A policy food crisis

IMPACT ASSESSMENT ON THE WITHDRAWAL OF EIGHT ACTIVE INGREDIENTS AND ASSOCIATED PEST CONTROL PRODUCTS IN KENYA.

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Abbreviations

AFA- Agriculture and Food Authority
BT- Bacillus Thuringiensis.
CAGR- Compound Annual Growth Rate
CBB- Coffee Berry Borer
CBD- Coffee Berry Disease
CCCEH- Columbia Centre for Children's Environmental Health
CGA- Cereal Growers Association
CIMMYT - International Maize and Wheat Improvement Center
CPR- Committee on Pesticide Residues
DBM- Diamondback Moth
EPA- Environmental Protection Agency
EU-European Union
FCM- False Codling Moth
FAO- Food and Agriculture Organization
GDP- Gross Domestic Product.
GLS- Gray Leaf Spot
GMO- Genetically Modified Organism
GNI- Gross National Income
IPM- Integrated Pest Management
KNBS- Kenya National Bureau of Statistics
NOAEL- No Observable Adverse Effect Level
NHL- Non-Hodgkin Lymphoma
MLND- Maize Lethal Necrosis Disease
MLN- Maize Lethal Necrosis
MRL- Maximum Residue Level
PCPB- Pest Control Product Board
PCN- Potato Cyst Nematodes
RDI- Recommended Daily Intake
ToCV-Tomato Chlorosis Virus
TLB- Turcicum Leaf Blight
TYLCV- Tomato Yellow Leaf Curl Virus
WHO- World Health Organization
WITS- World IntegratedTrade Solution
WTO- World Trade Organizations

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The primary data was compiled by the researchers: George Munene, Lizzy Adhiambo, Sharon Karwitha and Gloria Isaacs. Special recognition goes to Jenny Luesby, for compiling the literature review that informed the research, conceiving and analysing the econometric modelling that has delivered the forecasts outlined, and for authoring this entire report.
We are also indebted to the 226 individuals that participated in our quantitative research polls and qualitative interviews, with special thanks for their expert insights on the industry to: all aak-GROW team led by the CEO, Eric Kimunguyi and the staff, Joel Mutai, Benson Ngigi, Merryl Yongo and Velma Nasimiyu.

Foreword

It is the essence of government policy that a driving consideration in policy change must be the welfare of the nation's citizens. In many areas, this has driven the need for impact analyses when reviewing changes to legislation, to avert moves that cause disastrous and most especially deadly outcomes.

In 2023, a review of pest control product approvals produced a decision to withdraw eight pest control products in Kenya, citing potential health and environmental risks, and introducing a new criteria for pest control of trade interests.

In the absence of information on the health and trade damage that might follow the removal of these pest controls, we set out with this report to develop a credible impact analysis, mapping the losses these withdrawals are likely to deliver to Kenya's yields, incomes, food security, trade, and economy.

Our aim has been to produce a science-based and credible impact analysis, for which reason we opted to adopt deeply conservative forecasting assumptions, which are laid out in each section of the report. Our mapping of the pests and crops affected and the alternative protection available was derived from the PCPB's registered products database. We sourced the information on the damage inflicted by these pests on the crops affected, and of their prevalence on these crops in Kenya, from best-fit, empirical, peer-reviewed studies. We, similarly, undertook an extended literature review investigating all IPM alternatives, in use and in development, and to establish current levels of IPM use for each pest and crop affected.

We further supported this research with qualitative and quantitative surveys of agriculturalists throughout Kenya.

We have laid out the detailed assumptions of our modelling in Chapters 3 to 5 of this report, along with the context surrounding the significance of the results the model generated. For instance, the 10 per cent decline in calories per head for every Kenyan is made far more grave in its impact by the fact that Kenyan calories per head are already almost 15 per cent lower than the average across Africa.

Our conclusions, in terms of the impact we forecast, are estimated. We believe they are likely to represent an understatement of the actual impact, for the many reasons cited in the report, and including our step away from estimating the impact of these changes on food prices. They will also be affected over coming years by the launch of new pest control methods we have not foreseen and the arrival of new pests that are exogenous to this analysis, which is tied tightly to the impact of the eight active ingredients withdrawn and their present registered uses.

However, the rigour of this research and methodology has demonstrated that pest control does impact trade. It further demonstrates that Kenya's position on a knife edge of food security creates the need to consider all changes in agricultural and pest control policies - and the planning for how they are managed and communicated - as a matter of national security. Food insecurity has the power to cause the premature deaths and disablement of potentially millions of Kenyan citizens, as illustrated by this analysis, which represents a prime facie issue of national security that needs to be considered in policy formulation.

We hope that this analysis is illuminating, and that, set against the backdrop of spiralling pest problems in Kenya and in SubSaharan Africa caused by climate change, it will stimulate further empirical work by national and international researchers in establishing the scale and mechanisms involved in the relationship between pest control tools and food security and incomes in Africa.

Executive summary

1. This impact analysis has been conducted to estimate the likely effects and the consequent policy issues arising from the withdrawal of 8 active ingredients contained in more than 142 pest control products that was announced in Kenya in 2023 driven by differing safety, environmental and trade concerns, itemised in Appendix 1.

2. The study is based on primary and secondary research, surveying 155 smallholders across Kenya, interviewing 67 agricultural experts, exporters, and specialist farmers, and conducting literature reviews on damage done to crops by the pests affected (see Figure9), their prevalence in Kenya, their development of resistance, and the availability, efficacy and adoption rates of alternative crop protection tools.

3. The starting point for this analysis is the level of damage done to crops in Kenya by pests. Kenya and her neighbours suffer more extremely than many parts of the world due to its heat and weather patterns, which accelerate pest growth and proliferation. This has been made worse by climate change, with current data revealing 2°C temperature rises taking crop losses without pest control to an estimated 90 per cent of all crops grown.

4. The rate of expansion of pests has leapt, for instance for coffee berry borer, it increased 2.5 million-fold between 1984 and 2011, even as the pest climbed to altitudes 300 metres higher each decade, to now reach almost all Kenya's coffee crops. The country's ideal pest conditions are also attracting alien species, such as Tuta absoluta in 2013 and Fall Armyworm in 2017, that are inflicting massive crop losses as their life cycles shorten by half and egg volumes rise.

5. The surge in insects has driven up viral infections, with more than 600 infections spread by insects. It has also increased the number of emerging plant diseases, such as Maize Lethal Necrosis Disease (MLND) in 2011, which destroys up to 95 per cent of a crop. Fungal diseases are also spreading, with a 2022 survey of farms across Kenya finding fungal infections in every Sorghum crop. Invasive weeds have also gained momentum, from striga weed, through mesquite, to parthenium, destroying crops, pastoral land, and biodiversity.
6. In the face of this increase in pests, 57.5 per cent of the farmers surveyed said they were losing income to pests every year or most years and 50.6 per cent that they were losing food every year or most years. Almost all (97.4 per cent) were using pesticides. Nearly 47 per cent reported that if they could not get pesticides, it would decrease income from their crops by more than three-quarters, while 58.9 per cent said stopping pesticide use would increase their food losses to over half their crop.
7. Against this backdrop, the Kenyan government in 2023 announced the withdrawal from the market of eight pest control products, listed in Figure 9, for differing reasons across human safety, environmental impact, and trade concerns, as itemised in Appendix 1. The international basis of pest control regulation is risk assessment, which considers any poisonous element, the dose that makes it poisonous and the volume of the product

reaching humans, animals and the environment. Kenya is strongly committed to risk- based assessments, and is in disputes at the WTO with the EU, which now implements a hazard-based assessment and precautionary principle where there is no evidence of risk.

8. Our analysis examined the risk assessments and hazard assessments for each of the eight active ingredients withdrawn and found that most of the Kenyan withdrawals were, in fact, precautionary. More than half of the active ingredients withdrawn have no established ‘risks of concern’ for humans, animals or the environment.

9. Having examined the withdrawals, our study mapped the previously registered uses for all eight withdrawn active ingredients and associated pest control products by pest and crop, finding the withdrawals affected the control of more than 105 pests on at least 31 crops. These included all the country’s staple foods, all its leading agricultural exports, and all the most-consumed vegetables in the country, with the crops affected accountingfor 75 per cent (74.8569%) of the volume of crop and vegetal output in Kenya.

10. We undertook literature reviews of peer-reviewed studies to map the crop damage done in the absence of crop protection in each pest pathway, and the prevalence in Kenya. We calculated the net loss without crop protection as the average damage multiplied by the prevalence. However, for many of the crops, this created a sum of damage adding up to more than 100 per cent. It is not possible to lose more than all of a crop, for which reason this raised a critical modelling challenge.

11. In fact, pests do not inflict damage in a linear sequence, one adding to the next. We, therefore, made a critical modelling assumption that if we took the most destructive and prevalent pest, all other damage would be subsumed beneath that percentage. To give an example, the withdrawals affect the pest control for 12 pests that affect flowers (thrips, aphids, hids & whiteflies, mealybugs, spider mites, caterpillars, powdery mildew, downy mildew, botrytis, black spots, and false codling moth). The damage these pests each inflict together with their prevalence in Kenya would see them cause average crop losses in a range from 3 per cent to 49 per cent each without pest control. Adding these average unprotected damage percentages together for all 12 pests equals total damage of 246.84 per cent. For the modelling, we modelled the impact of botrytis, which, at 49 per cent, was the most damaging pest if uncontrolled, and assumed that all of the damage done by aphids, hids & whiteflies, mealybugs, spider mites, caterpillars, powdery mildew, downy mildew, botrytis, black spots, and false codling moth, would be encompassed within that 49 per cent, and/or not add any further crop losses.

12. It is worth emphasising that this constitutes a very conservative assumption and is likely to mean that all the model outcomes are underestimates of the actual impact ahead. However, on the basis of this selection, the losses to the 31 crops without protection amounted to 42.8 per cent of their 2022 production levels.

13. We then mapped all alternative pest controls. For registered chemical control products, which were mapped from the PCPB database by pest and crop, we assumed their

equivalent efficacy to the withdrawn product as a baseline. The only differential applied to that baseline was the level of resistance already being reported for any of the alternative controls in relevant peer-reviewed studies. This was not an evaluation of pest sensitivity, but where, for instance, studies were reporting 35 per cent to 65 per centresistance to a product, we applied that resistance factor as a reduction in its equivalent efficacy.

14. We also derived from literature reviews the pace that a pest was developing resistance and applied that as a resistance factor reducing the control provided by synthetic alternatives in each successive year, as that expanding resistance removed more protection.

15. For IPM alternatives, such as hand weeding, the use of GMOs, parasites, pheromone traps, and suchlike, we carried out global literature reviews on every pest 'pathway' (being the pest on that specific crop) to identify all alternative means of control. We found that for many of the pest pathways no cultural or biocide controls existed, or where they did, their efficacy was very partial or minimal, and sometimes untested. However, for all IPM alternatives that offered significant pest control, we mapped their efficacy and degree of uptake. The pest control provided by IPM alternatives at the start was calculated as their efficacy multiplied by their uptake. For instance, GMO cotton gives strong bollworm resistance, but has enjoyed very poor uptake because of its vulnerability to drought. A factor of increased IPM uptake was then built into future years.

16. These calculations and findings are explained in detail in Chapter 3, where they were modelled to calculate the net impact of the withdrawals on crop yields. For 13 of the pathways, the withdrawals removed all pest control. For a further 20, the withdrawals will leave only one crop protection option, which, in the majority of cases, but not all, will quickly cease to be effective due to accelerated resistance. These include crops such as wheat, where there were only two fungicides available for leaf rust, which develops resistance to same-use fungicides within two to three seasons, and where Kenya only now has one, meaning there will be no control for the pest within two years.

17. For all crops, based on the use of alternatives and levels of resistance, our model forecast a fall of 10.1 per cent in the volume of output of the 31 affected crops in 2025. Of the 27 crops affected, 16 will not have restored output to 2024 levels by 2034. All the country's staple crops will be seriously affected, and most of its leading agricultural exports. Within the country's staple crops, our model reported a recovery to 2024 levels only in rice production. However, this was because the impact of the now aggressively expanding apple snail was not included in our model - since our model considered the present status quo plus the impact of the withdrawals, and not other extraneous changes, such as new and uncontrolled pests.

18. None of maize, wheat, potatoes, cut flowers, or coffee will return to their 2024 output level in the 10 years analysed.

19. The biggest setbacks by crop will be for cucumbers, cabbages and kales, and French beans, which will fall by more than 30 per cent in 2025, tomatoes, egg plants, kerala, cut

flowers, snow peas, squashes, tea, potatoes, barley and sorghum, which will fall by more than 20 per cent, while cotton, pineapples, courgettes, maize and coffee will fall by more than 10 per cent.

20. In forecasting the impact on farmers' incomes, we converted all crop volumes into value at their 2022 prices. The losses were concentrated in higher-value crops, meaning the loss to agricultural producers' incomes will be 17.6 per cent in 2025. The largest total income losses in 2025 were for cut flower, maize, tea and potato growers, ranging from Sh15bn to Sh37bn per crop, at 2022 prices. For 18 of the 27 crops analysed, farmers' incomes failed to recover to 2024 levels in the decade ahead, generating total income losses, at 2022 prices, of Sh 124.6bn in 2025 and Sh 487.78 billion by 2034
.

21. With 48 per cent of farming families currently living in poverty, the impact is set to be far more severe, however.

22. Kenya's smallholders sell, on average, only 26 per cent of the crops they produce. Our survey into the pest control strategies they use for crops produced for sale and the strategies used for crops produced for home consumption found farmers using almost the same pest control strategies for both end-uses. Thus, the 17.6 per cent yield loss will affect both the sold crops and home food supplies.

23. Our data revealed some end-use switching on yield losses, with farmers reducing crops for sale to prop up their own food supplies for home food consumption. But, whether swapped out from income, or bought as replacement food, the same farmers will be replacing a net 13 per cent cut in their home food supplies (76% retained x 17.6% reduction).

24. On this basis, we calculated the replacement costs for home food supplies by excluding crops such as cut flowers, tea, coffee, and cotton. We assumed farmers could replace foods at a price broadly equivalent to farmgate prices, versus the normal spread from farmgate to consumer prices of 80 per cent. This was a further deeply conservative assumption. On this basis, farmers will gain additional food replacement costs of Sh183bn in 2025, at 2022 prices.

25. Over the next decade, the impact on farmers of both lost sales income and new food replacement costs is set to reach at least Sh1 trillion shillings, while the double impact of a reduced volume of foods for sale and reduced home-grown foods is set to trigger a spike in food insecurity, as consumers seek to secure 30 per cent more food than was available for sale domestically in 2024, prior to the production falls.

26. This report has not estimated the rise in food prices this will generate, but it will be considerable as a result of import substitution, undermining the trade balance and exchange rate, combined with an excess of local demand and shortages.

27. Kenya is already suffering from high food insecurity, primarily because of the long-term failure of cereal crops to expand at a sufficient rate to keep pace with population growth. As a result Kenyans were getting an average 2,218 calories a day by 2021, 13.8 per cent below the average in Africa of 2,573. Its undernourishment rate has also risen steadily since 2010, from 21.3 per cent to 27.8 per cent of the population, while the number of food-insecure Kenyans has risen steadily from 24m in 2015 to 38m by 2022.

28. The crops affected by the pest control withdrawals account for 63 per cent of the calories consumed by Kenyans. Without import replacement, the yield drops forecast in this report will further reduce the calories per head to 1,872 per day, assuming the consumption of unaffected foods can continue at the same rate as previously, and to 1,767 by 2034, moving Kenya to the lowest national calorie count in the world.

29. Studies show that the long-term consumption of 1,800 calories per day moves consumers into 'semi-starvation neurosis', while severe calorie deficits drive up cancer cases by as much as 89 per cent, and diabetes by 55 per cent to over 75 per cent. Evidence from Kenya's anaemia data additionally shows climbing micronutrient deficiencies since 2011, from 39 per cent of children to 43 per cent by 2019.

30. In modelling the nutrient content of just onions, kale and tomatoes and the impact of their yield drops, this impact analysis found a further 7 per cent drop in iron availability and a more than halving in the average availability of vitamin A, with Kenya's 2011 Micronutirient Survey citing WHO figures reporting that vitamin A deficiencies cause a 23 per cent in all-cause mortalities.

31. The further increase in micronutrient deficiencies will also have other long-term impacts, reducing productivity, and introducing permanent developmental impacts, through lower IQs, reduced concentration and earning power, and reduced kidney and lung development. We have not included these impacts in the analysis on the economic impact of the withdrawals
.

32. Based solely on the yield cuts, and the consequent losses across the agricultural value chain, the reduction in Gross National Income will be a reduction of at least 6 per cent in 2025. Import substitution in 2017, when maize crops were decimated by Fall Armyworm, equated to the reduction in sold maize and did not also cover the home-retained losses, leading to a parallel 41.7 per cent increase in local maize prices. We have assumed imports to substitute for the gaps in the country's four staple cereals will also cover only the sold portion, however the pressure to arrest domestic price rises will be severe, with maize prices already at long-term highs. On this basis we estimate the shortfalls will generate additional imports of $211m, or Sh27.43 bn.

33. At the same time, the output of four out of Kenya's five largest exports will be affected by the pest control withdrawals, being tea, flowers, coffee, and tropical fruits. Across all affected exports, the fall in output is forecast to cut their export earnings by $492.7m in 2025 - or 19.3 per cent of their estimated 2024 earnings of $2.552bn - and by $1.77bn or

Sh230bn in the decade to 2034.

34. However, many of the pests for which controls have been removed are also quarantine pests in the European Union, which is Kenya's leading export destination. A series of crops, including coffee, snow peas, egg plants, cucumbers and chillies, are unlikely to be able to navigate the quarantine bans on the basis of the controls that have been removed. This won't affect export levels in 2025, but over the decade ahead is likely to lead to lost export income of approximately $11bn or Sh1.43 trillion.

35. Based on our most conservative assumptions, we estimate the pest control withdrawals will reduce Kenyan GDP by 7.28 per cent in 2025.

36. In terms of policy considerations, the withdrawals appear to have been driven by export market needs and not the previous regulatory framework that was based on risk assessment and necessary mitigation measures. At least six of the eight withdrawals raise no risks of concern, across human and environmental risks, but instead represent the application of the European Union's precautionary principle of withdrawing on un-evidenced concerns, following from trade restrictions and trade pressures. This is despite Kenya's active participation in WTO disputes rejecting the validity of the EU's pest control registration regime.

37. The withdrawals, however, extend beyond the adoption by Kenya of the EU's contested regulatory methodology, and in the case of 2-4-D, set aside all regulatory regimes in an ad hoc override, on a globally approved pest control product, prompted by a small number of MRL-breach notifications. This implies the transition of pest control registration away from any regime dedicated to the health and welfare of Kenyans to an unpredictable tool of trade support over which Kenya no longer has sovereignty, and which might better be addressed through the enhanced facilitation of MRL observance.

38. The enormous impact of these withdrawals raises further policy issues around the need to promote and accelerate alternative pest control tools, prior to withdrawing existing tools, or in some other way manage the transition in such a way as to prevent a surge in Kenyan mortalities.

39. We recommend, based on this report's findings that:
- A consistent and transparent methodology and criteria be adopted and promulgated for pest control product approvals
- This methodology and criteria be aligned with national priorities, national commitments and national security in incorporating considerations of food security and public health impacts.
- The government initiate an urgent public information campaign informing farmers of the pest control withdrawals and the alternative protection they can deploy
- The government review the trade impact and national security impact of the announced withdrawals and take all necessary measures to mitigate the negative impacts at a pace sufficiently timely to prevent the consequent surge in mortalities, morbidities and mass financial distress.

1 Chapter 1: Introduction

This impact analysis has been conducted following a series of pest control product withdrawals announced in Kenya during 2023, for implementation from December 2024.

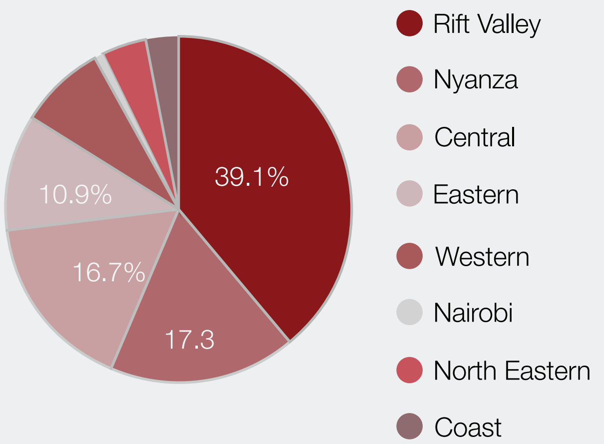
Pest control products in Kenya are regulated by the Pest Control Products Board, which monitors new information on the safety of registered products to humans and the environment. .In 2020, the board requested review data from producers on various active ingredients as part of a stakeholder exercise that led to its decisions, attached as Appendix 1, on withdrawals, on various grounds of potential safety and environmental concerns and trade barriers.
This report's aims to establish the likely effects of these withdrawals as an aid for the agricultural industry in achieving a smooth transition, and for policy makers in facilitating that transition and in mitigating its extreme impact.

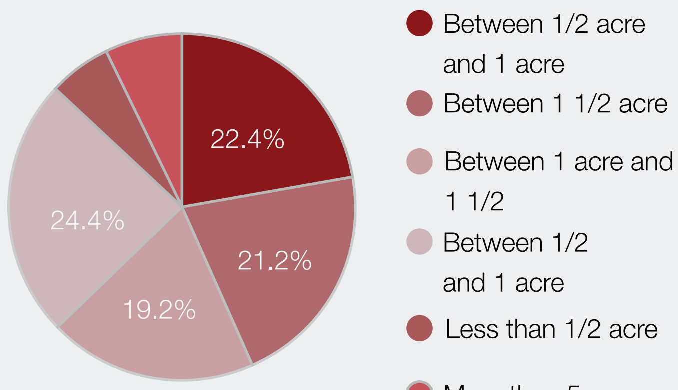
To that end, research was undertaken over 10 months, from October 2023 to May 2024, as primary research and through extensive literature reviews to ensure a full scientific grounding for the econometric modelling of the withdrawals' impact.

The primary research spanned a survey of 155 farmers across Kenya, shown in Figure 1, and 66 extended qualitative interviews with:

- 27 smallholders,
- 19 mid-sized and specialist farmers, including coffee, tea and flower farmers
- 7 agricultural exporters
- 9 extension officers, agronomists, and agricultural specialists, and
- 4 agrovets.

Figure 1 Survey respondents by region and plot size





The qualitative survey respondents and the quantitative interview participants did not overlap. Further information was additionally gathered in direct correspondence with key industry associations.

The survey questions, interview scripts and information requests were formulated following an initial analysis of the crops affected by the eight active ingredient withdrawals announced in Kenya in 2023. The researchers used the online database of the Pest Control Products Board to record all products using the withdrawn active ingredients and map their registered uses. The database was then searched for all the alternative products and active ingredients registered in Kenya for these pests on the same crops.

The researchers then undertook an extensive series of literature reviews, gathering data on the range of damage done to crops by the pests identified, their prevalence in Kenya, their development of resistance, and the availability, efficacy (as in, the pest clearance rates and control achieved through this method) and adoption rates of alternative crop protection tools. The team also gathered data for the crop modelling and impact analysis that included national crop production data, by value and volume, export and import data, and health and nutrition data.

On the basis of this research, this introductory Chapter 1 lays out the nature and impact of the pest challenge facing Kenya, before detailing, in Chapter 2, the withdrawn pest control products, their uses and the grounds for their withdrawal.

Chapters 3, 4, and 5, report the methodology, assumptions and outcomes for a series of econometric models undertaken to establish the likely impact of these product withdrawals. Chapter 3 lays out the expected yield reductions. Chapter 4 considers the impact of farmers incomes, food security and health. Chapter 5 evaluates the impact on Gross National Income, imports, exports and Gross Domestic Product.

Chapter 6 lays out the policy issues raised by the information and forecasts presented in Chapters 1 to 5, before Chapter 7 presents the conclusions drawn from the study's research findings and model results.

1.1 Pests in Kenyan agriculture

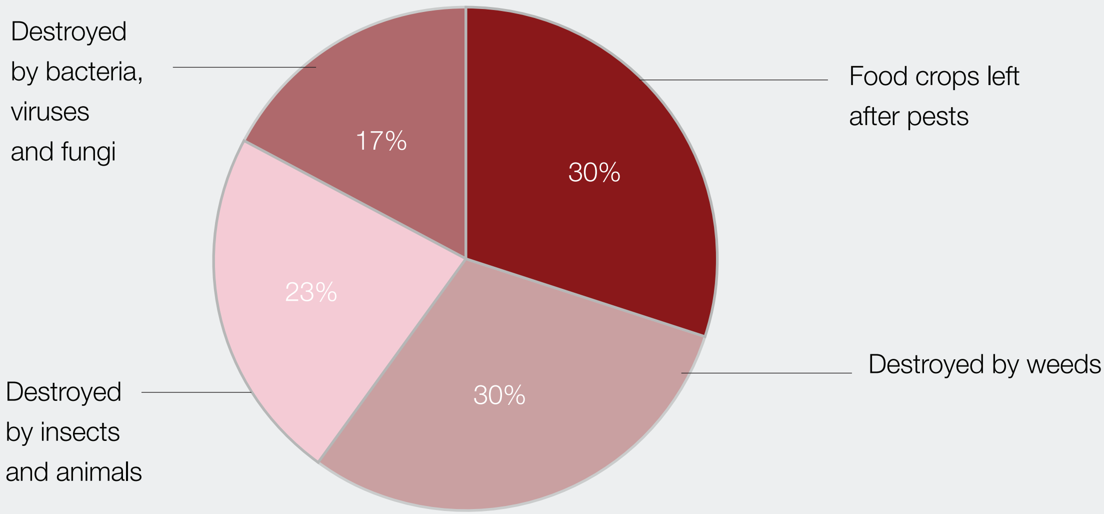
Kenya, the tropics, and Sub-Saharan Africa suffer more heavily from pests than most of the rest of the world due to their greater heat, with Africa positioned as the world's hottest continent.

Higher temperatures accelerate the growth of insects, plant viruses, bacterial diseases, fungi, and plants, including weeds. This is being further exacerbated by the temperature rises and erratic weather patterns caused by climate change.

This has created chronic and acute challenges for Kenya that extend beyond the challenge of producing enough food for the nation's expanding population. The country's exponential rise in pests is increasing human and animal diseases, such as malaria and dengue fever, causing infrastructure losses to termites, and seeing pests attack the country's forests, unmanaged eco-climates, wildlife, and biodiversity.

These impacts have been made worse by plants' response to drought, which increases their nitrogen levels, further accelerating the growth and proliferation of larger and more fertile pests. As a result, global agricultural losses to pests have risen from an estimated 40 per cent to current estimates of 70 per cent losses, broken down by the FAO as itemised in Figure 2.

Figure 2 The world's food losses to pests



This deterioration has been more severe in Kenya, with estimates suggesting losses to pests in Africa are now running at up to 90 per cent.

The greater impact in Africa is because the region does not benefit from **periods of extreme cold** that reduce the activity and population of pests. Its ideal conditions have additionally seen it suffer exceptionally from **pest migration** and the accelerated expansion of incoming **alien species.**

At the same time, Kenya's temperatures have risen relatively sharply. WISER project meteorological data for Kakamega and Siaya counties from 1901 to 2009 found temperatures had increased by an average 2°C over that time. The World Bank further forecasts Kenya's temperatures will rise by 1.5°C to 2.5°C by 2050, making for a total rise of up to 4.5°C.

As Carbon Brief reports: "While estimates vary, some figures assert that every 1 degree increase in global temperatures increase pest-linked yield losses by 10% to 25%."

Kenya's yield losses appear to align with this estimate, with the literature reviews undertaken for this study revealing increases in pest-linked yield losses of 30 per cent or more, since 1980. At the same time, the country's population and food needs have continued to rise, with the population forecast to rise by a further 80 per cent between 2024 and 2050.

1.1.1 Insects

The development time of insects is driven by heat. As temperatures rise, the time they take to reach adulthood and lay eggs shortens and the number of generations per year increases, as well as the proportion of eggs reaching adulthood. As shown in Figure 3, this is creating exponential growth in Kenya's insect population.

Detailed laboratory studies, such as the study cited on the Sycamore Lace Bug, have delivered data on the impact of temperature increases on eggs, development time, and survival. Narrower studies, looking at annual generations or development time, but not fecundity, have revealed massive jumps in the population growth for common pests in Kenya, such as coffee berry borer, the tomato leaf miner, and the Fall Armyworm - which develops more than twice as quickly at 30°C than at 20°C.

Figure 3 The change in growth rates for three insects

Coffee Berry Borer in East Africa

1984
1 generation a year
one female: 30 - 50 eggs

2011
5 generations a year
one female: 102,400,000 eggs

2050
10 generations a year
one female: 10,485,760,000,000,000 eggs

Tomato Leaf miner /Tuta Absoluta

20°C
Life cycle: 41 days
Generations: 7 a year
One female leads to 45,864,700,000,000,000 adults by year end

32°C
Life cycle: 21 days
Generations: 13 a year
One female leads to 8,764,880,000,000,000,000,000,000,000,000 adults by year end

240 Average eggs laid per female

The Sycamore Lace Bug

19°C
Eggs per female: 87.7
Time to laying first eggs: 10.8 days
Egg to adult time: 47.6 days
Eggs developed to adults: 40.5%

30°C
Eggs per female: 286.8
Time to laying first eggs: 3.9 days
Egg to adult time: 20 days
Eggs developed to adults: 75.6%

Source

- *https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3281381/*
- *https://www.researchgate.net/publication/298966716_Temperature-dependent_development_of_the_tomato_leaf_miner_Tuta_absoluta_Meyrick_Lepidoptera_Gelechiidae_on_tomato_plant_Lycopersicon_esculentum_Mill_Solanaceae_1_Tuta_absoluta_Meyrick_Lepidoptera_Gel*
- *https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2715104/*
- *https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0024528*
- *https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0024528*

However, climate change literature had lent heavily on the laboratory development of upper threshold temperatures at which insect development began to be impaired. But, as more studies emerge, these thresholds appear to require continuous temperatures, with natural conditions, temperature variations, and night cooling increasing the upper range to typical levels of 37°C to 45°C.

Increased temperatures are additionally driving pest migration to areas that were previously inhospitable at higher latitudes. A 2010 study in Tanzania found that Coffee Berry Borer, which could not previously survive at higher altitudes in Arabica coffee, had spread to areas 300 metres higher than 10 years earlier. It forecast a rapid shrinking of viable coffee-growing areas in Kenya, as a result, which is now becoming apparent.

In interviews with 64 farmers and agricultural experts for this report, many reported the near complete destruction of their coffee crops by Coffee Berry Borer and Coffee Berry Disease in 2023.

Coffee Berry Borer/Coffee Berry Disease

"I was expecting almost 12 tonnes. I didn't even get one tonne. All of it came and everything went down, and I'm not alone, even my neighbours this pest is the major problem with Kenyan coffee."

Kimanthi, Coffee Farmer, Embu

At the same time, an accelerating flow of invasive pests has migrated into Kenya. These include the diamondback moth (DBM), fruit flies, Liriomyza leafminers, thrips and spider mites, as well as those shown in Figure 4, below, showing pests that Kenya did not have 10 years ago that are now some of the country's most destructive pests.

Figure 4 | New pests that have arrived in Kenya in the decade 2013 - 2023

Tomato leaf miner / *Tuta absoluta*

2013

Papaya mealybug

2016

Potato cyst nematodes *(PCN) G. pallida, 2016*

2015

Fall Armyworm

2017

Spotted-wing Drosophila

2019

> "We sell the best, and they reject when the pests are there. I just lost 20 crates, which go for Sh3,000 a crate, so that's Sh60,000. And Tuta absoluta and white fly are whole-time pests for tomatoes now."
>
> Joshua, tomato farmer, Chuka-Meru.

Insects that eat plants are also eating more, as they grow faster, and as plant composition changes due to rising CO_2 levels. There has been no consistent measurement of carbon dioxide levels in Kenya, and the concentration of CO_2 in the atmosphere is always higher in urban areas. However, records gathered in Meru and north of Mount Kenya in 1977 and 1978 found CO_2 concentrations of around 330 ppm, while a 2019 study in the Nairobi metropolitan area recorded levels of 414 ppm rising to 420 ppm by January 2020.

A series of studies have now shown that higher CO_2 levels reduce the plant's ability to defend itself from pests, and also increase the fertility of pests.

1.1.2 Bacteria, viruses, and fungi

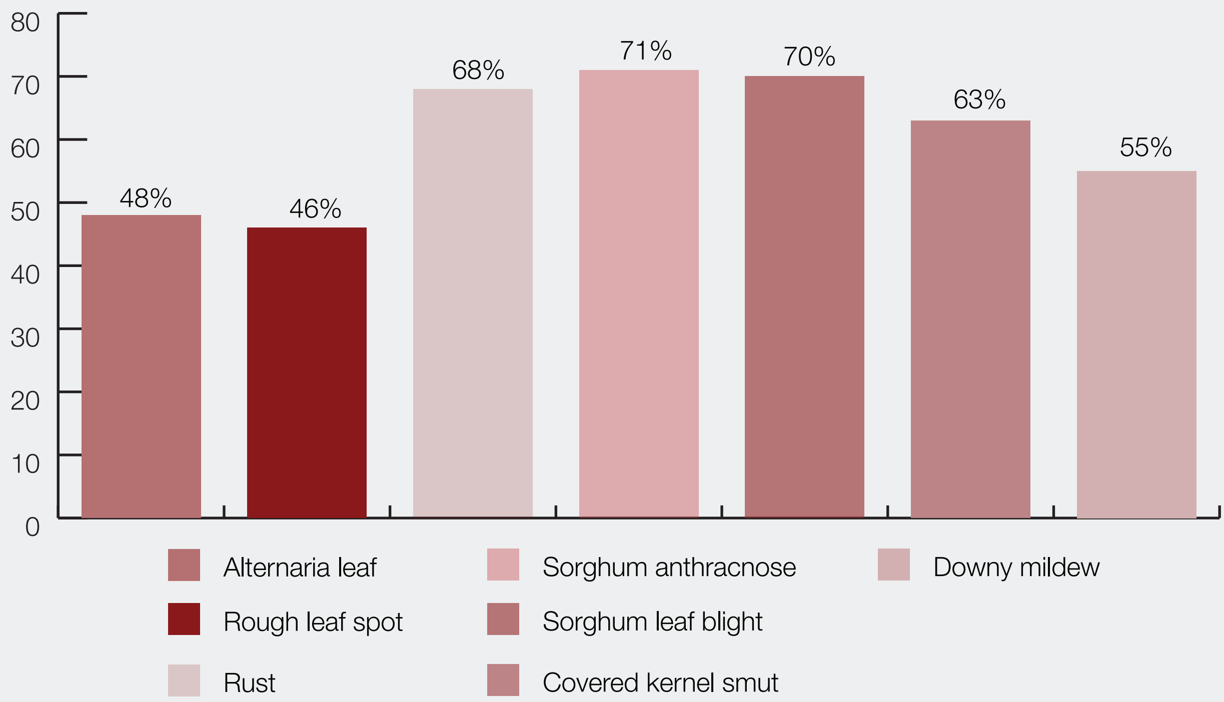
Insects act as vectors for plant diseases, transmitting 600 plant viruses, of which 275 are transmitted by aphids alone. This creates a direct relationship between the surge in the insect population and the spread of plant diseases.

At the same time, the country's rising temperatures and CO_2 levels are increasing the rate of growth of bacteria, viruses, and fungi and the rate at which new viruses are being generated, as well as reducing crops' immunity, in trends that CABI reports are "particularly severe in the tropics and subtropics".

As a result, viruses are now the principal cause of emerging plant diseases, with Kenya having gained a host of new and virulent plant viruses in the last two decades. These include the arrival of Maize Lethal Necrosis Disease (MLND) in 2011, causing yield losses of up to 95 per cent.

The country is also facing spiralling fungal infections, with almost every crop in Kenya now afflicted. A 2022 survey of sorghum grown by 384 smallholders in each of Kenya's climate zones, from semi-arid to tropical and temperate, found fungal infections in every crop, distributed as shown in Figure 5. This is particularly important in the context of the current pest control withdrawals, as the protection has now been removed for many crops against these conditions.

Figure 5 Distribution of viruses across smallholder-grown sorghum in Kenya



Amongst bacteria, one of the most damaging is soil borne bacterial wilt, which kills entire plants. A Rift Valley study in 2006 found the disease affecting 35 per cent to 99 per cent of potato farms, at the same time as the country's potatoes are being damaged by bacterial blackleg, and late blight, caused by a fungus. Together these diseases have slashed potato yields in Kenya from around 21 tons per hectare in 2008 to less than 9 tons per hectare by 2018.

> "I have 4 seasons that I haven't harvested well. I always get affected by diseases like rust in green grams. Four years back, I used to get Sh100,000 or even Sh200,000. But from then till now I haven't got anything good. About Sh20,000 or Sh50,000."
>
> Hamisi, farms 21 acres, Tana River.

1.1.3 Weeds

Plants also grow faster as temperatures rise, growing more stems and more leaves. This may be a bonus for leafy crops, but it has fuelled a take-off in weeds and their spread as invasive species. In Western Kenya, the Striga weed, now affects over 340,000 ha of land in Kenya, according to CIMMYT, and is deadly for maize and cereal crops.

Mesquite trees and bushes that originated from Mexico have also spread vigorously damaging the ecosystems in Kenya's arid and semi-arid regions, and closing down large tracts of land previously used by pastoralists. While the parthenium weed, widely cited as one of the worst weeds in the world for suppressing other plant life and leading to reduced biodiversity, has spread into much of Kenya, since arriving in Kisumu in the 1970s.

In agricultural crops, weeds including broad-leaf weeds have been found to reduce yields of grasses in semi-arid areas by 24 per cent to 74 per cent. The yield impact across multiple crops, of weeds alone, is now ranging from 50% upwards.

> "Sometimes I don't farm the entire farm, because I can't afford chemicals to clear weeds so I leave out about 1½ acres."
>
> Hassan, farms 7.5 acres, Tana River.

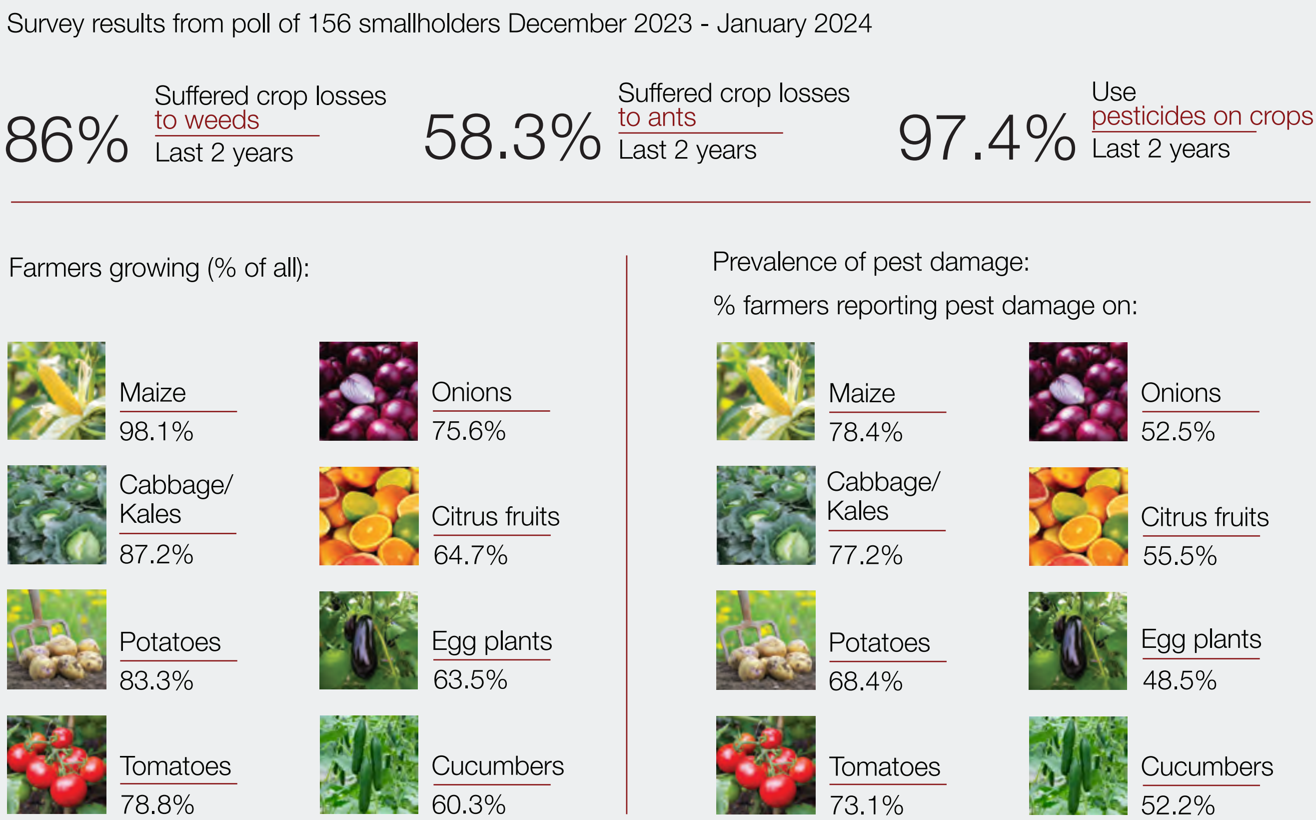
The combined effect of all these pests is proving sometimes overwhelming, with a study published in 2023 reporting the most critical pests for maize as: “fall armyworm and desert

locusts, two fungal pathogens: grey leaf spot (GLS), and Turcicum leaf blight (TLB) and one viral disease: maize lethal necrosis (MLN). These biotic stresses are very common, occurring every maize growing season and have the potential to cause yield losses of 100%.”

The large scale of present losses was affirmed in our country-wide poll of 155 farmers, with 41.7 per cent reporting their family had gone hungry in the last three years due to pest damage, while 50.6 per cent reported they lose food to pests every year or most years and 57.7 per cent that they lose income to pests every year or most years.

This was despite the fact that almost all of them (97.4 per cent) were using pesticides to control the problem. Nearly 47 per cent reported that if they could not get pesticides, it would increase the income they lost from their crops to more than three-quarters, while 58.9 per cent said stopping pesticide use would increase their food losses to over half their crop.

Figure 6 Prevalence of pest damage and pesticide use across Kenyan farmers



The enormity of Kenya's current, and rising, challenges with agricultural pests has made pest control critical to ensuring the country's food security and economic progress.

Against this backdrop, and having established the gravity and scale of this threat, Chapter 2 considers the grounds for the country's pest control withdrawals, before proceeding, in Chapters 3 to 5, to examine the levels of hunger and economic damage that will ensue for Kenyans as a consequence of the loss of these controls in the country's deteriorating pest environment.

2 Chapter 2: Withdrawals

2.1 Global pesticide regulation methodologies

The prevention of risk from pest control products has a global methodology based on risk assessment. This first assesses the hazards caused by a product through comprehensive testing seeking, for example, any damage it causes to skin, eyes, internal organs, the nervous, reproductive and other systems, and including testing for any chronic toxicity, which can emerge as DNA disruption or other consequences from repeated exposure.

Calculating the damage these hazards can do to humans, animals, plants and the environment falls under the science of toxicology. The first rule of toxicology is that 'the poison is in the dose', since not all hazards are poisonous. .A classic example of this is sweet almonds. Almonds contain cyanide, which is fatal for humans. But at the levels that we consume the cyanide in almonds, they cause no damage, as shown in Figure 7, because the dose is too low to have any impact.

Figure 7 The risk of toxicity from almonds

Almonds
Contain cyanide
(25 mg per almond kg)

805 Number of Almonds in 1 kg

Cyanide and almonds

Need to eat at least 1.2kg,
or 966 almonds in one day to
be poisoned or up to 6,762 almonds.

Cyanide
Fatally poisonous
(Stops cells taking up oxygen)

0.5 - 3.5(mg) Fatal dose per kg of bodyweight

Cyanide and humans

For an average adult at 60kg, a
fatal dose would be from 30 milligrams.
Is it safe to eat one almond or even 100
almonds? Yes.

https://www.livestrong.com/article/494578-can-almonds-cause-cyanide-poisoning/

Thus, once a hazard is established, scientists test for two further elements to establish whether a risk exists:

- What dose is dangerous?
- Are humans, animals, or the environment exposed to a dangerous dose?

Hazard + Dose + Exposure = Harm

As shown in Figure 7, the hazard from cyanide is fatal, but the dangerous dose is beyond what any human could consume from almonds. Cyanide is additionally broken down quickly in the body, removing the risk of accumulation from repeated, small doses.
However, the scientific nature of calculating when a poison becomes poisonous leaves data open to manipulation by those unfamiliar with the relationship between volume and toxicity. This has given rise to headlines in Kenya, for instance, suggesting Chlorpyrifos is 'highly hazardous', using the terminology of chemical classification to mobilise alarm for a chemical classified by the WHO as moderately hazardous. It also sees reports claiming 'poisonous sukuma wiki' on the basis of residue tests in parts per billion, which would require the consumption at high speed of many tonnes of kale to reach any part of a moderate risk. Thus, sukuma wiki that is less toxic than sweet almonds is portrayed as poisonous to eat.

Similarly, in Europe, this has generated campaigning headlines that claim a pesticide is carcinogenic, but fail to point out that it shows only the first signs of precancerous changes in daily tests over two years and across three generations at 45,000 times the daily dose the EU has set.

In reality, and as demonstrated in the example in Figure 8 given for Chlorothalonil, scientists test for dangers from a sudden, acute dose, such as when someone accidentally drinks 2 litres of pesticide. They also test for chronic exposure, through, for example, repeated consumption of residues on food.

Different doses are tested, measured in the equivalent of one billionth of each kilogram of bodyweight (micrograms per kilogramme) to establish the very first point at which any impact is observed, across the many impacts tested for. The level at which a substance causes no harm (the No Observable Adverse Effect Level - NOAEL) is then set substantially below the level of a first observable effect.

This NOAEL becomes the 'point of departure' in calculating a safe reference dose, with a series of extra safety adjustments as shown in Figure 8 for Chlorothalonil. In this case, this gives a safe reference dose that is 1/448th of the dose at which there is no observable effect.

Figure 8 Calculating safety in pest control: the example of Chlorothalonil

6.13 mg/kg/day — Point of departure
Level of consumption in animal tests, per day that produces no observable effects.

0.014 mg/kg/day — Uncertainty factor
Reduce to 100th of human equivalent of no observable effects to allowfor any uncertainty.

1.35 mg/kg/day — Human equivalent dose
Adjusted for body weight scaling.

0.014 mg/kg/day — The Reference Dose (RfD)
At 1/448th of the “no effects” dose per day in animals.

https://www.health.state.mn.us/communities/environment/risk/docs/guidance/gw/chlorothlnil.pdf

Scientists then measure the volume of crops treated, the volume of those crops eaten, the residues in water and how much water is drunk, and every other possible avenue by which people or the environment could be exposed to this chemical.

From this, national authorities, and the World Health Organisation and the United Nations’ Food and Agricultural Organisation through the CODEX Committee on Pesticide Residues, determine usage that is allowed and set maximum residue levels to ensure exposure does not exceed the safe reference doses.

However, following changes to its pesticide legislation in 2007, the European Union often sets aside the reference dose from a hazard, instead setting the exposure dose at negligible, as a precaution.

Once a pesticide is moved to a requirement for negligible exposure, any tests showing any exposure at all mean the EU bans the pesticide - again as a ‘precaution’ - in a loop that does not require any evidence of any risk.

This, thereby, dislocates bans and restrictions from risk based on scientific data. It has also stimulated widespread reporting, as cited above, where a single almond would be equivalently characterised as highly hazardous and poisonous.

2.2 Kenya's withdrawals

Most of the new restrictions in Kenya are based on the precautionary principle adopted by the European Union, with no evidence of a risk of concern to humans, animals or the environment. As discussed in Chapter 6 under policy, this is unlikely to represent a change in the basis of Kenyan regulation or a replacement of risk assessments with hazard-based precautionary regulation. Rather, it appears to be an ad hoc override of the country's policy on regulatory methodology driven, primarily, by trade considerations.

However, ahead of the analysis of the policy and regulatory basis for the withdrawals, we have laid out below the current scientific evidence and international regulatory status of the eight pest control products withdrawn.

2.2.1 2-4-Dichlorophenoxyacetic acid (2-4 D)

First approved in 1945, it is the most widely used herbicide for broad-leaved weeds in the world.

Regulatory status outside Kenya
The US EPA reports 2-4-D has 'generally low toxicity for humans'. Currently in a regular, scheduled registration review by the EPA, the latest Human Health Risk Assessment published in 2020 found no risks of concern in any sub-element, acute or chronic, of food, drink, or residential exposure, and no risk of concern in an aggregate exposure to any group or sub-group.

EPA classifies 2-4-D as not carcinogenic for humans on the basis of existing studies. The WHO's IARC classifies it as possibly carcinogenic on the basis of insufficient evidence to state categorically that it is impossible it could cause cancer, but observes: "However, epidemiological studies did not find strong or consistent increases in risk of NHL (Non-Hodgkin Lymphoma) or other cancers in relation to 2,4-D exposure."

Approved as safe for use in almost all world markets, including the USA and EU. 2 4-D is available in multiple forms (esters, acids and salts) of which one, the highly volatile ester (but not the low volatile ester) is banned in Australia, the EU and North America as a precaution in case of vapour drift damaging other crops. There are no restrictions on the ingredient's other forms.

Drivers of Kenyan restriction: export notifications into Japan and Korea, following reduced MRLs in those markets
Almond status: No risks identified as averted for Kenya or Kenyans

2.2.2 Acephate

An insecticide, first approved in 1973, commonly used for thrips, aphids, whiteflies, and for pests such as false codling moth.

Regulatory status outside Kenya
Currently approved for use in the US, but due a review decision in 2024, following from a Human Health Risk Assessment in 2023 that found risks of concern in drinking water exposure to one of acephate's degradants, methamidophos, produced by the breakdown of acephate.

Banned in the EU since 2003 based on a hazard. It does not have any cumulative effect, but there is a potential hazard to a sudden and extreme overexposure, which "can overstimulate the nervous system causing nausea, dizziness, confusion," reports the EPA.

Drivers of Kenyan restriction: Trade restrictions by the EU, following the EU's internal application of its precautionary principle.

Almond test: only dangerous in used form on misuse

2.2.3 Chlorpyrifos

Chlorpyrifos, first approved in 1965, is a widely used insecticide for Fall Armyworm, aphids, thrips, multiple other crop pests, Coffee Berry Borer, termites, ants, and bed bugs.

Regulatory status outside Kenya
Chlorpyrifos is currently the subject of a regulatory wrangle. It was widely used for residential pest control in the US, until its ban for indoor use in 2001, driven by Columbia Centre for Children's Environmental Health (CCCEH) data detecting it in 100% of indoor air samples and 70% of umbilical cord blood collected from babies.

However, there was no evidence of developmental impacts, with wide-ranging animal tests only showing any brain and nervous system impacts at levels that were higher than lethal (capable of causing death). No impact was found at any lower levels. For this reason, agricultural use continued, while in the EU, Chlorprifos continued to be used in homes, for bed bugs and termites, as well as agriculturally.

But in 2011, the CCCHE examined Chlorpyrifos levels from the placentas of 265 New York city minority children born before the indoor ban and found a correlation between higher Chlorpyrifos placenta levels and lower IQs and working memory. This left regulators with a challenge. They lacked evidence that the reduced IQs were caused by the Chlorpyrifos, with the same patterns of reduced IQ and working memories arising from parallel conditions of poor housing, poverty and poor nutrition. Moreover, with no mirrored impact in animals, the evaluators lacked a zero-impact exposure level below which there was no risk.

The EPA tried to estimate the exposure in homes to work out a level below which there was no risk of concern from agriculture, but finally decided to end all food tolerances to Chlorpyrifos, in 2021, as the outcome from an unsatisfactorily evidenced risk assessment in 2016.

In 2020, the EU also banned Chlorpyrifos on a precautionary basis, following a meeting of experts, a discussion, and vote, which concluded that "concerns related to human health exist, in particular in relation to possible genotoxicity and developmental neurotoxicity".

In November 2023, five months after a ban was also announced in Kenya, the US Court of Appeal reinstated Chlorpyrifos's agricultural use and said the EPA should have calculated modified agricultural residues drawing on scientific grounds. The EPA is now recalculating agricultural tolerances.

Drivers of bans in Kenya: trade concerns, on changed MRLs by Japan and the EU on the application of the precautionary principle.

Almond test: impossible to assess any benefits, as no risk has been established.

2.2.4 Chlorothalonil

Chlorothalonil, first approved in 1966, is a leading global fungicide in preventing powdery and downy mildew, botrytis on vegetables and leaf, stem and yellow rust in wheat.

Regulatory status outside Kenya
Chlorothalonil is approved for use in the US, with the interim decision on its most recent review issued in September 2023, after the announcement of its withdrawal in Kenya.

The EU banned chlorothalonil in 2020, as a precaution on insufficient information of the carcinogenic effect of one of its metabolites, chlorothalonil R471811. This precaution meant that the EU does not follow the reference dose, but automatically seeks negligible exposure.

Chlorothalonil, itself, breaks down quickly, but its metabolite chlorothalonil R471811 has been found in water samples at above the negligible level of 1 part per billion, and does not break down quickly. There is no evidence of any carcinogenic effect or precancerous changes at this level, but the fungicide has been banned as a precaution.

The no adverse effects level is 6,000 times higher than the current EU threshold.

Driver of Kenyan withdrawal: trade pressure from the EU to apply precautionary principle

Almond test: No risk can be identified as averted.

2.2.5 Diuron

Diuron is a herbicide, registered in 1966, that is used to remove broad-leafed weeds and grasses

Regulatory status outside Kenya
The EPA proposed in April 2022 to ban the use of Diuron on all food crops following its human health risk analysis 2021, which took a new approach to the statistical analysis of cancer risk.

The key study in mice and rats delivered a NOAEL (no observable adverse effect levels) of 50.8 micrograms per kilogram per day over two years. The new cancer model found aggregate dietary, water and residential exposure of 0.00011 micrograms per kilogram per day, but deemed this too high to be safe based on the cancer risk statistical modelling.

The exposure was 1/ 54043 of the level at which there was no effect in tests.

Industry withdrew Diuron from the approval process in the EU in June 2023

Driver of withdrawal in Kenya: possible cancer risk, withdrawn on precaution that 1/54043 of the no adverse cancerous affect level may be too great a risk

Almond test: has averted health risks equivalent to eating 1/10th of one almond.

2.2.6 Propineb

Propineb is a fungicide, first registered in 1962, that prevents blights and mildews

Regulatory status outside Kenya
Propineb is not registered in the US and was banned in the EU in 2018. High-dose tests on rats identified a reduction in the size of animals' testicles and in the movement ability (motility) of sperm, although not in the sperm count. In this case, the EU used its precautionary principle and has not used the reference dose derived from the level at which there were no adverse effects.

Driver of withdrawal in Kenya: precautionary withdrawal on endocrine disruption, adopting EU policy on the precautionary principle and on endocrine disruptors that have been rejected by Kenya at the WTO as technical trade barriers

Almond test: appears to be less than a one-almond risk.

2.2.7 Pymetrozine

Pymetrozine, first registered in 1999, is an insecticide used to control thrips, whiteflies and aphids

Regulatory status outside Kenya
Pymetrozine is approved for use in the US. However, it was banned by the EU in 2019. The EU set aside the scientific evidence on carcinogenicity and the NOAEL, rooted in a key study of rats, following concerns about one of its metabolites CGA 300407. The Canadians ran a special review on CGA300407 and could find no conclusive evidence, including studies showing the metabolite was unlikely to be carcinogenic. However, once exposure levels were set at extremely low levels as a precaution, the risk assessment found exposure levels surpassed.

The EU also set the safe human exposure levels at 'negligible', surpassed at one part per billion by metabolites in groundwater tests. Much as with Chlorothalonil, the ban is not on a health risk, but on the absence of information removing all possibility of any unknown health risk.

In its most recent review, and in a general trend within the EPA towards hazard-based precautions for cancer hazards, the EPA applied new restrictions on Pymetrozine's use, ruling that it cannot be used in poor, sandy soils with shallow groundwater in order to prevent its metabolites entering ground water

.

Driver of withdrawal in Kenya: trade pressure from EU to adopt EU's precautionary principle

Almond test: no risk known of.

2.2.8 Thiacloprid

Thiacloprid is a modern insecticide, first registered in 1999, that counters thrips, aphids, whiteflies, and other insects such as mealybugs and spider mites.

Regulatory status outside Kenya
It is approved for use under risk assessment criteria in the US, but was banned in Europe in 2020 as a precaution against two hazards. The first is derived from a two-generational study in rats, where high levels of daily dosing with thiacloprid were found to increase the number of births deliveries impeded by the offspring's shoulder becoming stuck (dystocia) in the birth canal. The NOAEL (no observable effects) level was 2.7mg/kg per day, forming grounds in the US for the calculation of a safe reference dose and exposure analysis.

Europe ruled that because there was no scientific explanation for why thiacloprid was causing the increased dystocia (the mechanism), the pesticide could only be deemed safe at negligible levels. This negligible exposure was met through food, but the EU found an operator in one of three manufacturing sites producing thiacloprid-coated seeds that was using 'compressed air during cleaning of the treatment chamber'. Without any study on the exposure this generated, it ruled the pesticide could not be approved, due to the potential hazard for this operator.

It also found metabolites in ground water and ruled that without data on the impact of water purification of surface water to drinking water, there was a gap in data that could constitute a potential hazard.

Driver of withdrawal in Kenya: intense trade pressure from EU.to apply the EU's precautionary principle

Almond test: no health risk removed.

3

Chapter 3: Yield Impacts

With the introduction of any new policy or measure, the guiding aim is to achieve a positive impact on the welfare of the population and the common good. In many areas this obligates legislators to produce an impact analysis, but this requirement does not always extend to regulators, or to the introduction of specific measures.

The aim of this chapter is to assess the likely yield and output losses caused by the withdrawal of pest control products containing eight active ingredients in Kenya, as announced in 2023 and due for implementation from December 2024.

This analysis of yield impacts is an essential underpinning in assessing the likely impact of the measures on incomes, food security and trade. For this reason, we approached this estimation with rigour, seeking to base our figures on peer-reviewed empirical evidence and to model the likely damage based on explicit and conservative assumptions, as outlined in this chapter and Chapters 4 and 5..

We further cross-referenced our modelling data with information from the survey of 155 farmers across Kenya and 67 qualitative interviews, to confirm whether the results from both the primary and secondary research aligned and were consistent, which they were.

We began this research by mapping the active ingredients withdrawn and their registered uses. Following from this analysis, this study is focussed solely on the crops and pests affected by the withdrawals, as laid out in Figure 9. For ease of reference, we have also indicated the number of alternatives available, colour coded for:

Green: low risk, more than 8 alternatives
Orange: significant risk of resistance, 4 to 8 alternatives
Red: high risk of resistance, 1 to 3 alternatives
Pink: no alternative product registered.

Figure 9

Affected pest controls, by product, crop and pest, as per their former PCPB registrations

	Pymetrozine	Thiacloprid	Diuron	Chlorothalonil	Propineb	Chlorpyrifos	2.4-D	Acepthate	Alternatives
Flowers									
Roses									
Thrips	■	■				■		■	47
Aphids	■	■				■		■	24
Hids & whiteflies	■	■				■		■	21
Mealybugs		■							11
Spidermites		■							15
Caterpillars						■			27
Powdery mildew				■					31
Downy mildew				■	■				17
Botrytis				■					15
Black spots				■					7
False coddling mot								■	30
Carnations									
Thrips		■							15
Powdery mildew									3
Botrytis carnation									25
Cereals									
Maize									
Fall Armyworm						■		■	7
Aphids						■			4
Wireworms						■			1
Cutworms						■			2
Chaffer grub						■			1
Leather jackets						■			0
Termites						■			2
Leaf hopper						■			2
Broad leafed weeds							■		11
Rice									
Broad leafed weeds							■		3
Wheat									
Stem rust & yellow rust				■					5
Leaf rust				■					1
Broad leafed weeds							■		12
Aphids						■			11
Barley									
Aphids						■			6
Broad leafed weeds							■		4
Sorghum									
Broad leafed weeds							■		1
	Pymetrozine	Thiacloprid	Diuron	Chlorothalonil	Propineb	Chlorpyrifos	2.4-D	Acepthate	Alternatives
Commodity crops									
Coffee									
Broadleaf and grass weeds			■				■		4
Coffee berry disease				■					6
Coffee berry borer						■			1
Antestia bugs						■			4
Armyworm						■			1
Coffee green scales						■			1
Thrips									4
Cotton									
Broadleaf and grass weeds			■						1
Aphids						■		■	5
Bollworm						■			4
Cotton stainers						■			2
Amyworm						■		■	1
Tea									
Scaly insects and termites						■			2
Aphids						■			1
Tobacco									
Aphids								■	2

	Pymetrozine	Thiacloprid	Diuron	Chlorothalonil	Propineb	Chlorpyrifos	2.4-D	Acepthate	Alternatives
Whiteflies								■	2
Budworms								■	0
Thrips								■	1
Grasshoppers								■	1
Sugarcane									
Broadleaf and grass weeds			■				■		24
Agroforestry									
Termites						■			2
Fruits									
Pineapples									
Broadleaf and grass weeds			■						3
Mealy bugs						■			2
Citrus									
Broadleaf and grass weeds			■						1
Vegetables									
Potatoes									
Early blight				■	■				5
Late blight				■	■				7
Tomatoes									
Thrips		■							12
Aphids		■							20
Whiteflies		■							23
Early blight				■	■				11
Late blight				■	■				11
French beans									
Thrips	■								24
Bean aphids	■								19
Angular Leafspot				■					12
Anthracnose				■					12
Rust				■					13
Botrytis				■					4
Onions									
Thrips		■							3
Downy mildew					■				9
Purble blotch					■				8
Rust					■				3
Cucumbers									
Downy mildew				■	■				1
Powdery mildew				■					1
Leaf spot			■						1
Anthracnose				■					1
Squash									
Downy mildew & botrytis				■					1
Cabbage & Kales									
Cabbage aphids on kales	■								14
Leaf spot, black leg and c				■					1,1,0
Chillies									
Thrips	■								1
Aphids	■								1
Whiteflies	■								0
Eggplants									
Thrips	■								0
Aphids	■								0
Whiteflies	■								0
Karela									
Thrips	■								0
Aphids	■								0
Whiteflies	■								0
Broccoli									
Downy mildew and rust				■					3
Snow Peas									
Aschochytes				■					4
Botrytis				■					1

	Pymetrozine	Thiacloprid	Diuron	Chlorothalonil	Propineb	Chlorpyrifos	2.4-D	Acepthate	Alternatives
Downy mildew									4
Baby corn									
Broad leafed weeds									8
Courgettes									
Anthracnose & downy mildew									3
General farm									
Ants nests									0
Agricultural pasture broad leaf weeds									0

Ample replacements

Raises accelerated resistance issues

Few replacements/ likely to lose all protection to resistance

No replacements / complete loss of protection

We found the withdrawals affected the control of more than 105 pests on at least 31 crops. These included all the country's staple foods, all its leading agricultural exports, and all the most-consumed vegetables in the country, with the crops affected accounting for 75 per cent of the volume of crop and vegetal output in Kenya.

Having established the points of impact, we used a multi-staged model to assess the likely damage from each withdrawal.

We first determined a baseline of the output damage that would ensue in Kenya if there were no crop protection for these 105 pest pathways. To do this we undertook more than 200 literature reviews of peer-reviewed studies to establish:

- The spread of available data on the crop damage on each pest pathway
- The prevalence in Kenya of the pest on that crop.

For instance, a single pest pathway was for coffee berry borer in coffee. Various yield impact studies placed the damage caused by CBB infestations in Kenya at between 50 per cent and 100 per cent of infested crops, on which basis our model worked with a yield impact of 75 per cent, while prevalence sources ran at 90 per cent and higher. We adopted 90 per cent, meaning that our damage estimate for Kenya was 75 per cent damage on the 90 per cent infested crops, equal to total damage of 62.8 per cent.

However, this method of calculation, in compiling data of the average damage from each pest and its prevalence, created an issue that led to our most significant modelling assumption.

In many cases, the combined damage from the different pests analysed for each crop totalled damage of more than 100 per cent.

For instance, in the case of maize, the withdrawals removed controls for 9 different pests. Based on empirical studies assessing the damage that each pest typically inflicts on the crop,

and the prevalence of these pests in Kenya, the total potential damage to unprotected maize in Kenya equaled a 263.78% crop loss, as shown in Figure 10.

Figure 10 Yield losses to unprotected maize crops from selected pests

	Mid-point yield impact%	Upper yield impact%	Lower yield impact%	Current prevalence	Simple impact on no control
Maize					
Fall Armyworm	58	70	33	83	48.14
Aphids	50	100	10	62	31
Wireworms	40	100	5	62	24.8
Cutworms	26	28	22	3	0.78
Chaffer grub	16			36	5.76
Leather jackets	70	100	43	29	20.3
Termites	20	68	6	100	20
Leaf hopper	55	100	16	60	33
Broad leafed weeds	80	85		100	80
Total					263.78

Source: Author's estimates based on 18 literature reviews on damage inflicted to maize by individual pests, and on the prevalence of those pests in Kenya

Pests do not inflict damage in a linear sequence, with, for instance, Fall Armyworm destroying 48.14% of the crop, and then aphids a further 31%, and wireworms a further 24.8%. However, there was no data available on the net damage from multiple combinations of multiple pests.

We, therefore, made a critical modelling assumption that if we took the most destructive and prevalent pest, all other damage would be subsumed beneath that percentage. To give an example, the withdrawals affect the pest control for 12 pests that affect flowers (thrips, aphids, hids & whiteflies, mealybugs, spider mites, caterpillars, powdery mildew, downy mildew, botrytis, black spots, and false codling moth). The damage these pests each inflict together with their prevalence in Kenya would see them each cause average crop losses in a range from 3 per cent to 49 per cent each without pest control. Adding these average unprotected damage percentages together for all 12 pests equals total damage of 246.84 per cent. So, for the modelling, we modelled based on the impact of botrytis alone, which, at 49 per cent, was the most damaging pest if uncontrolled, and assumed that all of the damage done by aphids, hids & whiteflies, mealybugs, spider mites, caterpillars, powdery mildew, downy mildew, botrytis, black spots, and false codling moth, would be encompassed within that 49 per cent, and not add any further crop losses.

It is worth emphasising that this constitutes a very conservative assumption and is likely to mean that all the model outcomes are underestimates of the actual impact ahead.

In fact, many of the crops assessed would assuredly be destroyed entirely from a combined cocktail of the pest pathways affected at their present prevalence levels in Kenya, but our baseline of combined-pest destruction delivered a mean average across all crops of 42.8 per cent.

That mean average is the average of the damage done per crop - of the 31+ crops affected - once we selected the most damaging pest alone and assumed the other 70+ pest pathways added no additional damage.

For five of the 105 pest pathways analysed, we were unable to identify meaningful or reliable data on either or both of the damage inflicted by a pest on that crop, or on its prevalence in Kenya, and in these five cases, we classified the baseline damage without protection as zero.

A further challenge was the damage caused by pests that act as disease vectors. Many of these are insects that cause direct damage, but also introduce viruses, or fungi by creating honeydew. In these cases, we confined ourselves to direct damage figures, except in the case of four vectors, aphids, thrips, leaf hoppers and mealy bugs, which cause large-scale crop damage in Kenya through their transmission of Maize Lethal Necrotic Disease, via Maize Chlorotic Mottle Virus and Maize Streak Virus, and fungi damage brought by mealy bugs. In these four cases, we also assessed the damage caused by the viruses transmitted by the pests and the prevalence of these viruses and fungi.

3.1 Assessing the change in protection

To establish the impact of the withdrawals on crop protection and yield losses, we next established the opening levels of crop protection. Our survey of 155 farmers found 97.4 per cent were using pesticides on their farms, which aligned with the findings of peer-reviewed studies.

By type of pesticide, 93.6 per cent of the respondents reported they used pesticides to protect crops from insects, 85.9 per cent used them to protect crops from diseases, while 57.7 per cent used them to protect crops from weeds.

We gathered further insights on protection against specific pests from peer-reviewed empirical studies and qualitative interviews with extension officers and specialist farmers. These did not cover all crops, but enabled us to adjust the IPM factors in many specific pathways. For instance, coffee farmers and agronomists reported relatively low levels of pesticide use in the country to counter coffee berry borer, versus information from two extension officers, several farmers and two peer-reviewed papers showing very high usage of pesticides to counter potato late blight by Kenyan farmers growing potatoes.

With existing protection mapped, we calculated the effect on protection levels of the withdrawals by applying three measures:

The alternative pesticides available
For 13 of the 105 pest pathways the withdrawals removed all registered pesticides for that pest pathway. For a further 20, the withdrawals leave only one synthetic crop protection option, which, in the majority of cases, but not all, will quickly cease to be effective due to accelerated resistance.

The gap presented by these 33 pathways to zero protection conflicted with general perceptions, presented by one government extension officer during our qualitative interviews with his view that: 'There are dozens of alternatives to any one of these withdrawn chemicals. They won't make any difference to farmers'.

For the remaining two-thirds of pest pathways, where more than one alternative remains, we presumed like-for-like efficacy and equal accessibility with the remaining options, applying a fractional reduction in whole supply and in overall protection. Thus, if there had been 11 options, of which two were removed, we applied a 2/11 reduction factor in supply and access.

The resistance vulnerability of alternatives
To estimate the rate of erosion of remaining chemicals, we drew on peer-reviewed studies on the resistance cycle of each pest, in both single and repeated same-pesticide use, and intermittent use.

This raised hot spots of resistance risk, such as for leaf rust, which is quickly resistant if not interchanged from one fungicide to another, but where Kenya will now have only one fungicide. Data suggests this remaining sole option will cease to perform well from its second or third consecutive season, moving leaf rust to zero protection in the country.

Figure 11 | Pest pathways moving to zero crop protection, as per PCPB product registrations

All Protection Removed	Unprotected crop losses in Kenya, % (damage/prevalence
Cereals	
Maize	
Wireworms	24.8
Chaffer grup	5.76
Wheat	
Leaf rust	8
Sorghum	
Broad leaf weeds	25.8
Coffee	
Coffee berry borer	67.5
Army worm	N/A
Coffee green scales	12.4
Cotton	
Broadleaf & grass weeds	25.8
Armyworm	N/A
Tobacco	
Thrips	9.72
Fruits	
Citrus	
Broadleaf and grass weeds	25.8
Vegetables	
Cucumbers	
Downey mildew	12
Powdery mildew	19.5
Leaf spot	38
Anthracnose	24
Squash	
Downy mildew and botrytis	N/A
Cabbage and Kales	

Back leg	N/A
Snow peas	
Botrytis	10.5
General farm and pasture	
Agricultural pasture broad leaf weed	68

All Protection Removed	Unprotected crop losses in Kenya, % (damage/prevalence
Cereals	
Maize	
Leather Jacket	2.3
Commodity crops	
Tea	
Scaly insects and termites	25.5
Aphids	23
Tobacco	
Budworms	N/A
Vegetables	
Cabbage and kales	
Club root	N/A
Chillies	
Whiteflies	30
Eggplants	
Thrips	15
Aphids	32
Whiteflies	30
Karela	
Thrips	15
Aphids	32
Whiteflies	30
General farm and pasture	
Ants nests	2.9

Integrated pest management - biological and cultural alternatives
With the use of integrated pest management, pests can also be controlled through biological and cultural means. To assess the degree of protection these could provide in plugging the gaps created by the eight chemical withdrawals, we carried out a literature review on each pest pathway seeking all IPM tools available globally and assessing their data-evidenced efficacy, and their uptake and barriers to uptake in Kenya. These included pheromone traps, resistant, hybrid and GMO seeds, biocides, cultural techniques, and farm management elements, such as shading.

We created factors for the degree of ‘infill’ protection these alternatives might provide in 2025, taking into account the absence of their special promotion ahead of the withdrawals. We also built in a factor every year for the 10 years ahead for their increased uptake, based on their availability, accessibility, and ease of use.

In some cases, our expectations of a strong IPM alternative were disproven, for instance, in the case of BT cotton, which has quickly been found to be a water intensive crop with lower yields than conventional cotton. All available data shows low farmer uptake, and for so long as farmers are without irrigation, we modelled a substantially unmitigated deterioration in yields due to damage from cotton boll.

In many more cases, extensive literature reviews failed to retrieve any viable IPM protection, most notably in countering plant diseases. This represented a considerable gap around the cluster of new exposures to powdery mildew, downy mildew, club foot, purple blotch in onions, rust, anthracnose and botrytis. Indeed, for late blight in potatoes, we found that one of the most resilient multi-site fungicides had been removed in a situation of already substantial resistance to the alternatives, and no viable IPM alternatives, making for a steep fall in 2025 potato production, forecast to drop by 22.5 per cent.

For some pathways, early stage R&D was underway to develop new means of protection, and our researchers included some possible future protection where these could potentially come to market within the 10-year timespan of the forecasts.

A further factor, which we were unable to model, was raised in the qualitative interviews by two of the agrovets, who reported that some of the withdrawn products were being replaced by smuggled supplies from neighbouring countries. Many of the withdrawals are for products that have been risk assessed and approved for use in most of the rest of the world, meaning they are widely available elsewhere. Moreover, none of them are subject to the global treaties on the transport or import of dangerous chemicals. However, it was not deemed possible to quantify the impact of contraband supplies.

Similarly, the team was advised that, in some cases, farmers will switch to unregistered chemicals, authorised for other uses, to address the pests for which they no longer have controls. We note this likelihood, but, bearing in mind, the potential for reduced efficacy, and the extremely conservative modelling assumptions adopted above, would not expect these cultural responses to substantially alter the impacts predicted.

Finally, in estimating the full yield impact over the decade ahead, we calculated the compound average growth rate (CAGR) for each affected crop based on its historical production data, and applied the CAGR to each year of forecasts, alongside the deterioration caused in remaining crop protection by resistance, and the added protection from the additional uptake of IPM tools.

3.2 Yield Results

Based on the research above, it was estimated that the crop protection withdrawals announced during 2023 were likely to reduce the output across all the affected crops by a total of 10.1 per cent. The impact of the losses was uneven, with the volume losses from 2024 to 2025 greatest in:

Cucumbers - 32.5%
Cabbage and kales - 32.3%
French beans - 31.6%
Tomatoes - 29.5%
Eggplants - 25.6%
Kerala - 25.6%
Flowers: roses, carnations 23.9%
Snow peas - 23.9%
Squashes - 23.9%

Tea - 23%
Potatoes - 22.7%
Barley - 25.5%
Sorghum - 20.3%
Cotton - 18.2%
Pineapples - 16.5%
Maize - 15.1%
Courgettes - 12.6%
Coffee - 11.8%

In volume terms, the anticipated falls in export production are forecast to be largest for:

- Tea
- Pineapples
- Cut flowers
- French beans
- Snow peas

The full impact on exports is laid out in Chapter 5. The larger impact, however, will be on domestic income and food security, as explained in Chapter 4.

Of the 27 crops affected, 16 will not have restored output to 2024 levels by 2034. Figure 12 provides the 10-year forecasts, together with the year, shown in orange, in which each crop will re-establish its 2024 level of production.

Only rice and baby corn will surpass their 2024 output levels in 2025, presuming they are not affected by any other factors outside this model, such as apple snails. The remaining eight crops will recapture their 2024 output levels in two to eight years. Notable in these recoveries is the restoration by 2026 of 2024 output levels for sugarcane and onions, and by 2027 for cabbages and kales.

The hardest hit area over the decade ahead will be the country's staple foods, with only rice set to recover and surpass 2024 production levels by 2027, while none of maize, wheat, barley, sorghum or potatoes will resume 2024 output levels within the next 10 years.

In the country's export markets, neither coffee or cut flowers will succeed in recovering to their 2024 output levels in the 10 years analysed.

Figure 12 10 year output forecasts and year in which output is restored to 2024 levels

Crop	2022	2024(est)	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Flowers, roses, carnations	199,000	219398	175310	177764	180253	182776	185335	187930	190561	193229	195934	198677
Cereals												
Maize	3,089,901	3022297	2537705	2527554	2517444	2507374	2497345	2487355	2477406	2467496	2457626	2447796
Rice	186,000	217795	232612	253315	275860	300411	327148	356264	387971	422501	460103	501052
Wheat	270,700	220682	182915	166270	151139	137386	124884	113519	103189	93799	85263	77504
Barley	20,079	16177	10818	8936	7381	6097	5036	4160	3436	2838	2344	1936
Sorghum	112,988	95841	70351	65215	60455	56041	51950	48158	44642	41384	38363	35562
Commodities												
Coffee	51,852	52507	46603	39380	33276	28118	23760	20077	16965	14336	12114	10236
Cotton	3,762	3254	2475	2208	1969	1757	1567	1398	1247	1112	992	885
Tea	538,000	566340	447420	505137	570299	643868	726927	820701	926571	1046099	1181045	1333400
Tobacco	10619	11191	10386	10552	10721	10893	11067	11244	11424	11607	11792	11981
Sugarcane	8,799,769	9639017	9593873	10054379	10536989	11042765	11572818	12128313	12710472	13320575	13959962	14630040
Agroforestry												
Fruits												
Pineapple	257,022	230208	181920	172460	163492	154991	146931	139291	132048	125181	118672	112501
Citrus	120,893	133767	128468	135405	142717	150424	158547	167108	176132	185643	195668	206234
Vegetables												
Potatoes	1,754,130	1803589	1413693	1419348	1425025	1430725	1436448	1442194	1447963	1453755	1459570	1465408
Tomatoes	616,617	623542	448330	439363	430576	421964	413525	405254	397149	389206	381422	373794
French Beans	69,124	69956	48137	48281	48426	48572	48717	48863	49010	49157	49304	49452
Onions	161,434	172598	164546	172609	181067	189939	199246	209009	219250	229994	241263	253085
Cucumbers	6,303	6778	4744	4450	4174	3916	3673	3445	3232	3031	2843	2667
Squash	9,812	7410	4900	4023	3303	2712	2226	1828	1501	1232	1011	830
Cabbage & Kales	1,991,208	2524605	1924511	2184320	2479204	2813896	3193772	3624931	4114297	4669727	5300140	6015659
Chillies	1,421	1415	1031	1081	1132	1187	1244	1304	1366	1432	1500	1572
Eggplants	19,129	24599	20754	25880	32273	40244	50185	62580	78037	97313	121349	151322
Karella	462	323	201	185	170	156	144	132	122	112	103	95
Broccoli	4,762	3449	2679	2256	1900	1600	1347	1134	955	804	677	570
Snowpeas	22,884	22925	17462	16886	16328	15789	15268	14765	14277	13806	13351	12910
Baby corn	15,898	25521	28907	35527	43663	53662	65950	81053	99614	122426	150461	184917
Courgettes	3,640	2593	1913	1589	1321	1098	912	758	630	523	435	361

Source: Results of the econometric forecast model for which the assumptions and methodology are outlined above in the text in this chapter

4 Chapter 4: Farmers' incomes and food security

The yield drops forecast in Chapter 3 will impinge on the wellbeing of Kenyans by reducing farmers' incomes and food security for both farmers and the general population, in that 90 per cent of the food consumed in Kenya is produced and grown by Kenyan farmers.

This chapter lays out the likely impact on incomes and food security and the consequences in reduced nutrition and health.

4.1 Farmer's income

In forecasting farmers incomes, the value of each crop was gathered from the AFA 2023 yearbook at farmgate prices, with the following exceptions:

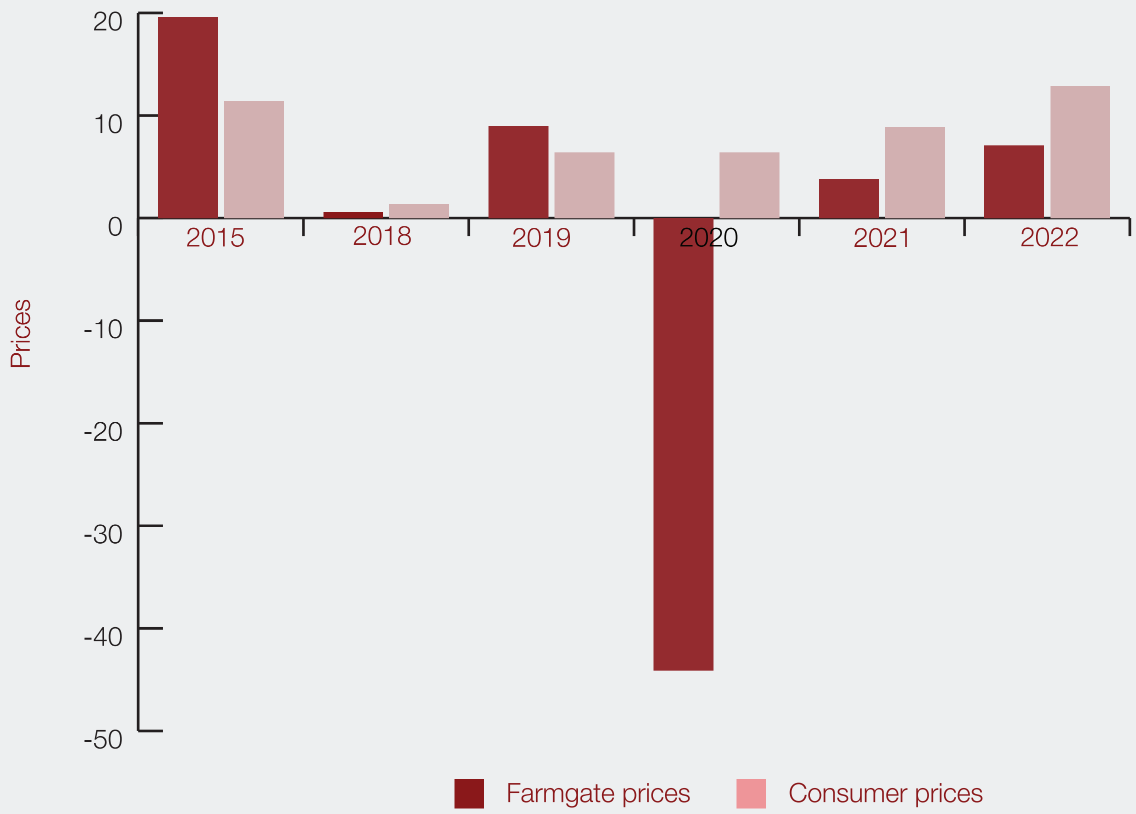
- Coffee, sourced from the Coffee Directorate as the tonnage price;
- Tobacco revenues to farmers, sourced from the World Bank,
- Cucumber revenue, provided by Tridge intelligence
- Cotton prices, estimated from AFA data.

Only tea was valued at greater than farmers' earnings, based on the auction prices for 2022.

The 2022 data was extrapolated to create a base year income for 2024 for the affected crops using the Compound Average Growth Rate (CAGR) of each crop based on its historical performance. However, all forecasts were maintained in constant prices (2022), due to:

- The volatility of farmers' prices, which eroded the degree of certainty for price-based forecasts,
- The likely impact on food prices caused by the impending food shortages, and
- The irregular relationship between rising consumer prices for food, and changes in farmgate prices, as laid out in Figure 13 below

Figure 13 Food price rises to farmers and consumers, 2015 - 2022



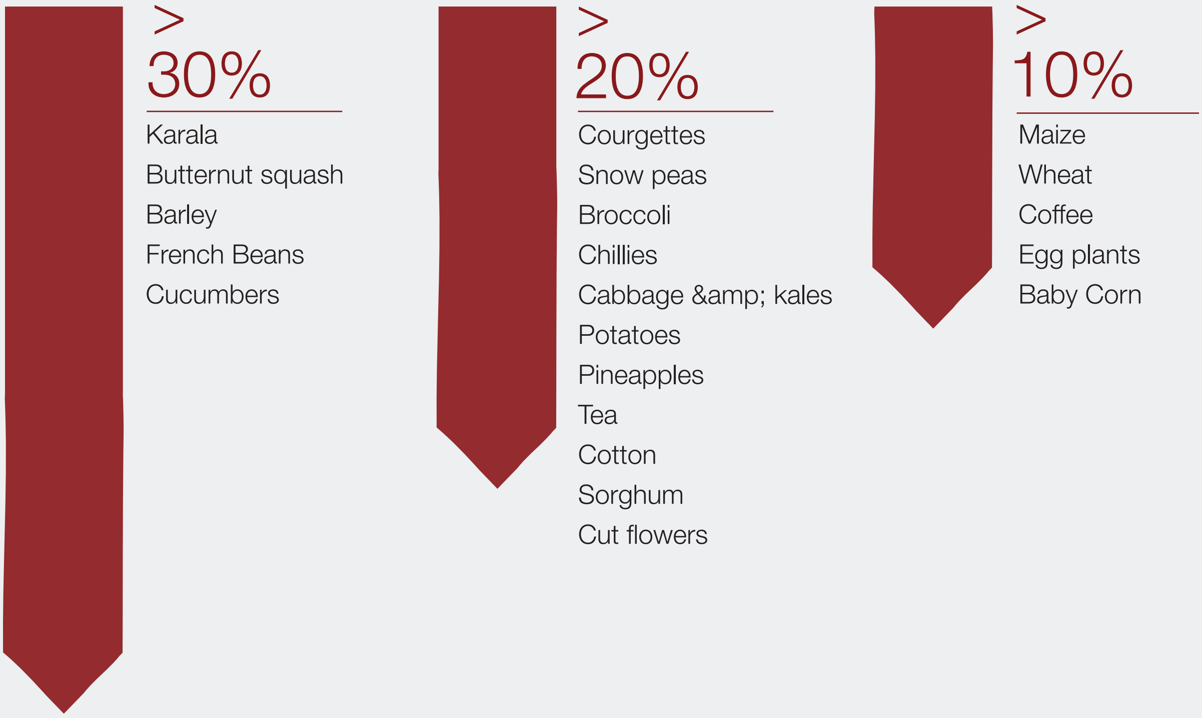
Source: FAO

On this basis, the total estimated fall in farmers' incomes between 2024 and 2025 as a consequence of the reduced yields is 17.6 per cent. This amounts to a total of Sh125bn (Sh124,758 million) in lost incomes, at 2022 prices.

The greater financial loss than volume loss is a consequence of the 'mix' of the crops affected, with a tonne of cut flowers, for instance, worth far more than a tonne of sugar cane. Thus, with the losses mapped crop by crop, versus through any single financial value per tonne for all agricultural output, the financial impact is bound to be different than the volume impact.

In fact, few of the 27 crops analysed maintained their 2024 incomes, but some were far more seriously affected than others, with the spread of percentage declines shown by crop in Figure 14.

Figure 14 Falls in farmer income by severity of crop impact



Source: Results of the econometric forecast model for which the assumptions and methodology are outlined above in the text in Chapters 3-5 of this report

The largest total income losses in 2025 were for cut flower, maize, tea and potato growers, ranging from Sh15bn to Sh37bn per crop, at 2022 prices.

For 18 of the 27 crops analysed, farmers' incomes failed to recover to 2024 levels in the decade ahead. This was the case for all staple foods, with the exception of rice, leading to total losses to farmers incomes, at 2022 prices, of Sh 487.78 billion by 2034. However, this total loss was substantially reduced by gains in rice earnings, and the recovery of earnings for sugarcane from 2026, onions from 2027, and cabbage and kales from 2028.

For staple crops alone, the losses to farmers' incomes from maize, wheat, sorghum and potatoes over the full decade was KSh 504.89 billion, at 2022 prices.

At the same time, a forecast recovery by 2030 in incomes in the flower industry to 2024 levels saw its income losses for the decade reduced to KSh 23bn, but coffee farmers losses accumulated over the decade to exceed KSh 30bn by 2034.

In assessing the significance of these falls, it is worth noting that the starting point for farmers' income is one of extreme vulnerability, with the FAO reporting that 48 per cent of family farms in Kenya are living in poverty. Moreover, the impact on these households is set to be far more severe than indicated by the fall in income alone.

The FAO reports that rural households sell an average 26 per cent of their farm output, but retain 74 per cent. Thus, most small farm produce is used for subsistence. This aligned with the results of our own farmers' survey, which found, for example, that, of maize production:

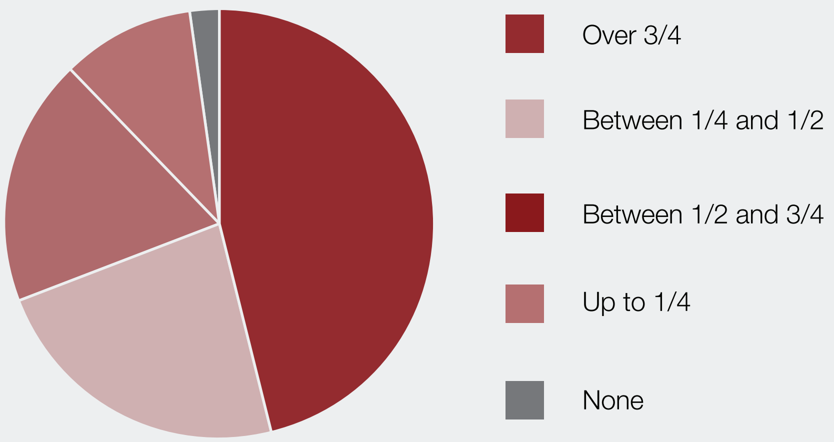
- 2.6% did not grow maize
- 10.1% grew maize and retained it all for household food
- 73.1% per cent grew maize, retained some for home use and sold some
- 14.1% grew maize solely for sale.

We also gathered survey data on how significant retained food was to the family diet and, therefore, to the cost implications raised if its output was reduced.

As shown in Figure 14, 46.2 per cent of the farmers surveyed reported that more than ¾ of their family food came from home-grown crops. Only 10.9 per cent derived ¼ or less from their own crops

Figure 15 Proportion of family food derived from farmers' home-grown crops

How much of your family's food comes from your crops?

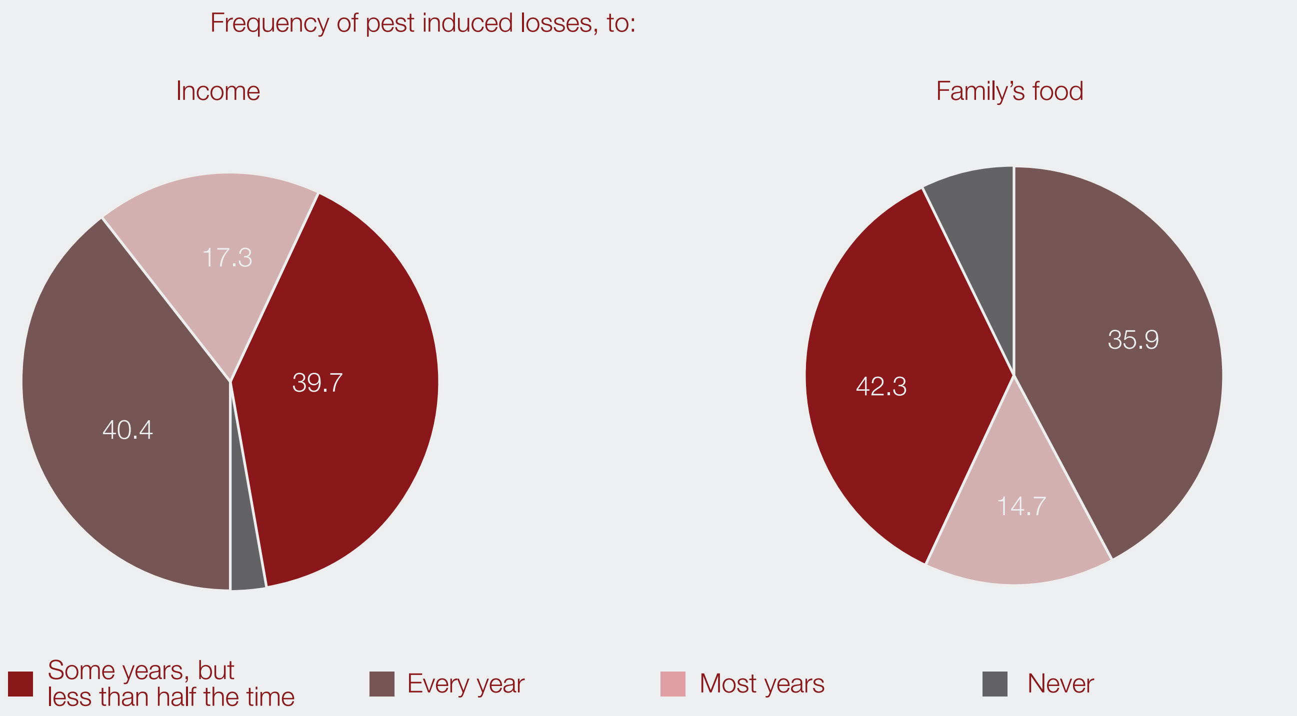


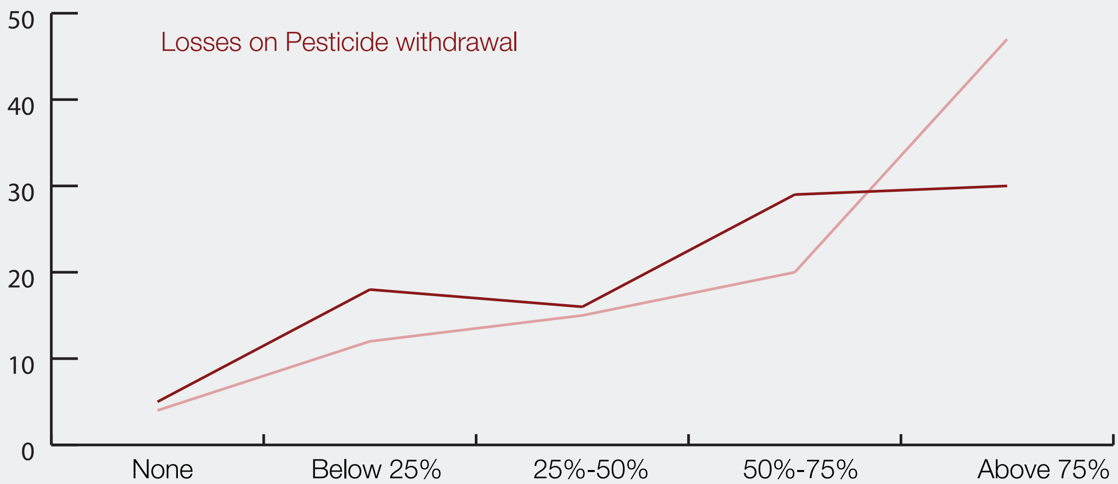
Source: Quantitative survey for this report, detailed in Chapter 1

We, further, investigated differences in the degree of crop protection between crops sold for income and crops retained for the family's food supply. In this, the opening level of whole-farm IPM per crop, such as manual weeding and other controls, was built into our aggregate yield sums.

However, on asking farmers to assess the frequency of losses to their income, and separately to their family's food supply, from pests, farmers reported more losses to sold crops than to retained ones, as shown in Figure 15. This does not reflect a greater usage of pest control on home crops, but a well-documented response in the face of crop losses by small-scale farmers, which sees them consistently reduce the sales of crops on losses, before reducing their own food supply.

Figure 16 Pest impact on sold crops, versus family's food





Source: Quantitative survey for this report, detailed in Chapter 1

The relative positioning of the sold and home crops down the impact curve, in the event of the withdrawal of pesticides, was, likewise, indicative of switching of food from sales to retention,

versus any marked difference in protection levels between the two end uses, on which basis, we concluded:

(i) the modelling of a 17.6 per cent loss in farmers' incomes based on a pro-rata allocation of the yield losses to sold crops was likely to be an underestimate, as families retreat from selling crops in the face of home shortages.

(ii) the financial loss generated by extra family food costs was also likely to be larger than 17.6 per cent, as replacement costs will be at consumer prices rather than farmgate prices, introducing greater costs than those saved by crop switching of around 3.5 percentile points.

In this, FAO data places agricultural value chain income at just over 80 per cent of underlying direct agricultural income, but many farmers will not face food replacement costs at the full value-chain 'mark-up'. However, our sums represent a further conservative assumption.

In calculating the net impact on farmers' incomes of the home crop losses, we applied the family food replacement costs only to crops grown as Kenyan foods, such as cereals, and vegetables, at the rate of loss per crop. We also collected data in our farmers' survey on the retention levels of fruit production, which we modelled into this calculation, finding that only 53 per cent of farmers grew citrus fruit, for instance, but that almost half of these retained all their fruit output for home consumption.

Cut flowers and commodity crops, including tea and coffee, were excluded from the calculation of home food replacement costs, on the assumption they presented no repurchasing needs.

On this basis, with the addition of food replacement costs, the total impact on farmers income of the yield falls is forecast to be Sh308bn in 2025, at 2022 prices, reducing steady state incomes by 43 per cent from 2024.

Over the next decade, the impact on farmers of both lost sales income and new food replacement costs is set to exceed Sh 1 trillion shillings.

4.2 Food insecurity

The volume shortfall in food crops for consumption in Kenya in 2025, according to the yield forecasts presented in Chapter 3, amounts to 2.48m tonnes. At the same time, farmers will be seeking to replace around 4.59m tonnes in lost home production.

This amounts to a total of just over 7m tonnes to be sourced on the open market, or 35.9 per cent of the volumes of the 22 food crops affected that were sold in 2024.

This represents a food shock that will inevitably lead to a steep rise in food prices, either through increased import substitution and associated exchange rate falls, or through excess local demand and shortages.

As the country navigates this, it is noteworthy that it already suffers more severely from food inflation than most other nations in the world, as well as most other African nations. This further speaks to its vulnerability to food disruptions and limited options for price-compatible substitution, as shown in Figure 16, below.

Figure 17 Food price inflation, 2014 to 2022, Kenya, Africa and World

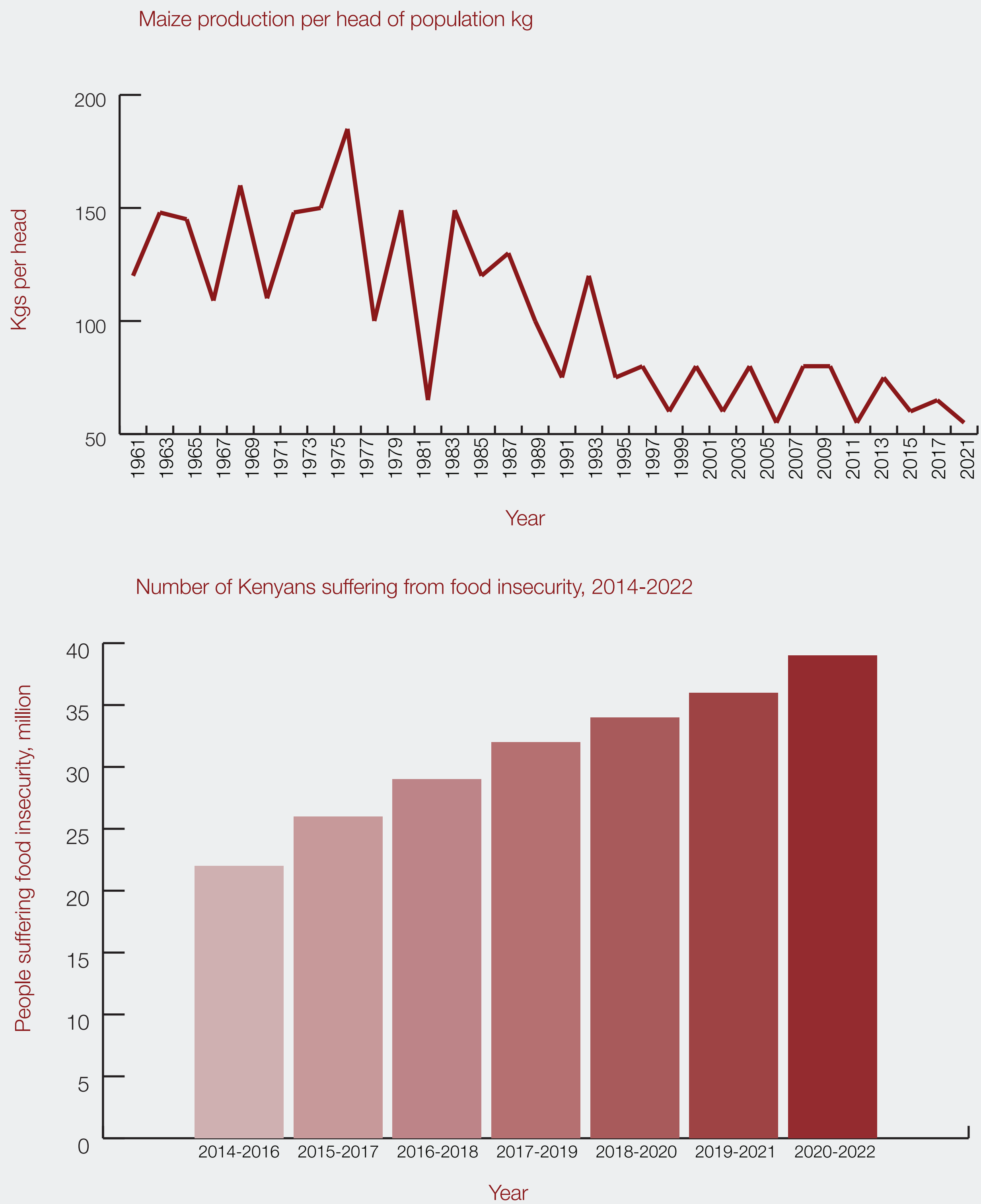
Food price rises	Kenya	Africa	World
2014	8.7	4.4	2.2
2015	11.4	4.7	2.5
2016	10.1	5.2	1.7
2017	13.4	4.7	2.1
2018	1.4	5.2	2.2
2019	6.4	3	2.7
2020	6.4	6.8	3.3
2021	8.9	4.1	3.7
2022	12.9	8.7	10.6

Source: FAO

Increased food prices make food too expensive for many families to afford, thereby exacerbating food insecurity. The food prices triggered by the pest control withdrawals are also set to arrive at a time when Kenya's levels of food insecurity are high. These levels were

exacerbated by the recent East African drought, but were already suffering a long-term upwards trend, driven over the last two decades by the failure of staple food production to keep pace with population growth, as shown in Figure 17.

Figure 18 | Falling maize production per head in Kenya as a driver of rising food insecurity



Source: FAO

To assess the possible scale of this impact, we analysed the country's food balance sheets, which itemise the average number of calories (energy units) Kenyans get from their diet (per person, per day) and from which foods.
By 2021, the average calorie intake per person in Kenya was 2,218 per day. This was substantially lower than the average for Africa, of 2,573 calories per day, as shown in Figure 18.

Figure 19 Kenya's food position relative to the average for Africa

Average dietary energy supply (KCALs per capita per day)

Country	2010	2014	2015	2016	2017	2018	2019	2020	2021
Africa	2571	2585	2578	2564	2572	2575	2578	2580	2573
Kenya	2182	2241	2247	2186	2204	2238	2301	2262	2218

Prevalence of undernourishment (Percent) (Continued)

Country	2000-2002	2004-2006	2009-2011	2015-2017	2016-2018	2017-2019	2018-2020	2019-2021	2020-2022
Kenya	32.3	28.4	21.3	21.5	22.8	22.2	23.0	24.7	27.8
Africa	21.8	19.5	15.9	16.3	16.6	16.7	17.4	18.4	19.3

Source: FAO

To calculate the further impact on the calories available for Kenyans in 2025, and over the decade to 2034, we selected the calories from food balance sheets for the crops affected by the pest control withdrawals. These accounted for 63% of Kenyans' total calories in 2021, as shown in Figure 20.

Figure 20 | Calories consumed in Kenya, per person, per day, by food types, 2018 to 2021

Calories per person per day	2018	2019	2020	2021
Animal fats	19	20	19	18
Cereals - excluding beer	1143	1145	1040	1026
Eggs	5	6	6	5
Fish, sea food	6	6	5	5
Fruits - excluding wine	86	97	105	108
Meat	84	62	55	50
Milk - excluding butter	152	162	158	170
Oilcrops	16	18	16	14
Pulses	142	161	157	131
Starchy roots	159	171	142	131
Sugar and sweeteners	181	210	218	227
Sugar crops	16	12	34	34
Treenuts	6	5	5	4
Vegetable oils	158	158	227	227
Vegetables	33	38	46	42
Total	**2238**	**2301**	**2262**	**2218**
Of which affected foods	1483	1515	1487	1398
Affected foods as percentage of total	66.3	65.8	64.0	63.0
Affected foods without sugar	1293	1301	1202	1144
Staple foods affected				
Maize	694.38	655.4	591.56	532.06
Wheat	286.34	288.88	289.18	348.61
Rice	137.41	132.46	132.98	122.26
Potatoes	56.87	58.44	53.17	55.14
Sorghum	13.73	47.09	17.36	16.11
Calories per person per day	1188.73	1182.27	1084.25	1074.18
Calories per person per day	53.1	51.4	47.9	48.4

Source KNBS and FAO

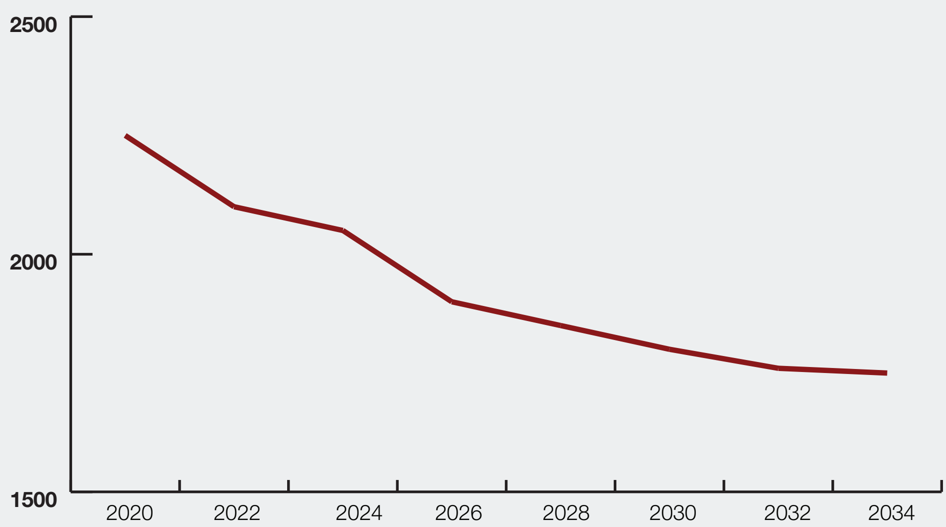
The only assumption in calculating this baseline was for vegetables, with calorie data for specific vegetables only available for potatoes, tomatoes, and onions.

For the single grouping of 'other vegetables', where the calorie contribution was less than 32 calories per person per day, we judged the limitation of being unable to pick out the 10 specifically affected vegetables did not generate a large margin of error, most especially since the affected vegetables included the country's mainstay vegetables, such as cabbage and kales.

Working from the most recent food balance sheet, which is from 2021, we estimated a 2024 baseline by applying the production CAGR of each crop for 2021 to 2024, as well as population growth at the reported rate per year, which was just below 2 per cent a year.
We then produced forecasts for the calories available in the decade ahead, by applying our forecast yield falls and population growth from 2024 to 2034.

The results, assuming all other (unaffected) foods continue to be consumed at the previous level, was a drop in the total calorie consumption of 203 calories per person, or 9 per cent, moving the calories per head from 2,075 in 2024, to 1,872 in 2025, declining to 1767 by 2034, as shown in Figure 20.

Figure 21 Total calories per person in Kenya, estimated 2024, forecast for 2025 - 2034



Source: Econometric model for this report, for which the methods and assumptions are given in Chapters 3 to 5

This step-fall represents a perilous drop, in an era when the calories per head are anyway suffering a systemic decline. More worryingly still, it would move Kenya to 27 per cent below the average calorie per person in Africa in 2025, from 13.8 per cent in 2021.

By 2034, that gap will have widened to 31.3 per cent, and Kenya would be reporting the lowest calorie count per person in the world at 1767, approached only by Burundi at 1775, and the Central African Republic at 1785.

This will deliver further deterioration to Kenya's current position, with one of the highest proportions of population undernourished in the world, at 27.8 per cent from 2020 to 2022. Only 20 countries of 192 for which data is compiled had a higher proportion of malnourishment over this period.

4.3 Health impacts

In assessing the value of the withdrawals for Kenyans, one of the two declared gains was in the health of Kenyans. However, adequate food supplies are critical to human health, and scant attention has been directed towards the health implications of increased food insecurity. This is important in a policy context, as, without measuring the net health impact of the changes, it is possible new policies might lead to many times more mortalities than they save.

In this context, it is well understood that short-term or acute famine causes mortalities, as well as plummeting immunity and a surge in 'lifestyle' diseases, such as heart attacks and strokes.

However, as Kenya moves to implement the regulatory decisions in 2025, it will also create a tail of long-term health consequences.

As in many study reports, short-term famine is associated with increased life-long risks of cancer, with a review of studies of over 6m participants finding that adolescents exposed to famine had a 76 per cent greater chance of developing cancer over their lifetimes. Early-life exposure, at under 10 years of age, also raised cancer risks significantly, lifting the cases of later breast cancer by 9 per cent and of stomach cancer by 89 per cent. While, in very young children, severe calorie deficits more than doubled the risk of cancer later in life.

Famine has also been linked to highly reported fourth and fifth most prevalent cancers in Kenya, esophageal and colorectal cancers, which account for around 4,500 deaths a year, as well as liver cancer, particularly in men.

Nor is the sharp rise in cancer cases caused by malnourishment confined to the born, with studies showing that both prenatal famine exposure and subsequent calorie deficits cause biochemical and DNA changes that increase lifetime cancers.

Many studies have similarly documented the far greater levels of diabetes among populations exposed to famine. Exposure in infancy and early childhood has consistently been found to increase diabetes by over 75 per cent in men and over 55 per cent in women.

Likewise, severe calorie deficits increase the incidence of heart disease and high blood pressure in the generation exposed and in the subsequent generation. For instance, any famine exposure of at least 10 weeks during gestation has been found to increase hypertension for the unborn child at 59 years old by 44 per cent.

Calorie deficits also have other, more immediate effects. A 1945 experiment that put 36 men onto a 1,800 calorie diet for six months found they developed 'semi-starvation neurosis', marked by depression, nervousness, social withdrawal, anaemia, fatigue, apathy, extreme weakness, irritability, neurological defects, edema, loss of sexual interest and inability to concentrate.

This calorie deficit is not as great as the deficit now predicted for Kenyans from 2025, while the symptoms of this 'semi starvation neurosis' are nowadays widely documented as the outcomes from the micronutrient deficiencies that arise alongside calorie deficits.

In considering the prevailing levels of these micronutrient deficiencies, Kenya last undertook a national survey of the micronutrient status of the country's population in 2011. At that time, Kenyans were already suffering widely from iron deficiencies, iron-deficiency anaemia, folate, vitamin B_{12}, zinc and vitamin A deficiencies, as shown in Figure 21.

Figure 22 Micronutrient deficiencies in Kenya

Indicators	National prevalence			
	n	%	95%CI	
Iron deficiency ((Based on age specific serum ferritin cut offs. Serum ferritin corrected for inflammations				
Pre-school children	918	21.8	19.1	24.5
School age children	942	9.4	7.5	11.3
Pregnant women	111	36.1	27.2	45.0
Non pregnant women	633	21.3	18.11	24.49
Men	247	3.6	1.28	5.92

Iron deficiency ((Based on age specific serum ferritin cut offs. Serum ferritin corrected for inflammations				
Pre-school children	827	13.3	11.0	15.6
School age children	942	4.9	3.5	6.3
Pregnant women	104	26.0	17.6	34.4
Non pregnant women	592	14.0	11.20	16.80
Men	243	2.9	0.79	5.01
Folate deficiency				
Pregnant women	78	32.1	21.7	42.5
Non-pregnant women	445	30.9	26.6	35.2
Vitamin B_{12} Deficiency				
Pregnant women	78	7.7	1.8	13.6
Non-pregnant women	445	34.7	30.3	39.1
Zinc Deficiency (Serum zinc corrected for inflammation)				
Pre-school children	711	81.6	78.8	84.5
School age children	901	79.0	76.3	81.7
Pregnant women	109	67.9	59.1	76.7
Non pregnant women	617	79.9	76.7	83.1
Men	239	77.4	72.1	82.7

2011 results:
Severe Vitamin A deficiency in 4.5 per cent of the population and 9.2 per cent for preschool children.

Sarginal vitamin A deficiency in 24.2 per cent of the population, and 52.6 per cent of pre-school aged children.

However, iron, folate, B and zinc deficiencies all drive anaemia, which means that while no micronutrient survey has been published since 2011, the records on anaemia levels in the country can give a strong indication on how these levels of deficiencies might have changed.

In fact, by 2019, anaemia levels were higher in Kenya than in 2011, having risen in preschool children from 39 per cent in 2011 to 43 per cent in 2019, as shown in Figure 22.

Figure 23 Prevalence of anaemia among children (% of children ages 6 - 59 months) - Kenya

Source: https://data.worldbank.org/indicator/SH.ANM.CHLD.ZS?locations=KE

In understanding where the micronutrient impact of the new food shock might be greatest, we analysed the micro nutritional impact of just three of the affected crops: kale, tomatoes and onions.

The fall in onion production is likely to have a fairly limited impact on the country's headline micronutrient deficits, but kale and tomatoes together account for almost all the recommended daily intake of Vitamin A. The average consumption of tomatoes and kale was providing 102.63% of the Recommended Daily Intake for Vitamin A.. But the production cuts will remove 59.31% of the RDI from these sources, meaning that where Kenyans were, on average, consuming at or around their Vitamin A needs from tomatoes and sukuma wiki, they will now be getting an average of 43.32% of the daily vitamin A needed from these two sources.

Vitamin A is essential to human immunity. The World Health Organisation data given in Kenya's Micronutrient Survey indicates that Vitamin A deficiencies increase the mortality from measles by about 50 per cent, deaths from diarrhoea by 40 per cent, and malaria cases by 30 per cent, increasing deaths from all causes by 23 per cent.

It is, therefore, the case that the reductions in the nation's key sources of vitamin A are likely to lead to many thousands of additional deaths.

Similarly, in our analysis of kale and tomatoes, the falls in output remove 7.5% of the RDI for iron, suggesting further increases in anaemia.

anaemia is the leading cause of child mortality in Africa, responsible for up to 18 per cent of under-5 mortality: a step-rise in iron deficiency will also cause thousands of additional mortalities, and through multiple pathways, including but not limited to increased childbirth complications, and increased vulnerability to infections for all age groups.

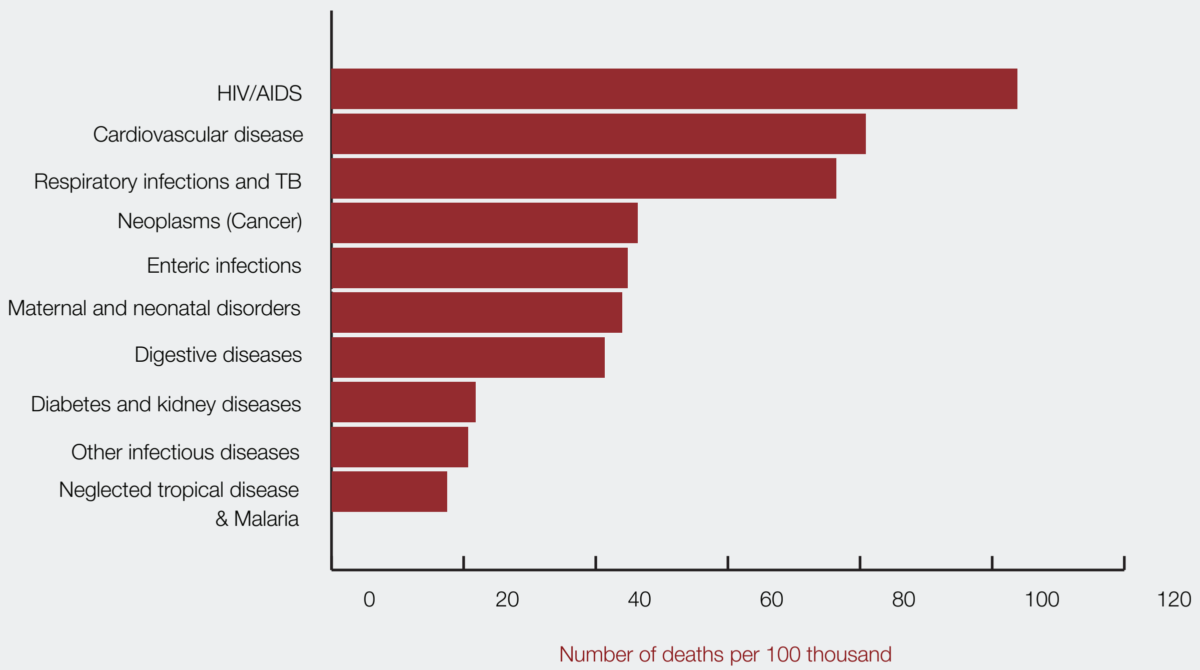
In addition, iron-deficiency causes developmental delays in children, and has been shown to decrease intelligence permanently. Infants with iron-deficiency anaemia score 6 per cent to 15 per cent lower in intelligence tests, while children with insufficient iron are three times less likely to finish secondary school. The deficiency causes difficulty focusing, lethargy and impaired social competence. Studies have additionally found that:

- Children stunted by micronutrient deficiencies at 2 years old, remain shorter, and have permanently reduced kidney size and reduced lung functions.
  Iron-sufficient infants have more than twice (2.29 times) the coordination skills of infants with iron-deficient anaemia.
- Adults who were iron-deficient in childhood are unhappier and tend towards negative thinking and depression.
- Stunted children have greater behavioural difficulties later in life, poorer social skills, and impaired relationships.
- Iron-deficient children are four times more likely to remain single in adulthood, and more than three times more likely to raise children as single parents.
- Anaemia is estimated to lower productivity in heavy manual labour by 17% and cause 2.5% loss of earnings due to lower cognitive skills.

Thus, a direct consequence of the new constraints on the country's food supply will be reduced energy and productivity across all age groups.

Our examination of the impact of the withdrawals on food security and on health have not been sufficient to generate forecasts for the number of Kenyan lives that will be prematurely ended or permanently depleted by the contraction of pest control in food production. But taken together, the relationships examined and the data laid out in this section demonstrate that the withdrawals are set to exacerbate nine out of the ten top causes of deaths in Kenya, and potentially all ten, as laid out in Figure 23.

Figure 24 Main causes of deaths in Kenya as of 2019



5 Chapter 5: Economic Impacts

Agricultural output accounts for 21.17 per cent of Kenya's GDP in 2022. It contributes through domestic income on agricultural production, earnings from the agricultural value chain of traders, logistics, processors and retailers, and through its contribution to the trade balance through agricultural exports.

All of these areas are set to be undermined in 2025 by the forecast drop in agricultural production.

The reduction of 17.6 per cent in farmers incomes on sold produce, Gross National Income (GNI) will be reduced by 3.3 per cent according to the econometric modelling produced for this report, which is calculated at 2022 constant prices and based on the same GDP structure as reported in 2022.

The FAO further estimates the earnings along the agricultural value chain at approximately 80 per cent of base agricultural incomes, taking the direct cut to 6.0 per cent once the impact on retail, wholesale, logistics and other domestic incomes are added.

The pressure of farmers seeking to replace lost home-produced food is also likely to have a very significant impact on domestic earnings, seeing funds diverted from multiple domestic sectors, such as telecoms, education, and furniture making. However, we have not modelled the impact on consumption spending.

Nor have we modelled the lost productivity from rising iron deficiency, or the income, consumption and government spending implications of the rise in morbidities and mortalities.

However, bearing in mind the impact of all these factors, we expect that the impact on GNI will be significantly higher than 6 per cent.

5.1 Food imports

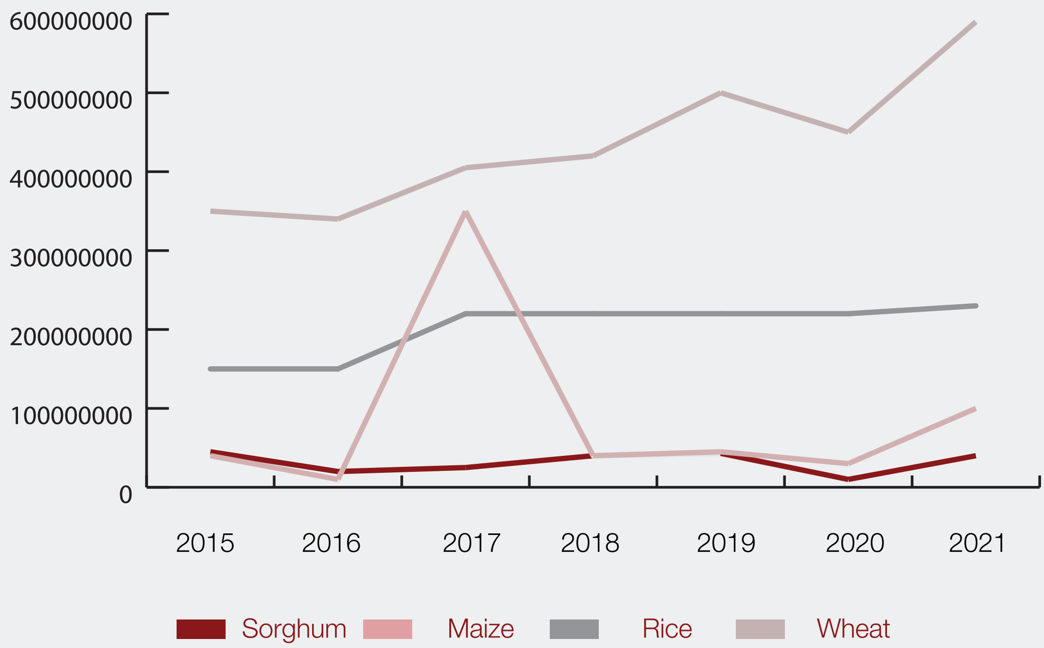
The impact on Kenya's trade balance is also set to be significant. As shown in Figure 24, maize imports rose sharply in 2017 when the Fall Armyworm reduced production by an estimated 37 per cent. This invasion affected both home production and sold production, causing a rise in maize imports from $9.5m in 2016 to $342.3m in 2017.

In tonnage, the jump in maize imports represented a tonnage increase of 1.1m tonnes, which is equivalent to around 37 per cent of the sold volume of maize in Kenya. This indicates that replacement supplies were imported for the approximately one quarter of maize that farmers

sell, but the country did not import replacement maize to cover the loss in the three-quarters of maize that is home-retained.

It is highly probable, therefore, that the costs of the losses to home production will be borne in reduced calories and increased food insecurity.

Figure 25 Staple food imports to Kenya 2015 to 2021

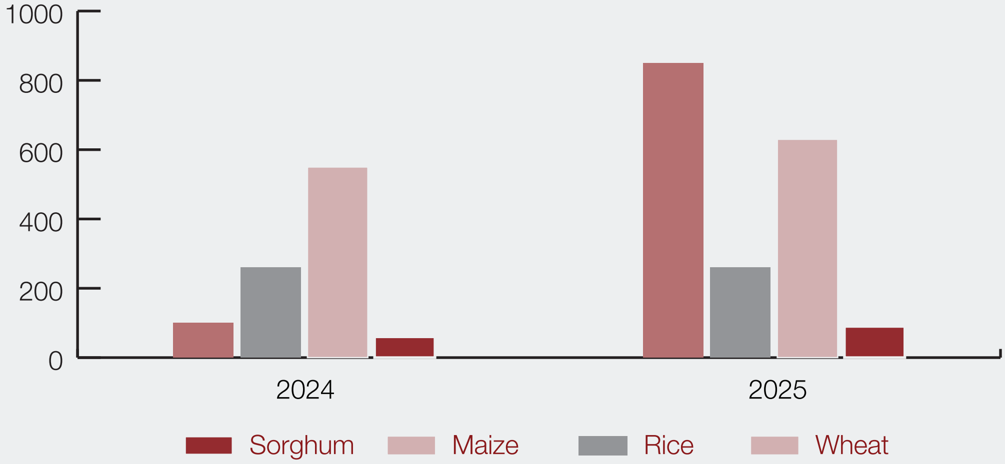


Source: WITS World integrated Trade Solution

On this basis, the modelled result of the 15.1 per cent predicted fall in maize production in 2025, will be an additional Sh22bn of imports at the January to June 2024 exchange rate of around Sh130 to the $, or an addition of $175m to maize imports.

Were the imports to span the shortfall in home production too, the import addition to cover the shortfalls in staple foods would equate to $881m, as shown in Figure 25.

Figure 26 Change to food imports for full crop loss replacement, 2025



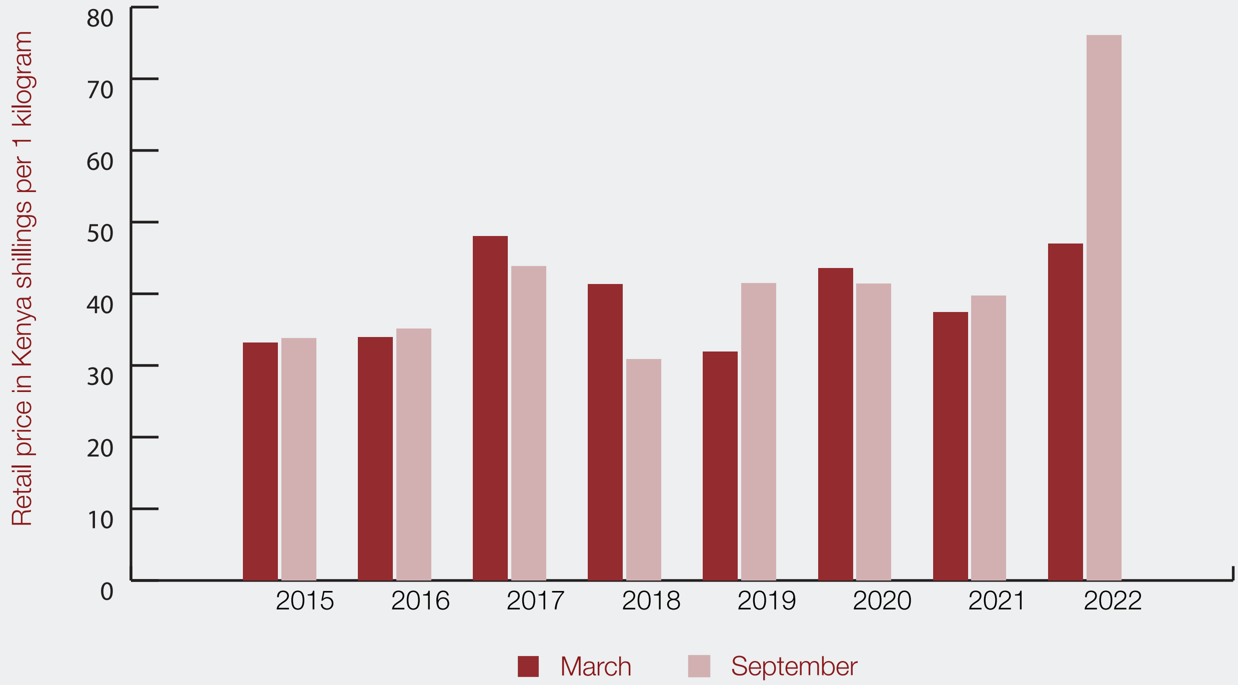
Source: the cost of full replacement of the volume declines forecast for each crop, at 2022 import prices

Instead, we have assumed from the 2017 pattern that only sold crops will be import-substituted, with a replacement cost at 2022 prices across all four staple food crops of $211m. We would also expect to see some rise in kale and tomato imports from neighbouring countries, which we have not factored in.

We would expect the remainder of the increase in demand for maize to be resolved through local shortages and rising maize prices, meaning lower income groups who have lost home crops will be excluded from the replacement marketplace. This was the case in 2017, as shown in Figure 26, when the lack of import substitution for home-retained maize delivered a 41.7 per cent increase in maize prices in March 2017 versus March 2016.

However, with local prices for maize currently at exceptionally high levels, the pressure to import versus partial import substitution and partial price exclusion will be greater in 2025 than it was in 2017.

Figure 27 Average retail market price of maize in Kenya from 2015 - 2022 (in Kenya shillings per 1 kg)



Source: Statistica

URL for designer to embed: https://www.statista.com/statistics/1170182/average-retail-price-of-maize-in-kenya/

5.2 Food exports

Four out of Kenya's five largest exports are agricultural exports that will be affected by the pest control withdrawals, being tea, flowers, coffee, and tropical fruits. The country's horticultural and vegetable exports are also substantial. The estimated harvest impact on the export crops affected is given in Figure 27, totalling $492.7m - or 19.3 per cent of their estimated 2024 earnings of $2.552bn.

Figure 28 Affected export crops and changes in US Dollar earnings at 2022 prices

	2022	CAGR - 2024	2024 (est)	Year 1 loss %	Year 1 loss $	2025
Exports						
Flowers	625,674,960	1.05	689,806,643	0.761	-138,616,645	551,189,998
Coffee	314,766,430	1.006	318,744,980	0.882	-35,840,769	282,904,211
Tea	1,348,442,550	1.026	1,419,473,110	0.77	-298,060,964	1,121,412,146
Tobacco	6,898,990	1.027	7,270,898	0.904	-523,167	6,747,730
Potatoes	3,973,000	1.014	4,085,023	0.773	-883,092	3,201,931
Tomatoes	1,958,000	1.006	1,979,991	0.715	-556,370	1,423,621

	2022	CAGR - 2024	2024 (est)	Year 1 loss %	Year 1 loss $	2025
Exports						
French beans	34,042,553	1.006	34,452,289	0.684	-10,745,531	23,706,758
Onions	725,000	1.034	775,138	0.922	-36,162	738,976
Egg plants	713,000	1.134	916,887	0.744	-143,313	773,574
Broccoli	7,206,710	0.851	5,219,107	0.913	-1,164,054	4,055,053
Snowpeas	8,510,638	1.001	8,525,964	0.761	-2,031,866	6,494,098
Baby corn	3,310,638	1.267	5,314,531	0.894	705,228	6,019,758
Pineapples	16,999,000	0.9464	15,225,545	0.835	-3,193,649	12,031,895
Citrus	36,739,986	1.052	40,652,560	0.913	-1,610,463	39,042,096
Total	2,409,961,455	1.006	2,552,442,664			2,059,741,847

Source: Report's econometric model, based on yield falls as outlined in Chapter 3

The largest losses will be in the exports of tea, flowers, coffee, french beans, pineapples, snow peas, citrus fruits, and broccoli. Only baby corn will earn more than in 2024, based on its trending CAGR, which is greater than the anticipated loss of output due to the withdrawn pest controls.

More than half of the 14 export crops affected will fail to restore their 2024 earnings by 2034, being tea, coffee, french beans, pineapples, snow peas, broccoli, potatoes, and tomatoes, which are estimated to have earnt $1.81bn in 2024, accounting for 70.9 per cent of the export value of the affected crops.

The losses from these exports are expected to exceed $2bn, at 2022 prices, over the decade ahead, based on the output changes forecast and given in Figure 12 in Chapter 3 on yield impacts. These total losses, however, will be offset by the ongoing growth in baby corn, and

resumed growth in citrus fruit exports from 2026, eggplant and onion exports from 2027, tobacco from 2028 and flowers from 2030.

The growth later in the decade in the exports of these crops will reduce the total losses in export income to 2034 to $1.77bn or Sh230bn, as shown in Figure 28.

Figure 29

Projected export earnings per affected crop, 2024 - 2034
(Darker shades indicate the year in which 2024 earnings are restored)

	2022	2024(est)	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	
Exports													
Flowers	625,674,960	689,806,643	551,189,998	578,749,498	607,686,973	638,071,322	669,974,888	703,473,632	738,647,314	775,579,680	814,358,664	855,076,597	
Coffee	314,766,430	318,744,980	282,904,211	284,686,507	286,480,032	288,284,857	290,101,051	291,928,688	293,767,838	295,618,576	297,480,973	299,355,103	
Tea	1,348,442,550	1,419,473,110	1,121,412,146	1,150,568,862	1,180,483,652	1,211,176,227	1,242,665,809	1,274,976,146	1,306,125,526	1,342,136,790	1,377,032,346	1,412,835,187	
Tobacco	6,898,990	7,270,898	6,747,730	6,927,220	7,111,484	7,300,650	7,494,847	7,694,210	7,898,876	8,108,986	8,324,685	8,546,122	
Potatoes	3,973,000	4,085,023	3,201,931	3,246,758	3,292,212	3,338,303	3,385,040	3,432,430	3,480,484	3,529,211	3,578,620	3,628,721	
Tomatoes	1,958,000	1,979,991	1,423,621	1,431,594	1,439,611	1447672.476	1,455,779	1,463,932	1,472,130	1,480,374	1,488,664	1,497,000	
French beans	34,042,553	34,452,289	23,706,758	23,848,999	23,992,093	24,136,045	24,280,861	24,426,547	24,573,106	24,720,544	24,868,868	25,018,081	
Onions	725,000	775,138	738,976	764,102	790,081	816,944	844,720	873,440	903,137	933,844	965,595	998,425	
Egg plants	713,000	916,887	773,574	877,232	994782	1,128,082	1,279,245	1,450,654	1,645,053	1,855,490	2,115,466	2,308,939	
Broccoli	7,206,710	5,219,107	4,055,053	3,450,850	2,936,673	2,499,109	2,126,742	1,809,857	1,540,188	1,310,700	1,115,406	949,211	
Snowpeas	8,510,638	8,525,964	6,494,098	6,499,943	6,505,793	6,511,648	6,517,508	6,523,374	6,529,245	6,536,122	6,541,003	6,545,890	
Baby corn	3,310,638	5,314,531	6,019,758	7,627,034	9,663,452	12,243,594	15,512,633	19,654,506	24,902,259	31,551,162	39,975,323	50,648,734	
Pineapples	16,999,000	15,225,545	12,031,895	11386985.72	10,776,643	10,199,015	9,652,348	9,134,982	8,645,347	8,181,956	7,743,404	7,328,357	
Citrus	36,739,986	40,652,560	39,042,096	41,068,381	43,199,830	45,441,901	47,800,336	50,281,173	52,890,766	55,635,797	58,523,295	61,560,654	
Total	2,409,961,455	2,552,442,664	2,059,741,847	2,121,133,965	2,185,353,311	2,252,595,369	2,323,092,808	2,397,123,582	2,475,021,271	2,557,188,233	2,644,112,310	2,736,385,020	

However, the outcome of the withdrawals is unlikely to be as positive as this, due to the nature of the pests on which the pest controls have been withdrawn.

Almost all the insects, fungi and plant diseases affected by the withdrawal of the four insecticides and two fungicides are on the European Union's quarantine pest list, as laid out in Figure 29.

Figure 30

EU Quarantine pest: Affected by the bans

Thrips
Coffee Berry Borer
Wireworms
Chafer Grubs
Fall Armyworm
Wheat Leaf Rust
Termites
Ants
Downey Mildew
Powdery Mildew
Cucumber leaf spot

Anthracnose
Botrytis
Cabbage leaf spot
Club Root
Black Leg

White fly vector viruses affecting aubergines and chillies:
Tomato Yellowleaf Curl Virus (TYLCV)
Tomato Chlorosis Virus (TCV)

Source: https://sitesv2.anses.fr/en/minisite/insects-and-mites/list-eu-quarantine-pests

Any crop found to be infested with a quarantine pest will be refused entry into the EU, which is Kenya's principal export market for agricultural crops.

Moreover, when spot testing of consignments generates repeated notifications of a quarantine pest, a crop will quickly be put onto a more rigorous testing regime, for instance, moving to the testing of 10 per cent of all consignments. This generates additional costs for exporters and acts as a strong deterrent to exporting by reducing exporters' earnings.

Currently, cut flower exports are already being affected by increases in notifications, due to the repeated presence of the False Codling Moth.

If a quarantine pest is found in repeated consignments, it is eventually banned.

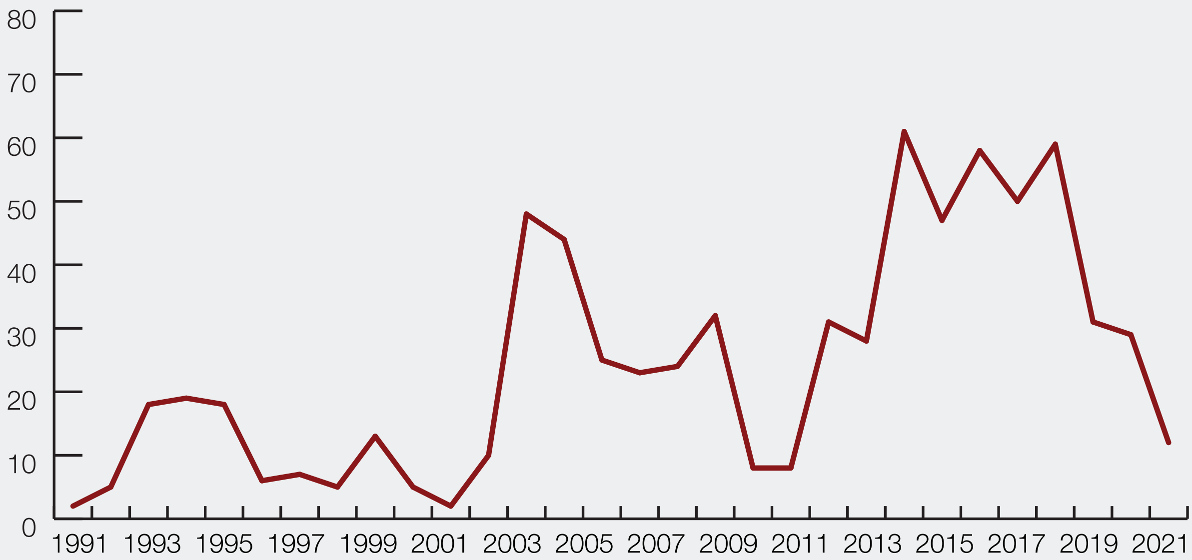
The coincidental alignment of the pest control withdrawals with the EU's quarantine pest lists means that many exporters face reduced output due to these pests, while also facing the destruction of export consignments and potential loss of market if they cannot completely eliminate the same pest.

This has created a series of crops where exports are set to be far more severely reduced, including coffee, where Kenyan coffee growers were largely protected from coffee berry borer due to their high altitude of growth, but are now dealing with widespread infestations.

For tea producers, the withdrawal of the same insecticide that was being used for coffee berry borer has removed their only registered protection against the quarantine pest of termites. Indeed, tea has lost the remaining synthetic control for two of its top pests, as tea aphids and termites, with infestation levels of 40 per cent and higher across Kenyan tea crops. Much work has been done to find alternative biological controls, but the progress towards the complete eradication of termites in tea has been limited, setting up substantial risks of further notifications.

A series of further export crops face no realistic future following the withdrawals. These include cucumbers and gherkins, the exports of which had been growing very rapidly, But the control of three quarantined diseases is now being closed down to one fungicide, which was reported as facing resistance of as much as 48 per cent in test research by 2021. Of these diseases, leaf spot is present in 95 per cent of cucumbers grown in Kenya. There are no IPM strategies available to tackle these diseases, with their levels of crop destruction and prevalence in Kenya shown in Figure 30.

Figure 31 Cucumber exports, and quarantine pests



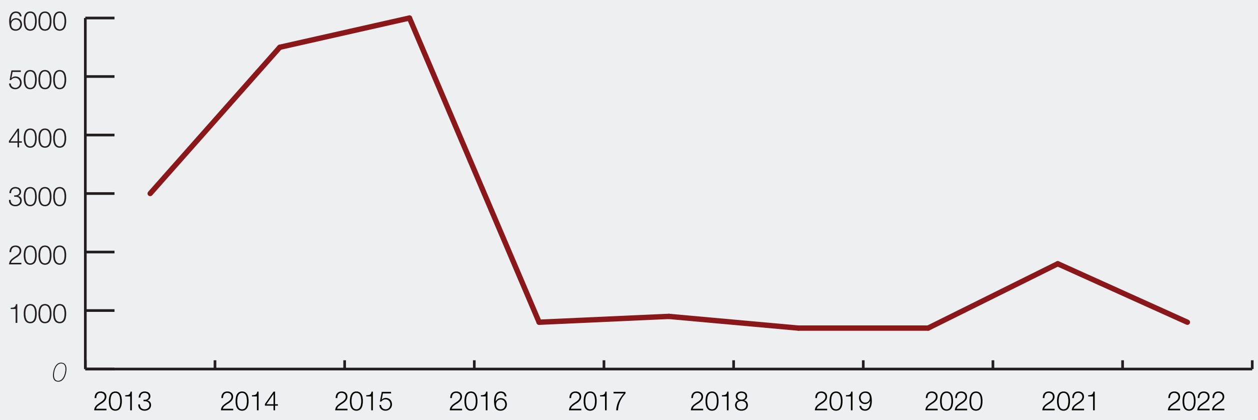
Downy mildew	40			30	12
Powdery mildew Leafspot	Mid-point yield impact%	Upper yield impact%	Lower yield impact%	Current Prevalence	Simple impact on no control
Anthracnose	60	75	30	40	24

Sources: export data, World Bank WITS, pest impact data, econometric model for this report, based on 8 literature reviews on the impact of each pest in cucurbits, and on the prevalence of each pest on cucurbits in Kenya

Other crops with a similarly curtailed future include egg plants. Our forecasting model based on historical market growth versus crop destruction and resistance, featured egg plants as an early recovery. But with all the registered synthetic controls removed for the plant for the quarantine pest thrips, which affects around 50 per cent of Kenyan egg plant growers, as well as for whiteflies and aphids, the impact on notifications and thus export processing is set to be severe.

The export of chillies, which had already declined precipitously on quarantine issues, also now faces no likely future, with a host of pest controls removed, after more than 100 exporters had been reduced to no more than a handful, albeit still exporting $896,000 of chillies in 2022.

Figure 32 Exports of chillies



Source: WITS

Another export casualty is set to be snow peas, due to botrytis, for which there is only one remaining control facing genetic mutations and rising resistance.

Botrytis is reported to destroy around 15 per cent of a snow pea crop when uncontrolled and is found in about 70 per cent of snow pea farms in Kenya. For this reason, it was factored in, alongside the efficacy of the remaining registered fungicide, at a 7.1 per cent reduction in the crop.

However, in a situation of rising resistance against the remaining fungicide combined with consequent quarantine notifications, the impact is likely to be far more severe, and amounts to another serious loss, at $8.5m, or approximately Sh1 trillion of export earnings in 2022.

Where export crops are now unlikely to be able to satisfactorily navigate the control of quarantine pests, there is likely to be a time lag as notifications begin to accrue, before triggering progressive barriers. However, for coffee, aubergine and snow pea exports, their continuation, in the face of the pest control withdrawals in combination with the EU's quarantine lists, will rest on the rapid development of new and widely adapted biological controls for these pests.

In the absence of those new alternatives, the losses on the current withdrawals rise to an estimated $11bn or Sh1.43 trillion in the decade to 2034.

5.3 GDP

Based on the assumptions outlined above, all of which have been calculated conservatively, we expect the pest control withdrawals to reduce Kenyan GDP in 2025 by 7.28 per cent.

This per centage reduction in GDP is at 2022 prices. based on the change from GDP estimates for 2024, in 2022 prices, to the level of 2025 at GDP prices. This change is driven by the fall in Gross National Income outlined above, the increase in exports, and the fall in exports, also outlined above in this chapter..

6 Chapter 6: Policy Issues

This chapter reviews the policy issues raised by the withdrawals, covering the existing and implied regulatory framework, the assessment of their impact, their implementation and their alignment with Kenya's overarching policy priorities.

6.1 The regulatory framework

Kenya's eight pest control product withdrawals were announced against the backdrop of an ongoing global dispute over the best methodology for regulating pesticides. But for all regulators, the aim of the methodology for pest control regulation is to secure the highest levels of human and environmental wellbeing.

As covered in Chapter 2, on this basis, the international system is based on risk assessment. It first assesses hazards that are caused by a chemical, across a range of approximately 100 measures, spanning from human skin irritation to aquatic life. It then studies the exposure to that chemical by farmers and workers, consumers (typically through food and water), the environment and all life forms.

Regulators combine this information to determine whether the use of the chemical presents any 'risks of concern'. If it does not, it may be registered for use and the hazard assessment information is used to determine the usage instructions for the chemicals, and the maximum residue levels (remaining on any crops) that must be observed when using these chemicals.

These levels can be set individually by countries and are also set by the World Health Organisation and the United Nations' Food and Agricultural Organisation through the CODEX Committee on Pesticide Residues. No country is bound by the levels set internationally and every country has sovereignty over the MRLS that it sets.

Kenya is committed to applying the principles of risk assessments in approval of pest control products taking into consideration the necessary data for adopting internationally determined MRLs..

In 2007, the European Union overhauled its legislation on pesticide regulation. It still terms its system risk assessment, but now uses the word 'risk' as a term to describe a hazard. This means, for example, that it may see an effect at levels that are never reached in practice, which is a hazard, but it deems this a risk. This distinction is explained in Chapter 2 with reference to the consumption of almonds, which contain cyanide that is deadly at high levels, but which are not themselves toxic and present no risk.

However, the greatest departure in the EU system is the use of the 'precautionary principle'. Under this principle, there need be no evidence of a risk, but the information may not be sufficient, or there may exist a notional possibility of future hazard and even risk that has not been, and frequently cannot be, scientifically disproven. This precautionary principle is now frequently used by the EU where there is no evidence a hazard exists, prompting the chemical's withdrawal.

This has created a disjuncture between scientific evidence and the EU's policies on pest control registrations, which has prompted vigorous global disputes and multiple trade disputes. Many countries, including Kenya, protest that this move away from evidence-based decision making is breaching world trade rules as a technical trade barrier.

In Kenya, pesticide regulation uses the international risk assessment methodology as the basis for its regulatory approval of pest control products. In policy terms, the country remains committed to this methodology. In one of many long-term disputes with the EU through the World Trade Organisation concerning the EU's pest control technical trade barriers, Kenya's representative to the WTO issued a statement in March 2023, stating

Kenya reaffirms that the risk-based approach is the international best practice and meets the objective pursued. The EU's adoption of a hazard-based system could create unnecessary obstacles to trade.

Against this backdrop, five of the eight pest control withdrawals announced in 2023 - Acephate, Chlorothalonil, Chlorpyrifos, Pymetrozine, Thiacloprid, Chlorothalonil - are active ingredients that have been withdrawn within the European Union under the precautionary principle, but classified as being without risks of concern by the Environmental Protection Agency in the US. A sixth, Propineb, was never registered in the US, but has also been banned in the EU under the precautionary principle. All six have been banned in Kenya on trade grounds.A further trade-based ban, of 2-4D, isapproved for use in both the US and EU. None of these seven active ingredients has ever been identified as raising any risk of concern in regulatory risk assessments examining human and animal health risks and environmental risk.

In this regard, Kenya's pest control product regulatory decisions in 2023 seem to have focused on pressure to comply with trade demands from markets where Kenya's produce is sold as exports without due consideration of the pest pressure and use of the products on other produce consumed locally. An alternative solution would have been to focus, instead, on the mitigation measures available to manage the exceedance of specific country MRLs.

Instead, the effective introduction by Kenya of trade barriers as an entirely new criteria for pesticide regulation, has seen withdrawals driven by the EU's changed policies through their impact on the trade of agricultural exports with the EU. This represents a departure from Kenya's statements to the WTO and its previous regulatory position, which has not been adopted via any process of public consultation, parliamentary consultation, white paper, or any existing legislative, regulatory or policy process.
This is made all the more significant by the scale of the impact of this policy shift.

Our analysis identified the withdrawal of the insecticide Thiacloprid as the main driver of multiple export crop losses, particularly of horticultural crops such as chillies and egg plants.

More grave, however, are the costs ahead as a result of the withdrawal of the widely used fungicide Chlorothalonil. This fungicide is a multi-site fungicide, which means it operates through multiple mechanisms and is, therefore, not prone to resistance. It raises no 'risks of concern' in risk-based assessments and is one of the most widely used fungicides in the world, due to its efficacy.

It is the withdrawal of this fungicide, Chlorothalonil, that is set to do the most harm to the country's domestic wheat production. Its withdrawal will open up new and considerable vulnerabilities to late and early blight for both tomatoes and potatoes, thus setting up a double strike for Kenya's staple foods.

It has also removed the only protection registered in Kenya for club root in cabbages and kales, and reduced the protection significantly for snow peas, setting up a serious barrier to their future successful exporting, as well as largely disabling the production of cucumbers and butternut squashes.

Therefore, the move to withdraw pest control products based on the non-evidence-based precautionary principle, which Kenya previously rejected, is set to have very serious consequences for its agricultural output.

The withdrawal of Chlorpyrifos is, likewise, set to be devastating for Kenya, as a critical control on Fall Armyworm on maize, and of Coffee Berry Borer, and of one of the most widely used and depended on crop protections. It is also an important active ingredient in the control of ticks in animals, which has not been evaluated in this report. However, at a time when climate change is leading to the rapid growth in tick-borne diseases, this represents a further acute danger.

Yet the grounds for its withdrawal in the EU were test results from the US that were scientifically inconclusive, and thus precautionary. These are covered in Chapter 2, but found that minority children in New York, who had been found to have absorbed the chemical at birth at a time when it was used to treat domestic pest infestations, notably of bed bugs, later had a lower-than-average IQ.

The problem with this result is that due to societal inequities and their developmental impact, all IQ testing of minority children in the US, and of inner city children, has established that these children have, on average, lower than average IQs. There has been no exception to that finding. Therefore, relating the lower IQs in this batch of tests to Chlorpyrifos would require some basis for believing these particular lower IQs were not caused by the same developmental impact of disadvantage that has always produced the same results previously.

This is made more problematic still by the failure of any animal testing to identify a neurological impact from Chlorpyrifos - at less than mortal doses.

Nonetheless, the lower IQ test prompted a precautionary ban in the EU, and has thrown the US into a confused position. Without any way of running a risk assessment - in the absence of any data confirming a hazard at all, or any toxicological level at which it begins to occur - the EPA simply withdrew the chemical, only to see that decision overturned by the US courts.

Thus, to all interests and purposes, its withdrawal in Kenya is a further application of the EU's precautionary principle, but it illustrates powerfully, with both coffee exports and domestic maize production sacrificed to that decision, the scale of the country's move away from evidence-based decision making, with so many mortalities, morbidities, and financial losses ahead based on a scientific non-sequitur.

However, the most striking withdrawal in policy terms, is that of 2-4-D. This herbicide is approved in both the US and EU, and is classified as of low toxicity to humans, raising no risks of concern in any aspect of risk assessment, and presenting no evidence of carcinogenic or DNA disruption.

At the same time, the motive for its withdrawal is also the most dislocated from the regulatory methodologies that the world is disputing, in that the grounds for the withdrawal were notifications that were issued by Japan and Korea rejecting imports of Kenyan coffee on breach of MRLs for 2-4-D that these countries had set at zero tolerance.

This new approach to pest control regulation marks an enormous shift from all previously documented pest control regulation, with seven of the eight pest control withdrawals apparently driven by trade considerations.

This move to regulation without any criteria or transparent methodology moves the country's pest control regulation into complete unpredictability.

Will all pest control products that trigger an MRL breach notification by any country, henceforth, be withdrawn for use in Kenya, regardless of their risk or domestic utility?

Has Kenya's policy sovereignty been ceded to any one of its over 140 trading partners to determine its domestic agricultural policies through MRL notifications on a single or handful of export consignments?

And what due process is in place to prevent such 'ad hoc' regulatory overrides from causing major harm?

For where risk was previously clearly calculated, there is now no sight of how this new trade-driven regulation will be assessed for its impact on the welfare of Kenya and Kenyans.

In this, taking 2-4-D alone, the number of notifications were very few, and occurred some years back, but, more significantly, South Korea has typically accounted for only around 9 per cent of Kenya's coffee exports, at $31m of purchases in 2022.

Yet, the proposed restrictions put Kenya on a direct path to a reduction in its coffee production of around 11.8 per cent, massive food insecurity, losses to farmers equivalent to $2.5bn in 2025 alone, and an addition of up to $1.37bn to the country's trade deficit.

At a cost/benefit level, it is hard to identify the winners from this new methodology.

6.2 The policy framework

Kenya has incorporated multiple reforms since the adoption of the 2010 Constitution to ensure that the impacts of new statutes are fully considered. The country has also made large strides in developing transparent policy agendas aligned with securing the country's Sustainable Development Goals and middle-income status by 2030.

At the same time, Kenya has emerged as a leader on the global stage in climate change, pulling ahead of most nations in the world in its energy transition and leading international thinking on financing models for climate adaptation. This is important in that agriculture and the livelihoods

of the 70 per cent of the country's population that depend on it are being severely affected by climate change. This decline is happening through multiple mechanisms, but the two most severe in reducing food security are the rise in pests, as covered in Chapter 1, and the impact on soils.

Against this backdrop, the ad hoc withdrawal of pest controls without reference to the country's agricultural and national security aims, presents a stark example of the scope that still exists to undermine the outcomes from overarching policy frameworks.

As well as contradicting the country's own policy statements at the WTO, this clearly contravenes the country's recent bilateral trade agreement with the EU, Kenya's top export destination, which states under Agriculture, as Article 64 (2):

The Parties shall ensure that actions taken under this Part aim at enhancing food and nutrition security, and avoid the adoption of measures that could endanger achievement of food and nutrition security at the household, national and regional levels.

At the level of micro-policies, major work and public spending through 2023 and 2024 aimed at enhancing coffee productivity now appears undermined by a coffee berry borer invasion for which the key pest control has been removed.

Likewise, when wheat farmers are wholly dependent on anti-rust fungicides, and the most robust of these is removed, it creates confusion as to the policy aims.

This is not helpful in upholding the government's credibility with farmers, who are already outspoken on the inadequacy of extension knowledge - their only, and increasingly occasional, interface with government. Indeed, from interviews it appears to have fuelled belief that the government may not be abreast of agricultural realities. For it seems certain that the government and national security council would not knowingly trigger a further agricultural and food crisis and trade balance deterioration.

These particular withdrawals are set to undermine food security, export flows, the trade balance and the economy, yet assessing the impact of pest control changes is normally inherent in pest control regulatory regimes.

On that basis, this set of withdrawals, and the apparent lack of government awareness on their impact, act as a stark example of the perils of regulation that is pursued without any mechanism or due regard to impact or alignment with overarching policies.

The policy consideration that this poses is what procedure should be followed to assess the impact for Kenya of withdrawals and the overlap or contradictions that these present to existing government commitments and priorities.

6.3 MRL capacity

The current international system, both risk-assessed and hazard-based, is built around the observance of Maximum Residue Levels (MRLs). The key driver of the changes that have now been adopted, at such huge cost for the country, has been communicated as notifications on exports, which marks their rejection by the importing country.

Some of these notifications are triggered by the presence of quarantine pests. But others are due to MRL breaches.
The availability of MRL testing in Kenya is scant. There has been, since 2014, a certified MRL testing facility in Mombasa, and it appears to have capacity to provide increased guidance to Kenyan exporters. A second provider sends crops overseas for testing.

However, with active ingredients known to break down over time, the turnaround time on the current MRL testing is impractical for exporters whose crops are ready to release, and also liable to give better results by the time of testing than when the sample was gathered and initially transported to Nairobi.

More significantly, in that the balance of agricultural produce consumed by Kenyans is far greater than the volume of food exported and consumed outside Kenya, there is scant monitoring of MRL levels domestically.

This has left MRL monitoring to be undertaken by campaigning organisations who have persistently omitted key information and used the data to create fear, generating MRL tests as feed for press campaigning and advocacy.

The restoration of science-based and systematic MRL testing would provide a valuable aid and greater accuracy for regulators in assessing risk and exposure.

Furthermore, it ties with renewed attention on the safe use of agrochemicals. In our survey of farmers, only 50 per cent were aware that PHI meant post-harvest interval, as the prescribed period before harvesting and consumption of a crop after the use of pesticides. This period is critical in ensuring consumer safety.

It is the nature of Kenyan and African agriculture that, unlike European, US and other food systems, it is dominated by untrained farming families, with the lead farmer, according to the FAO having an average of 6 years education, in contrast to professional farmers elsewhere. This requires bespoke solutions, and ideally public information campaigns, in training the population on the labelling and instructions given on pest control products.

This is particularly so when over 95 per cent of farming families are using pesticides.

The correct use of pesticides is a real issue, and solving it by withdrawing pest control and generating mass food insecurity represents a radically destructive option versus policy attention, including within the school curriculum, to mass education on the meaning of pest control product labels and the importance of observing them.

6.4 Pest control alternatives

Kenya's national policy, and the policy of all agricultural actors is strongly committed to integrated pest control management, based on the use of cultural options and biocides as a first preference.

However, the extensive literature review to identify IPM alternatives to pesticides for the 105 pest pathways affected - which was necessary in calculating the impact of the synthetic pesticide withdrawals - found that:

- There were substantial areas where no alternative IPM options existed, most notably for fungal, bacterial and viral plant diseases.
- That some proffered solutions showed poor efficacy and crop outcomes;
- That the testing of the efficacy of alternative IPM solutions was scant;
- That the testing of the safety of the majority of the non-cultural solutions was negligible or non-existent; and
- That some options that were available elsewhere were not available in Kenya.

These findings raised an important array of policy issues. Of primary importance in phasing out synthetic pest control products is the need to mitigate the impact on domestic food security by accelerating the development of alternatives. The policy options for promoting, encouraging and developing alternative pest control products are beyond the scope of this study, but might include the prioritisation of a research institution programme on the development of IPM solutions, and an array of incentives to encourage other researchers to engage as well.

The evidence is powerful on the strong returns for the economy from agricultural research spend, and this exercise, in withdrawing the existing products of crop science in the absence of any replacements has vividly demonstrated the urgent need to develop viable alternatives to synthetic chemical solutions.

A further area where policy attention is required is in the testing and registration of non-synthetic solutions. Testing data on such options remains scanty. This opens a pathway to far more serious harm, as it is not the case that all synthesised chemicals are lethal, and all naturally produced chemicals are safe. The study of Neem would be an ideal pathway to establishing appropriate biocide regulation, as it is frequently recommended for use, but only explored in medical circles for its endocrine disruption and risks in reducing male and female fertility, inducing miscarriages, and in its developmental impacts on infants.

On the basis of these findings and the principle of protecting farmers, consumers, and the environment, the accelerated development and advanced testing of natural pest control products and communication of their risks to users would appear to a clear need as the country pursues the reduction of human, animal and environmental impact through the development of biocides.

6.5 Transition

The final and perhaps most acute policy issue raised for 2024 by the findings from this analysis is the absence of transition support. In qualitative interviews that spanned December 2023 to January 2024, many of the smallholder farmers were unaware of the pest control product withdrawals. At the same time, a significant proportion of the experts interviewed were not familiar with the gaps the withdrawals were set to raise in pest control.

Two out of three agrovets, who were closer to matching farmers' needs with products, predicted that the gaps would be met through smuggling and/or the counterfeiting of products. While the large farms and exporters we interviewed had already reviewed the changes and were working on resolutions a full year ahead of the final withdrawal.

However, the absence of preparation and preparedness by the smallholders responsible for over 90 per cent of the country's food production will substantially increase the loss to pests in 2025, creating a larger public crisis, while also pushing the burden more heavily onto the smallest producers.

For an agricultural change as large as this, withdrawing some of the country's most widely used pest control tools in the midst of the exponential growth in pests underway as a result of climate change, a large public information campaign to aid the transition is now urgent.

Presuming that the intention is not to remove pest protection, per se, but to replace it with alternatives, it is urgent that the experts responsible for the withdrawal selections and for ensuring they do not result in acute food insecurity, now prepare information for the country's agricultural sector on the gaps and the alternative pest control methods to address them.

7 Chapter 7: Conclusions

This study has found that agricultural pests have been playing a considerable and expanding role in undermining agricultural productivity in Kenya. This is strongly and consistently demonstrated by the pest prevalence data, the declining production of many crops, falling yields, and rising food insecurity.

As a consequence, Kenyan farmers have resorted to the heavy use of pest control products, and report a strong dependency on these products to retain their food supplies and income. Over 30 per cent report they would lose more than three quarters of their food supply if pesticides were withdrawn and more than 45 per cent state they would lose over three-quarters of their income.

Against this backdrop, the study established that the withdrawal of the eight pest control products affected around 105 pest pathways across 31 crops, which together account for 74.86 per cent of vegetal output in Kenya.

It found evidence of a belief expressed by individual government officials that the withdrawals would have little or no impact on the country's agricultural output, because hundreds of alternatives existed. But, in fact, for 13 pest pathways, the withdrawals removed all pest protection, while for a further 20 they created a dependency on a single product already suffering resistance, or which would move to resistance very quickly, thereby leaving these pest pathways also without protection.

Together these pathways where all pest protection is being removed accounted for almost one third of the changes, and included crops that are critical to national import substitution policies, national security, food security and public health, including coffee, tea, wheat and sukuma wiki.

Literature reviews further revealed pathways where the control with the highest efficacy was being removed, notably affecting maize production.

A review of IPM alternatives found remarkably few options, with often limited efficacy, raising concerns around the basis and intentions of the policy, as the removal of pest controls, without alternatives, in a high-pest environment can only reduce agricultural output.

Based on rigorous and conservative modelling assumptions, the study found that agricultural output would fall by 10.1 per cent in 2025, affecting all staple foods, except rise, and almost all of the export crops covered by the withdrawals.

The 15.1 per cent fall in maize production, 32.3 per cent fall in the output of cabbages and kales, 29.2 per cent fall in tomato production, 22.7 per cent fall in potato output and 20.3 per cent fall in the production of sorghum presented a major blow to food security. At the same time the falls of 23.9 per cent in cut flowers, 23 per cent in tea production, and 11.8 per cent in coffee output were significant in the implied impact on export trade.

The study analysed the impact of these changes on farmers' income, finding a 17.6 per cent fall in 2025 incomes for sold produce, which together with subdued replacement costs for the three quarters of farm production that is used as a food supply, generated a cost of Sh814bn in 2025, and Sh 3.8 trillion in the decade ahead.

The foods affected additionally account for 63 per cent of the calories consumed by Kenyans, and the reductions will take the country to the lowest national calories per head in the world. In studying the health impacts of this change, we identified multiple areas where morbidities and mortalities would balloon, with a calorie deficit of the scale predicted increasing cancer cases by up to 89 per cent, diabetes by up to 75 per cent, cardiovascular diseases and infections, as well as causing grave developmental impairments for future generations.

The scale of this impact has led us to the conclusion that these changes amount to a national security issue, which requires urgent attention.

We additionally found that the withdrawals had not been based on the previous regulatory framework, but driven by trade notifications from other nations, often generating huge domestic losses for small trade gains, that will be more than counteracted by the export losses triggered.

The coincident match of the pest pathways on which pest protection has been withdrawn and the pests on the quarantine list of Kenya's top trading partner, the European Union, means that a series of exports will be far more seriously impaired than the predicted production drops imply, as exporters seek to eradicate quarantine pests with their pest controls removed.

Together with the sharp rise in staple food imports, which we calculate at an extra $211m of imports on the basis of partial replacement, and the fall in exports caused by the falling production, the measures are expected to have a $xxx negative impact on the country's trade balance in 2025.

The change in the pest control regime that has moved the regulation to adopt methods that the country is disputing in the WTO, in the form of the EU's precautionary principle of banning in the case of any potential but un-evidenced issue, also conflict with the bilateral trade deal with the EU, in engendering massive food insecurity.

But they further move pest control regulation into unpredictability, an absence of transparency, apparently moving between multiple different regulatory structures and criteria, most notably in the case of 2-4-D, where the criteria is a small number of trade notifications on MRL breaches and has set aside risk-based and hazard-based assessment models, including the precautionary principle, overriding all regulatory models with an ad hoc trade-motivated move that has not been discussed or analysed for its impact on the country's security.

We recommend as a result of these findings that:

- The consistent and transparent methodology and criteria in existence be adopted during approval and reviews of pest control products

- It be aligned with national priorities, national commitments and national security in incorporating considerations of food security and public health impacts
- The government initiates an urgent public information campaign informing farmers of the pest control withdrawals and the alternative protection they can deploy
- It reviews the trade impact and national security impact of the announced withdrawals and take all necessary measures to mitigate their negative impacts at a pace sufficiently timely to prevent any consequent surge in mortalities, morbidities and mass financial distress.