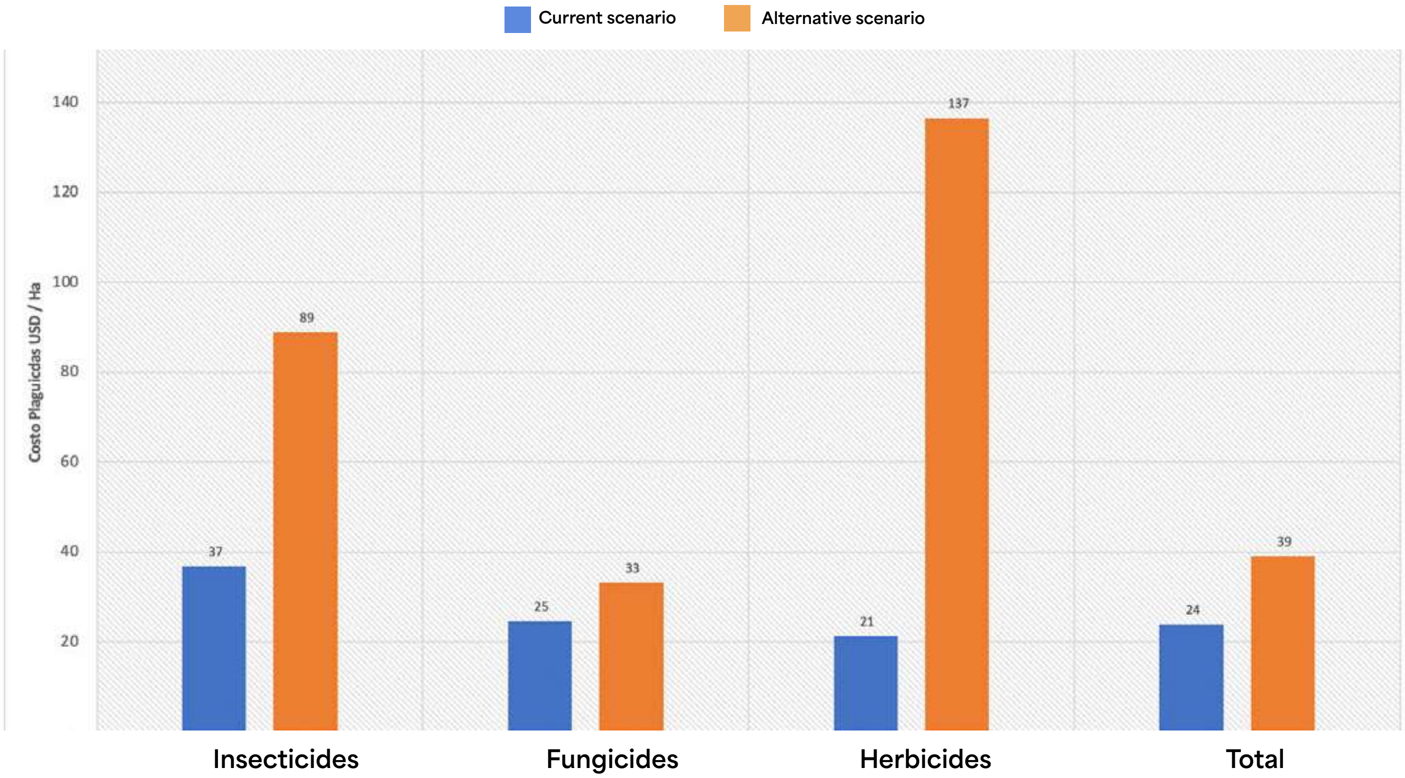
***Figure 29. Mexico: Cost of pesticide application in coffee, according to Active Ingredient Status. 2021 (Cost in USD per hectare)***




*Source: Authors' elaboration based on Sigma-Kynetec. Market Insights for crop protection & seed. 2022*

The most significant increase in costs by product category would be herbicides with an increase of 539%.

*Figure 30. Mexico: Cost of pesticide application in coffee, by category of active ingredients. 2021 (Cost in USD per hectare)*




*Source: Authors' elaboration based on Sigma-Kynetec. Market Insights for crop protection & seed. 2022*

# Analysis

The forecast of a restriction scenario of active ingredients and their formulations implies an increase in costs for farmers. On average across a select set of 15 crops, average costs per hectare would increase from USD33 to USD52 (or 58% increase).

Export products and strategic crops for the consumer market could have the greatest impact.

***Table 18. Mexico: Cost of pesticide application in selected crops, 2021 (Cost in USD per hectare)***

| Crop | Current scenario | Alternative scenario | Increase in cost |
|---|---|---|---|
| *Oilseeds* | 13.3 | 30.2 | 126% |
| *Agave* | 41.3 | 86.2 | 109% |
| *Avocado* | 27.6 | 52.6 | 91% |
| *Berries* | 42.5 | 79.2 | 86% |
| *Tomato* | 40.2 | 67.0 | 67% |
| *Mango* | 22.6 | 35.9 | 59% |
| *Coffee* | 23.9 | 37.2 | 56% |
| *Citrus fruits* | 41.3 | 62.5 | 51% |
| *Sugar cane* | 34.1 | 50.1 | 47% |
| *Beans* | 19.8 | 28.7 | 45% |
| *Potato* | 55.5 | 79.1 | 42% |
| *Maize* | 21.6 | 29.5 | 37% |
| *Green tomato* | 53.3 | 72.5 | 36% |
| *Apple* | 38.9 | 52.4 | 35% |
| *Sorghum* | 19.9 | 26.3 | 32% |
| *Grand total* | 33.0 | 52.6 | 57.6% |

*Source: Authors' elaboration based on Sigma-Kynetec. Market Insights for crop protection & seed. 2022*

# CONCLUSIONS

# Conclusions

• In the last three decades, pesticide use and food production have a direct relationship, which implies that any increase in agricultural productivity requires a proportional increase in pesticide use.

• There is a high correlation between the rate of growth in agricultural production and the use of pesticides in agricultural economies that account for more than one-fifth of the global food harvest.

• The Food and Agriculture Organization of the United Nations (FAO) concludes that climate change will increase the risk of pests spreading in agricultural and forestry ecosystems. It concludes that there is sufficient evidence to claim that invasive pests are a growing threat to food security.

• In Mexico, the impact on agricultural economy in a ban scenario would affect 4% of the national GDP and 43 billion dollars or 9% of the total value of exports.

• The implications of a reduction in productivity would affect 7 million jobs generated by agricultural activities, both directly and indirectly (11% of the country's economically active population).

• Food security would also be at risk because, although crop protection is in place, between 26% to 40% of global potential crop production is still lost to weeds, pests and diseases, and, according to FAO estimates, these losses can double if crop protection practices are not implemented.

• The lack of protection of crops due to restrictions on the use of chemical pesticides would affect the productivity of the main Mexican crops. Four out of every ten tons of maize could be lost; almost half of pulse crops could be reduced as a result of the lack of protection of these crops and a similar proportion would affect vegetables and fruits of high importance for national consumption.

• The impact on maize prices is estimated at 84%, and in the case of vegetables, price increases could be in the order of 3 digits (or above 100%).

• The ban on the use of current active ingredients would affect 58% of current sales value.

• In a scenario of a ban on active ingredients, production costs under the concept of pesticide application will impact farmers' pockets by an increase of 58%.

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