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QUALITATIVE ASSESSMENT OF PESTICIDE RISKS IN WEST AFRICA

By

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Abstract

Pesticide use has grown rapidly in West Africa over the past decade and a half. Yet regulatory capacity has not kept pace with the rapid proliferation of pesticide products and on farm use. As a result, health and environmental impacts from the growing use of pesticides, despite their potential importance, remain largely unmonitored, underreported, and poorly understood by key stakeholders. In this paper, we assemble new evidence on pesticide risks for human health by identifying the most critical emerging pesticide risks and key danger cropping zones in West Africa. We rely on a three-step approach to assess potential pesticide risks across Côte d'Ivoire, Ghana, and Mali. In 2019, expert panels assembled in each country independently identified three active ingredients -- chlorpyrifos, glyphosate, and paraquat -- as potential threats to human health and the environment. To monitor and mitigate the risks associated with the growing use of pesticides, local scientists consider it essential to establish a structure in charge of toxicovigilance to coordinate and harmonize pesticide monitoring efforts. Sentinel monitoring sites for each country are proposed.

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1. Introduction

In West Africa, application rates of pesticide are low but growing fast. From 2000/05 to 2014/18, pesticide use increased by 177% in West Africa compared to 30% worldwide (FAOSTAT 2019). Despite rapid growth in pesticide use over the past decade and a half, the enforcement and monitoring capacity of regulatory systems have not kept pace (Figure 1). As a result, roughly one-third of pesticides sold in West Africa are fraudulent (Haggblade et al. 2019; MirPlus 2012). Fraudulent pesticides refer to both counterfeit and unregistered generic products. Farmers raise frequent concerns about potential under-dosing and adulteration (Ashour et al. 2018; Assima et al. 2017; Haggblade et al. 2017a). Regulators and public health officials, likewise, fear that the combination of rising volumes, mishandling, and uncertain quality may pose growing risks to human health and the environment.

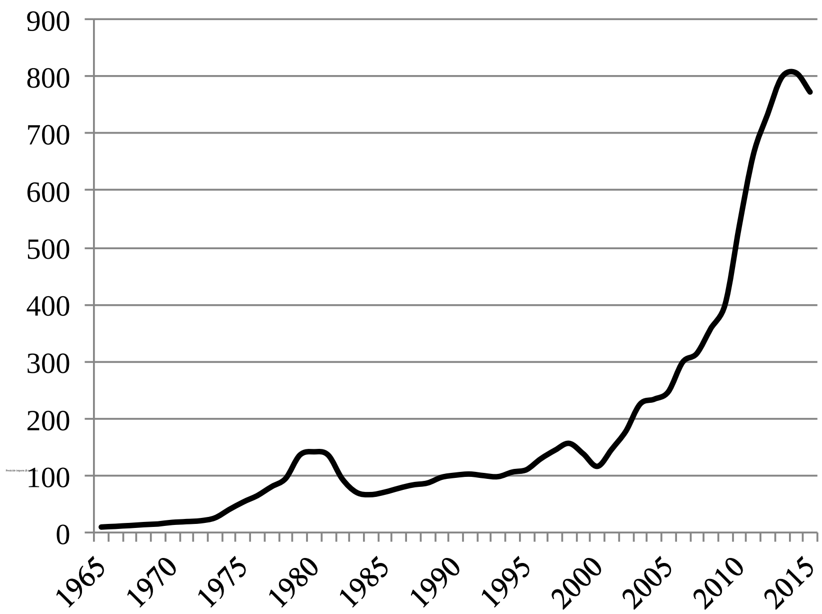

Figure 1. Trends in pesticide imports into West Africa (millions of US dollars, 3-year centered moving averages))
Source: Authors based on data from FAOSTAT (2019).

The initial spurt in West Africa's pesticide volumes occurred between 2005 to 2015, driven by rapidly growing on farm demand for low-cost, generic herbicides in the face of rising rural wage rates in many locations (Luna 2020; Haggblade et al. 2017b). As that first wave of herbicide-induced pesticide growth plateaus, plant protection specialists anticipate a second surge in pesticide use, this time driven by major recent insect infestations. The Fall Armyworm, inadvertently introduced into West Africa from the America's in 2016, has now spread throughout the continent, posing serious threats in major cereal-producing zones (FAO 2019; Tambo et al. 2020). More recently, in 2019, abnormally wet weather conditions have induced a serious desert locust outbreak in Eastern Africa. Early responses, by farmers and plant protection agencies, involve increased applications of highly toxic insecticides (Murray et al. 2019). As a result, the second wave of increased pesticide use will likely involve more highly toxic classes of pesticides than the first wave. Hence the importance of identifying and monitoring the most serious potential risks.

There are risk trade-offs in pesticide use and regulation. The bans of some pesticide products to reduce pesticide-related risks to consumers and farmers can lead to increase use of substitute pesticides, with varying level of toxicity and income losses due to increased yield damage (Gray and Hammitt 200). Overuse of pesticides as well as under-dosage of pesticides can lead to pest resistance and, thereby, to yield damage and income losses (Varah et al. 2019; Haggblade 2020). Yield damage due to pests and diseases remain a major threat for agriculture and food security in the region. In the early 2000s, before the first wave of pesticide use, actual yield losses to pests were estimated at 19% for maize and 51% for rice in West Africa (Oerke 2006). The use of pesticide has allowed to increase crop productivity by minimize yield damage due to pests and diseases.

Despite the potential risks to health and the environment, the rising use of pesticide remains largely unmonitored, underreported, and poorly understood by key stakeholders, such as policymakers, farmers and consumers. In this paper, we aim to bring new evidence on pesticide risks for human health and the environment by identifying the most critical emerging pesticide risks and key danger cropping zones in West Africa. While many prior pesticide risk studies have focused on the impact of banned pesticides applied decades earlier, this study aims to look forward to identify the active ingredients likely to pose the most serious potential risks during the current ongoing surge in pesticide use throughout the region (Kouadio et al. 2014; Manda et al. 2017; Maïga et al. 2018). This assessment of key pesticide risks in West Africa focuses on three countries -- Côte d'Ivoire, Ghana and Mali – which we consider representative of the full range of cropping and agroclimatic systems found in the region. This selection builds on a recent inventory and on-site assessments of pesticide testing laboratories across West Africa by duBois (2019) and Jiang et al. (2019), through which the study team was able to establish scientific collaboration with key scientists working on these issues. The case study countries are major agricultural producers in the region. Together they transect the region from north to south, spanning the full range of agroclimatic and cropping systems common throughout the region, from the dry Sahelian zone of Mali to the humid tropical coastal zones of Côte d'Ivoire and Ghana.

We rely on mixed methods. First, we review previous scientific work on pesticide risks in the three case studies. Second, we conduct a qualitative risk assessment with a panel of experts in each country following a three-step procedure: a) identification of high risk active ingredients contained in pesticide products available in the market, utilizing information on imported volume and consumption; b) completion of a risk assessment matrix in each country, which scores the probability of exposure and severity if exposed to an active ingredient in order to identify the most critical emerging pesticide risks; c) identification of three potentially high-risk zones in each country in light of the qualitative risk assessment results as well as previous scientific work on pesticide risks.

The paper is organized as follows. Section 2 reviews prior empirical work on this topic. Section 3 describes the risk assessment matrix, which was developed to analyze pesticide use risks while section 4 summarizes key empirical results from this three-country study. The paper concludes by discussing key regional hot spots for monitoring.

2. Overview of pesticide risks in the three case study countries

The available published literature on pesticide risks in West Africa, though episodic and intermittent, offers potentially valuable initial insights into the areas of greatest expressed concern among African scientists and the funding agencies who have financed their work. Reviews by Jepson et al. (2014), Donkor et al. (2016), Manda et al. (2017) and Ingenbleek et al. (2019) help to focus and amplify issues of particular concern.

The ensuing summary relies on an English language search of the terms "pesticide risk" in Côte d'Ivoire, Ghana and Mali plus a French language search of "risques pesticides" in the same three case study countries using Google Scholar. In total, these searches yielded 52 published works, 16 to 20 per country over the past 20 years (Table 1 and appendix). Since approximately a dozen of the studies examine multiple risk pathways (impacts on water and soil, for example), the total number of risks examined and classified in Table 1 totals 65, exceeding the total number of studies by 13. Overall, the pesticide risks investigated by these studies fall into the three main categories outlined below.

Table 1. Summary of published literature on pesticide risks in three West African countries

	Côte d'Ivoire	Ghana	Mali	Total
Human health risks				50
Consumers				31
Food-borne pesticide residues				
Vegetables & fruits	3	11		14
Fish	1	2		3
Milk	2		1	3
Cereals		2		2
Other foods	2		1	3
Direct consumption				
Acute poisoning	1		5	6
Farmers				19
Cotton	4		6	10
Vegetables	6	1		7
Irrigated rice		1	1	2
Environmental risks				15
Water	3	2	4	9
Soil	1	1	2	4
Non-target species				
Mammals			1	1
Insects	1			1
Publications				
Impact citations	16	20	16	52
Total publications	24	20	21	65

Source: Authors

Note: See the annex for a full listing of the literature summarized in this table.

2.1. Human health risks from ingestion of pesticides and pesticide residues in foods

A preponderance of published studies on pesticide risks focuses on human health risks from food-borne pesticide residues. Roughly, half of the published studies (31 out of 65) examine consumer risks from oral intake of pesticides or pesticide residues in foods (Table 1).

Across food commodities, horticultural products have attracted the greatest concern as vehicles for introducing pesticide active ingredients into human diets. About 48% of the consumer-intake studies (14 out of 31) focus on fresh vegetables and fruits. All of these took place in the two coastal countries of Côte d'Ivoire and Ghana, where higher humidity, greater prevalence of fungal diseases, larger cities and widespread peri-urban horticulture exacerbate consumer risks.

Environmental pressure from heavy pest loads combines with economic pressure on farmers to intensify production on increasingly expensive peri-urban land to increase pesticide use. In these conditions, horticulture producers apply high levels of pesticides – primarily fungicides and insecticides – to control a wide array of pests. In the locations studied, over 90% of horticultural producers applied pesticides. Studies that examined pesticide registration status find that many of the pesticides most commonly applied to horticulture crops were either unregistered or registered for cotton (Soro et al. 2018; Tano et al. 2011) or for other non-horticultural crops (Tiembre et al. 2016; Ntow et al. 2006). Active ingredients most frequently detected in horticultural products include chlorpyrifos, cypermethrin, endosulfan, endrin, heptachlor and lambda-cyhalothrin (Donkor et al. 2016; Yao 2016; Ingenbleeka et al. 2019). Exposure levels, however, vary significantly across study sites. A review of pesticide risks in horticultural crops in Ghana concludes that children, because of their lower body weight and higher hazard indices, constitute the population group at greatest risk (Donkor et al. 2016).

Another one-third of the consumer-based studies (11/31) report pesticide residue levels in a range of other foods, including fish, milk, cereals, and other foods. Many of these studies focus on organochlorine pesticide residues remaining in the environment and food system from prior decades of public health campaigns against malaria, emergency spraying to contain locust invasions and concentrated spraying to control pests among key cash crops, such as cotton, cocoa and coffee, with highly toxic and now-outlawed classes of persistent organic pollutants (POPs).[1] Indeed, a series of studies has detected organochlorines, such as DDT and endosulfan in fish, milk and other dairy products, even in human breast milk (Kouadio et al. 2014; Maïga et al. 2018, Manda et al. 2017, Traore et al. 2003, 2008). Most studies, though not all, detect pesticide levels below safety thresholds specified by international maximum residue limits (MRLs). Nonetheless, risk of bioaccumulation makes them potential long-term health hazards, which continue to attract interest by scientists in the region (Kouadio et al. 2014).

Methods used in these food residue studies rely on food sampling protocols followed by pesticide residue testing using liquid or gas chromatography, depending on the active ingredients studied and the equipment available locally.

Unlike the coastal zones, in the more arid Sahelian climate of Mali, pesticide risks to consumers surface primarily in a handful of studies (5/31) that examine causes of acute poisonings based on

[1] The Stockholm Convention classifies seven pesticides as POPS: aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, hexachlorobenzene, mirex and toxaphene.

case records from hospitals and clinics. In general, these studies find pesticide poisoning from direct ingestion to be rare, accounting for only 2% to 5% of total reported poisonings (Diallo et al. 2013, 2016). Rather than pesticides, the most frequent sources of poisonings stem from direct ingestion of medicines and industrial acids. Typically, these incident reports point to accidental poisonings among children, though sometimes intentional among adults (Coulibaly et al. 2018; Diallo et al. 2013). Attempted suicides (mostly among women) most frequently rely on medicines such as chloroquine or industrial products such as hydrochloric acid (Diallo et al. 2013).[2]

2.2. Farmer exposure

A further approximately 30% of published pesticide risk studies (19/65) examine on-farm risks faced by producers from inhalation or dermal exposure during spraying. Cotton dominates among these studies, particularly in Mali and in the arid northern regions of Côte d'Ivoire, accounting for 10 out of 19 such studies. Parastatal cotton companies have promoted cotton production across West Africa for well over 50 years. Given cotton's high vulnerability to insect attacks -- from bollworm, various mites and caterpillars -- extension staff teach cotton farmers to scout pests daily and to spray, depending on pest load, five to six times per season (Michel et al. 2000). To combat pest resistance, the cotton ginning companies supply input packs including an evolving cocktail of insecticides (Tefft 2010).

Horticultural products come in a close second, accounting for 7 out of the 19 farmer-based pesticide risk studies. A final pair of reviews (2/19) has focused on irrigated rice, typically a high input operation given moderate to good water control, which favors crop responsiveness to fertilizer and other inputs.

Methods used in the farmer-focused risk studies typically center on farm interviews, to assess standard behavior and environmental conditions. The studies then apply these exposure parameters to various simulation models to estimate anticipated dermal and pulmonary exposure (see Jepson et al. 2014 for good examples of this approach).

2.3. Environmental impacts

The remaining pesticide studies (15/65) examine environmental impacts of pesticide use. Mostly, these deal with pesticide runoff in surface and ground water (9/15) but also in soil (4/15) and in non-target mammals and insects (2/15). Given the absence of piped drinking water in many rural settings, surface and groundwater contamination significantly amplifies the danger of pesticide exposure for human consumers. As a result, the bulk of these studies of the environmental impact of pesticide use have focused on pesticide residues in water. Most of these studies test for traces of highly toxic pesticides used decades earlier to combat malaria and severe locust incursions with now-illegal organochlorines such as DDT, endosulfan and endrin. Fat solubility of these POPs leads to bioaccumulation in the food chain, most commonly in dairy products and in fish (Maïga et al. 2018; Kouadio et al. 2014; Manda et al. 2017; Traore et al. 2003, 2008). Looking forward, given continued widespread pesticide applications in cash cropping zones and growing levels of peri-urban horticultural production in close proximity to urban water supplies, potential downstream effects on

[2] In contrast, Asian countries frequently report highly toxic pesticides – such as the herbicide paraquat or the insecticide endrin – as the leading method of suicide in China, India, Sri Lanka and South Korea (Myung et al. 2015, WHO 2019, Matthews 2018).

drinking water and aquatic life compound the potential risk of pesticide exposure among urban consumers. [3]

As with the food-based MRL studies, methods used in these environmental studies rely on sampling protocols for the affected matrix (soil, water or non-target species) followed by laboratory analysis using liquid or gas chromatography, depending on the active ingredients studied and the equipment available locally.

3. Methods for risk assessment

In contrast to the EPA four step risk assessment (EPA 2020a) that measures the harmful effects to human health and/or the environment from exposure to a stressor (e.g., active ingredient), our three-step risk assessment takes into consideration scientific knowledge to come up with a collective appreciation of potential risks. It is a qualitative assessment of pesticide risks that leverages on secondary data analysis rather than information obtained in the course of laboratory and/or field testing.

In collaboration with pesticide experts from Côte d'Ivoire, Ghana, and Mali, the authors organized workshops to identify and prioritize key risks on human health and the environment from pesticide use. These risk assessment workshops followed a three-step process. First, the identification of key pesticide products available in the market that are considered high risks. Second, a risk matrix is used to evaluate the level of risk of the active ingredients found in key pesticide products identified in the first step. Both the probability of exposure and the severity of impact on health if exposed to the active ingredients are considered. Third, utilizing findings from steps 1 and 2, sentinel sites for further monitoring are proposed.

These risk assessment workshops took place in Bamako, Mali in June 2019, in Abidjan, Côte d'Ivoire in June 2019 and in Accra, Ghana during August 2019.[4] Following the country-level risk assessment workshops, the team has compared and contrasted findings to identify common threats as well as location-specific particularities.

Step 1 - Identification of key pesticide products.

We assembled a panel of experts composed of regulators, toxicologists, chemists, pharmacists, agronomists, representatives of the national companies for export crops (i.e., cotton, cocoa, and banana) and the private sector (i.e., CropLife). Each expert was asked to identify up to ten pesticide

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[3] Under *Codex Alimantirus* guidelines, foodborne risks include plants, animals and prepared or packaged beverages. Thus, bottled water is considered a food, but not open-source drinking water. Though not formally classified as a food, contaminated drinking water nonetheless poses a potential human health risk to the many households who rely on surface and well water for drinking, washing and food preparation.

[4] The Côte d'Ivoire expert workshop, hosted by the Centre d'Excellence Africain pour le Changement Climatique, la Biodiversité et l'Agriculture Durable (CEA-CCBAD) at the Université Félix Houphouët-Boigny, included 15 pesticide specialists from 13 local institutions including AMEPHCI, CEA-CCBAD, CNRA, Croplife, DPVCQ, INHP, INPHB, INSP-IPRN, Lanada, MSU, PROGEPCI, SECI, and IPR/IMSP. The Ghana expert workshop, hosted by the Ghana Environmental Protection Agency, included 13 pesticide specialists representing 10 local institutions NBT, Croplife, EPA, Splendid Agro Products, Ghana Standards Authority, Cocoa Research Institute, Jack-Vestper Co., University of Cape Coast, MSU, Ghana Health Service, Macrofertil Ghana and University of Ghana, Legon. The Mali expert workshop, hosted by MSU's Projet de Recherche sur les Politiques Alimentaires du Mali (PREPOSAM), included 15 pesticide specialists representing 8 local institutions, including LNS, INSRP, CMDT, LCV, OPV, Croplife, PEPPO and University of Ségou.

active ingredients contained in products available in the market that she/he considered as high risks for human health. In addition, information on whether the product has been authorized for use in the country, type (e.g., herbicide, insecticide) as well as the crops and zones where it is being applied was collected. During the workshop, the panel of experts had the opportunity to present, discuss, revise their choices and come up with a consensus rating used to develop the risk matrix and identify hot zones.

Step 2- Risk Assessment.

A matrix that allows assessing the risk of active ingredients in key pesticides identified in step 1 was developed. This matrix takes into account the probability of exposure to the active ingredient contained in the pesticide product and the severity if exposed to it (Figure 2).

The probability of exposure to the active ingredient is evaluated on a 0 to 5 scale (0 = null, 1 = unlikely, 2 = seldom, 3 = occasional, 4 = likely, 5 = frequent). The score takes into account the availability of pesticide products containing the active ingredient in the market and the number of users.

The severity if exposed to the active ingredient is also measured on a scale of 0 to 5 (0 = null, 1 = negligible, 2 = mild, 3 = moderate, 4 = high, 5 = extremely high). The product hazard, which refers to the level of toxicity of the product as classified by the World Health Organization (WHO 2020a), and conditions of use are both taken into consideration in the severity measurement.

The calculated risk is the product of the probability of exposure and the severity if exposed. There are five level of risks; null, low, medium, high, and severe. A pesticide product with a negligible (=1) level of toxicity and that is unlikely to be used (=1) has a low risk. Extremely toxic pesticide products (=5) used frequently (=5) have severe risk. The multiplication of the probability and severity scores gives us the level of risk, which ranges from 0 to 25.

	a) Probability of Exposure					
b) Severity if exposed	Null	Unlikely	Seldom	Occasiona	Likely	Frequent
Null	**Null**					
Negligeable		**Low**				
Mild			**Medium**			
Moderate				**High**		
High					**Severe**	
Extremely high						

Figure 2. Conception of the risk assessment matrix

Source: Authors.

Note: Risk scores: null = 0; low= [1,2], medium= [3,6]. High [8-12], severe=[15-25].

Step 3- Identification of hot spots for monitoring.

Using the information collected in the previous steps, the panel identified three potentially high-risk zones and ways to monitor them.

4. Empirical assessment of pesticide risks

Key findings from the risk assessment matrix per country are presented and discussed in light of relevant data and scientific literature on pesticide use and risks. Then, we compare the pesticide risk ratings for active ingredients rated “severe” or “high” across countries and discuss those that pose the most serious threats to human health and the environment in the West Africa region.

4.1. Arid Sahelian zone (Mali)

Most of the thirty-three active ingredients identified by the group of Malian experts belong to four chemical families: organophosphates, pyrethroids, organo-chlorines and carbamates (Table A1 in appendix). Three active ingredients were identified as posing potentially severe risks to human health and the environment in Mali: chlorpyrifos, glyphosate, and carbosulfan (Figure 3).

Although chlorpyrifos and glyphosate are not the most toxic active ingredients, farmers use them widely and without protective equipment. According to Haggblade et al. (2019), glyphosate is by far the most commonly used active ingredient, accounting for over half of all herbicide volume sold and 38% of total pesticide volumes sold. Among insecticides, chlorpyrifos is the third most commonly used insecticide active ingredient after lambda-cyhalothrin and acetamiprid, accounting for approximately 11% of all insecticide volume sold. Both, chlorpyrifos and glyphosate, belong to the organophosphate family and can cause severe skin and eye irritation (PPDB 2016). Chlorpyrifos is known as a cholinesterase inhibitor. It is recommended that farmers who have used pesticide products containing this active ingredient for a long time to periodically check the level of cholinesterase in their blood. If the level of cholinesterase in their blood is low, then farmers should stop applying these products for at least one cropping season. (Cissé et al. 1993).

Given that Malian farmers do not wear protective equipment during pesticide application, their skin, eyes, and respiratory tract are exposed to pesticides. Therefore, pesticides that are dangerous for the skin, eyes, and respiratory tract are considered as risky by the Malian panel of experts. Chlorpyrifos and glyphosate were scored as having a high probability of exposure and a high severity of impact due to the high number of users and lack of safety practices. Although carbosulfan (carbamate family) is banned due to its high toxicity, it is still possible to purchase it in the market under the commercial name FURADAN (Haggblade et al., 2019) and, therefore, was identified as posing severe risks.

Three other active ingredients identified by the panel of experts as high risks are available in the market albeit not authorized: atrazine, endosulfan, and paraquat. Endosulfan (organochlorine family), is not authorized for sale by the Sahelian Pesticide Committee (known in French as Comite Sahelien des Pesticide “CSP”) but can be found in the market (Haggblade et al., 2019). Carbofuran, which is an insecticide and nematicide, is also not approved for use in the European Union. It is highly toxic to mammals, birds, and honeybees and is known as an endocrine disruptor and a probable reproduction/development intoxicant (PPDB 2016). Endosulfan is banned for use in agriculture under international conventions, such as the Stockholm Convention, and is listed among the Persistent Organic Pollutants.

After comparing the list of active ingredients identified by the experts and the list of pesticide products available in the market (Haggblade et al. 2019), we find that approximately 1/3 of the active ingredients are not authorized for sale by the CSP (Table A1 in appendix), which raises concern for public health and the environment. Among the unregistered products, approximately 5% come from Ghana, 2% from Côte d'Ivoire and the remaining 19% come from unknown sources (Haggblade et al 2019).

The most frequent pesticide family identified by the experts, as posing high risk, is pyrethroid (Table A1 in appendix). Most pyrethroids can have an effect on the respiratory tract, is irritant for the skin and eye and is harmful if swallowed (PPDB 2016). Some of them can have an effect on the immune system and are a thyroid toxicant (PPDB 2016. Insecticide products containing the active ingredients lambda-cyhalothrin and acetamiprid were considered as high-risk.

	a) Probability of Exposure					
b) Severity if Exposed	Null	Unlikely	Seldom	Occasional	Likely	Frequent
Null	**Null**					
Negligeable		**Low**				
Mild			**Medium**			
Moderate			Diuron Profenofos	**High** Bensulfuron methyl Pendimethalin Permethrin	Cypermetrin Deltamethrin Haloxyfop-R-Methyl Lambda Cyhalothrin Nicosulfuron	Glyphosate
High		Fenitrothion Fenthion	Propanil	2,4-D Aluminium phosphide Atrazine Imidacloprid Thiram	**Severe** Chlorpyrifos	
Extremely high	Aldrin Dieldrin Endrin Heptachlor	Lindane Malathion	Acetamiprid Carbofuran Paraquat	Carbosulfan		

Figure 3. Qualitative Risk Assessment Matrix Mali

Source: Authors.

Note: Risk scores: null = 0; low= [1,2], medium= [3,6]. High [8-12], severe=[15-25].

4.2. Humid coastal zone (Côte d'Ivoire, Ghana)

4.2.1 Côte d'Ivoire

Out of 46 active ingredients identified by the panel of experts in Côte d'Ivoire, 24 insecticides, 11 in herbicides and 11 in fungicides (Table A2 in appendix). Among the insecticides, chlorpyrifos was identified as posing severe risks to human health and the environment (Figure 4). It is widely used on cotton, maize, fruit trees to kill insects (adults and larvae) and the residues of chlorpyrifos are persistent on food crops. High dose exposure to chlorpyrifos can lead to acute poisoning while low dose long-term exposure can affect reproduction adversely. Among the herbicides, glyphosate and 2,4-D were considered to pose the greatest potential risk to human health and the environment due to their widespread use. As in Mali, glyphosate is the most commonly used herbicide, accounting for roughly two-third of all pesticide import volume in Côte d'Ivoire, following far behind by 2,4-D (roughly 10% of pesticide import volume) (Traore and Haggblade 2017). Among the fungicides, the active ingredient, metalaxyl, was identified as severe risk due it high probability of exposure and high severity if exposed.

Other high risks active ingredients in insecticides include imidacloprid, acetamiprid, and profenofos, which account for approximately 31%, 13%, and 8% of insecticide import volume (DPVQC 2017). Among the fungicides, mancozeb, which is the second most imported active ingredient in fungicides (DPVQC 2017), along with maneb, zineb, dimethomorph were ranked as high risks for human health and the environment in Côte d'Ivoire. The probability of exposure is likely, even frequent due to their relatively widespread use and lack of protective equipment for farmers.

Although the severity if directly exposed to DDT is relatively high, the probability of exposure is null, according to the group of experts, since DDT is prohibited and not available in the market in Côte d'Ivoire.

	a) Probability of Exposure					
b) Severity if Exposed	Null	Unlikely	Seldom	Occasional	Likely	Frequent
Null	**Null**					
Negligeable		**Low** Clothianidin Prochloraz novaluron				Thiametoxam Cypermethrin Lambda-cyhalothrin Bifenthrin Deltamethrin Cyphenothrin
Mild			**Medium** Carbosulfuran	Fipronil		Imidacloprid Acetamiprid Mancozeb Maneb Zineb
Moderate		TCMB Pyraclostrobin		**High** Triclopyr Cycloxydcim Propanil Pyrazosulfuron Diuron Haloxyfop-R-Methyl Nicosulfuron Cupric oxide Triadimenol	Dimethomorph	Glyphosate
High	Malathion Fenitrothion Fenthion Diniconazole	Turbofos Temephos Piriphos Methyl	Profenofos Paraquat		**Severe** Chlorpyriphos Metalaxyl M	**2,4 D**
Extremely high	P,P-DDT Aldicarb					

Figure 4. Qualitative Risk Assessment Matrix Côte d'Ivoire
Source: Authors.
Note: Risk scores: null = 0; low = [1,2]; medium = [3,6]; High = [8-12], severe = [15-25].

4.2.1 Ghana

In Ghana, the panel of experts identified twelve active ingredients they deemed to pose danger to human health and the environment, which is fewer than in Mali and Côte d'Ivoire (Table A3 in appendix). Among the list, three active ingredients were identified as posing severe risks: paraquat, lambda-cyhalothrin, and chlorpyrifos (Figure 5).

Given its widespread use by farmers to kill weeds, the probability of exposure to paraquat is likely in Ghana and the severity of exposure is high, since it is exceedingly toxic to human and moderately to highly toxic to many species (Kamel 2013; Pezzoli and Cereda 2013; EXTOXNET[5] 1993). Although being sold in Ghana, paraquat is one of the pesticides banned for use in the European Union (Gunnell et al. 2017). It remains one of the most widely used herbicide in the USA (EPA 2020b).

Both active ingredients in insecticides, lambda-cyhalothrin and chlorpyrifos, were identified as posing high risks to human health and the environment, Chlorpyrifos can be harmful to humans if it is touched, inhaled, or eaten and is very toxic to many species of birds, fish, and bees (NPIC 2010).

[5] A Pesticide Information Project of Cooperative Extension Offices of Cornell University, Michigan State University, Oregon State University, and University of California at Davis.

The effects of lambda-cyhalothrin on human health and the environment was considered severe since it is widely used by farmers.

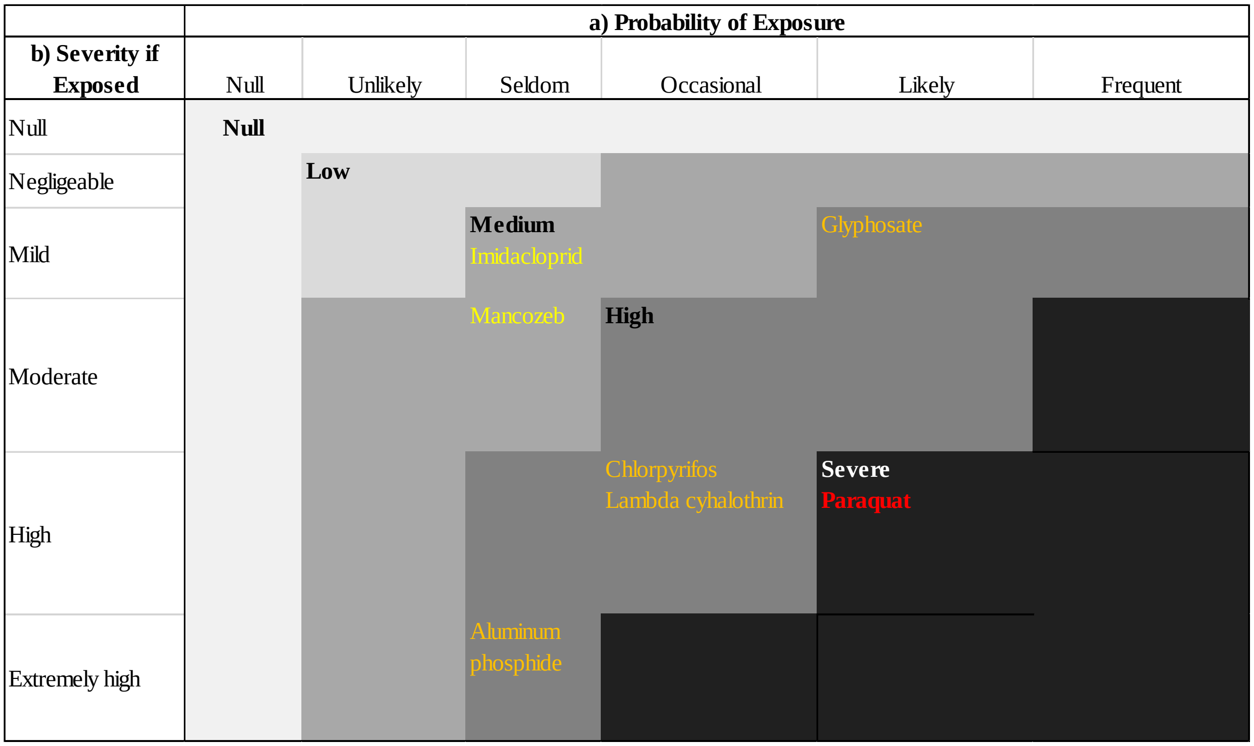

Figure 5. Qualitative Risk Assessment Matrix Ghana
Source: Authors.
Note: Risk scores: null = 0; low = [1,2]; medium = [3,6]; High = [8-12], severe = [15-25].

4.3. Common pesticide threats

Table 2 summarizes the pesticide risk rating for active ingredients rated severe or high by two or more countries. Across the three West African countries, chlorpyrifos, glyphosate, and paraquat were unanimously listed as potential threats to human health and the environment. The second group of pesticides causing threat to human health and the environment and nominated by at least 2 countries were 2,4-D, lambda-cyhalothrin, aluminium phosphide, atrazine, haloxyfop-R-methyl, nicosulfuron, and imidacloprid. Unlike in Mali and Cote d'Ivoire, imidacloprid was ranked as medium risk in Ghana.

Table 2. Active ingredients rated severe or high by two or more countries.

Active ingredient	a) Probability of exposure			b) Severity if exposed			c) Risk = a) * b)			
	Mali	CI	Ghana	Mali	CI	Ghana	Mali	CI	Ghana	Average score
All three countries										
Chlorpyrifos	4	4	3	4	4	4	16	16	12	15
Glyphosate	5	5	4	3	3	2	15	15	8	13
Paraquat	2	2	4	5	4	4	10	8	16	11
Two country "severe" or "high" ratings										
2,4-D	3	5		4	4		12	20		16
Lambda cyhalothrin	4		3	3		4	12		12	12
Aluminum phosphide	3		2	4		5	12		10	11
Atrazin	3	2		4	4		12	8		10
Haloxyfop-R Methyl	4	4		3	2		12	8		10
Nicosulfuron	4	4		3	2		12	8		10
Imidacloprid	3	5	2	4	2	2	12	10	4	9

Source: Authors.

Table 3 outlines the priorities for pesticide monitoring based on the three active ingredients independently identified by the panels of experts in each country: chlorpyrifos, glyphosate, and paraquat. The main routes of exposure identified for most of the pesticide products containing those active ingredients were dermal and inhalation. Oral exposure was considered the least likely. Being less aware of potential health risks related to pesticide use and less likely to use integrated pest management techniques, women's exposure to pesticides is greater than for men in Mali and Ghana (Christie et al. 2015).

Chlorpyrifos is one of the most widely used insecticide and acaricide used to control foliage pests in agriculture. Being highly toxic by ingestion, its extensive use on fruit and vegetable crops has led to growing concern of potential risk for consumers from residues in Ghana, both among our panel of experts and prior published literature (Donkor et al. 2016; Amoah et al., 2006). The widespread use of chlorpyrifos in the cotton farming zones of Mali threatens plants and non-target pest species as well as the health of farmers who are exposed to it through their skin and/or inhalation. Likewise, chlorpyrifos is extensively used on cash crops, such as cotton, cocoa, coconut, and palm oil, exposing farming communities to toxic pesticides.

Glyphosate is a broad-spectrum non-selective herbicide used in a wide range of crops to control annual and perennial weeds. It is also known to cause skin and eye irritation. Despite being of low toxicity, glyphosate was unanimously identified as posing a severe or high risk in all three countries due to its widespread use on all crops; food and cash crops alike. The experts are concerned about the pervasive use of glyphosate in the food system and water. The increasing demand for glyphosate had led to the proliferation of fraudulent products of uneven quality and uncertain effects of human health and the environment (Haggblade et al. 2019).

Unlike in Ghana, the active ingredients paraquat and/or atrazine are not authorized for use in Cote d'Ivoire and Mali. Despite being unauthorized, products containing paraquat and atrazine have been found in the market of these two countries (Haggblade et al. 2019; Traore and Haggblade 2018; Chouaïbou et al. 2016). This highlights issues with the regulatory enforcement in those countries (Diarra and Haggblade 2017). Paraquat has been banned in several countries worldwide, since it is extremely toxic and has been too often used for self-poisoning (Myung et al. 2015, WHO 2019, Matthews 2018; Kim et al. 2017). National bans on hazardous pesticides, such as paraquat, have been found effective in reducing suicides by pesticide poisoning (Gunnell et al. 2017). Of course, the effectiveness of such bans is conditional on the regulation being enforced.

Table 3. Priorities for pesticide monitoring

Active ingredient	Toxicity	Crops	Vulnerable populations	Rationale for priority monitoring
Chlorpyrifos	Moderate toxicity	Mali: Cotton. CI: Cotton, cocoa, coconut, palm oil. Ghana: horticultural crops.	Farmers (dermal, eye, spray inhalation)[6]. Pregnant rural women and fetuses. Consumers.	Widespread and growing use on horticultural and cash crops. Broad potential exposure to farming communities, children and urban consumers.
Glyphosate	Low acute toxicity Possible (though contested) long-term cancer risks[7].	Mali: All crops. CI: All crops. Ghana: All crops.	Farmers (dermal, pulmonary inhalation) Consumers (food residues).	Ubiquitous use. Likely low short-term health risk. Single best AI for tracking pesticide prevalence in food and water supplies.
Paraquat	High human toxicity;	Mali: Not authorized. CI: Not authorized. Ghana: Plantation crops, cassava, and cereals.	Farmers (dermal, eye, pulmonary inhalation). Widespread use for suicides in Asia.	Banned in many countries due to its extreme toxicity. Common use in West Africa despite bans in CI and Mali. Monitoring offers prospects for assessing both human health risk and fraudulent pesticide networks.

Source: Authors. Note: CI= Cote d'Ivoire

5. Priorities moving forward

There was an overwhelming consensus among the groups of experts that health and environmental protocols need to be better implemented and more strictly enforced. Among the recommendations are conducting more assessments of the best treatment options for different forms of pesticide poisoning and training more farmers, via extension services, on pesticide use and their related risks. This includes how to recognize fraudulent pesticides on the market, how to properly use and store pesticides, and how to dispose safely of old pesticide containers.

With regard to pesticide monitoring, local pesticide specialists consider the establishment of a list of pesticide products and structures in charge of toxicovigilance[8] essential to mitigate the risks

[6] Farmer dermal exposure exceeds recommended health limits (Jepson et al. 2014:9)

[7] See Agostini et al. (2020) for a review of the effects of glyphosate on human cell lines and overall human health.

[8] According to the WHO, "toxicovigilance is the active process of identifying and evaluating the toxic risks existing in a community, and evaluating the measures taken to reduce or eliminate them. It involves the analysis of poisons centre enquiries to identify whether there are specific circumstances or agents giving rise to

associated with the growing use of pesticides. The idea of setting up a toxicovigilance structure in the region has been on the table since 2002 (Cissé 2012). As of today, no administrative guide has been developed to improve the identification, evaluation, and implementation of measures to reduce toxic risks from pesticide use in West African communities.

This study is based on active ingredients taken alone while pesticide products sold in the markets in the three countries contain often more than one active ingredient. Manufacturers formulate pesticide products containing several active ingredients in order to manage several crop pest types, which in turn, can reduce the number of applications. The combination of several active ingredients in the same pesticide product has led regulators to draw up a list of pesticide products for monitoring in order to raise farmers awareness on the effects of these products on human health and the environment.

Based on the results from the identification of risky products, in term of active ingredients, available in the market and the risk assessment, each group of experts reflected on the establishment of sentinel monitoring sites. In Mali, the three "hot spots" proposed for future monitoring are: 1) Cotton production basin, where cotton is grown in rotation with maize, sorghum, and millet; 2) Office du Niger, where irrigated rice is grown during the rainy and the dry season and horticultural crops during the dry season; 3) Office du Périmètre Irrigué de Baguineda, where irrigated rice is grown during the rainy season and horticultural crops during the dry season. These are the zones where most of the pesticide products (insecticides, herbicides, and fungicides) are used.

In Côte d'Ivoire, the three hot spots are: 1) Cotton producing basin in the northern zone, where pesticides are widely applied on plots; 2) Cocoa plantation in the southern half of the country, where herbicides and fungicides are widely used and; 3) Peri-urban area of Abidjan, where large quantities of pesticides are applied to plots allocated to horticultural crops, maize, and irrigated rice.

In Ghana, the three hot spots are: 1) Derma in the Brong North region; 2) Akomadan in the Ashanti region and 3) and Begoro in the Eastern region. These farming communities are considered as hot spots due to the intensive use of pesticides, especially on horticultural crops.

In those hot spots, the risks of water and soil pollution as well as humans and livestock poisoning from pesticide use are considered very high. Through a validated toxicovigilance program, the risks of pesticide poisoning due to inappropriate application practices, poor packaging and inadequate storage as well as pesticide residue in food would be better monitored and regulations would be enforced to reduce or eliminate toxic risks to the environment and human health.

Moving forward, a legally and recognized toxicovigilance system is needed to ensure that pesticides available in the markets are those approved for sale and use by a government agency

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poisoning, or certain populations suffering a higher incidence of poisoning. Toxicovigilance can also reveal whether there is an emerging toxicological problem resulting from, for example, the reformulation of a product or a change to its packaging or labelling, the availability of a new drug of abuse, or an environmental contamination" (WHO 2020b).

and facilitates data collection and sharing regarding pesticide risks with regulators and public health officials at the country and regional levels.

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Appendix 1- Literature Search on Pesticide Risks in Three West African Countries

Côte d'Ivoire

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Appendix 2. **Table A1. Qualitative risk assessment - Mali**

List of active ingredients	Chemical family	Pesticide category	Authorized	Qualitative risk assessment* a) Probability of exposure	b) Severity if exposed	Risk score= a* b	Risk
Chlorpyrifos	Organophosphates	Insecticide	Yes	4	4	16	Severe
Glyphosate	Organophosphates	Herbicide	Yes	5	3	15	Severe
Carbosulfan	Carbamates	Insecticide	No	3	5	15	Severe
Deltamethrin	Pyrethroid	Insecticide	Yes	4	3	12	High
Cypermetrin	Pyrethroid	Insecticide	Yes	4	3	12	High
Lamda cyhalothrin	Pyrethroid	Insecticide	Yes	4	3	12	High
2,4 D	Phenoxyalkanoic acids	Herbicide	Yes	3	4	12	High
Atrazine	Triazines	Herbicide	No	3	4	12	High
Aluminium phosphide	Inorganic compound	Insecticide	No	3	4	12	High
Haloxyfop-R-methyl	Aryloxyphenoxypropionate	Herbicide	Yes	4	3	12	High
Imidacloprid	Neonicotinoid	Insecticide	Yes	3	4	12	High
Nicosulfuron	Substituted ureas	Herbicide	Yes	4	3	12	High
Thiram	Carbamates	Fungicide	Yes	3	4	12	High
Metolachlor	Chloroacetamide	Herbicide	Yes	3	4	12	High
Carbofuran	Carbamates	Insecticide	No	2	5	10	High
Acetamiprid	Neonicotinoid	Insecticide	Yes	2	5	10	High
Paraquat	Bipyridylium	Herbicide	No	2	5	10	High
Bensulfuron methyl	Sulfonylurea.	Herbicide	Yes	3	3	9	High
Permethrin	Pyrethroid	Insecticide	Yes	3	3	9	High
Pendimethalin	Dinitroaniline	Herbicide	Yes	3	3	9	High
Propanil	Phenylamides	Herbicide	Yes	2	4	8	High
Profenofos	Organophosphates	Insecticide	Yes	2	3	6	Medium
Diuron	Substituted ureas	Herbicide	Yes	2	3	6	Medium
Lindane	Organochlorine	Insecticide	No	1	5	5	Medium
Malathion	Organophosphates	Insecticide	Yes	1	5	5	Medium
Fenitrothion	Organophosphates	Insecticide	No	1	4	4	Medium
Fenthion	Organophosphates	Insecticide/acaricide	No	1	4	4	Medium
Aclonifen	diphenyl-ether	Herbicide	Yes	1	2	2	Low
Endosulfan	Organochlorine	Insecticide/acaricide	No	0	5	0	Null
Aldrin	Organochlorine	Insecticide	No	0	5	0	Null
Dieldrin	Organochlorine	Insecticide	No	0	5	0	Null
Endrin	Organochlorine	Insecticide/rodenticide	No	0	5	0	Null
Heptachlor	Organochlorine	Insecticide	No	0	5	0	Null

Source: Authors based on information compiled from the panel expert workshop.

Appendix 3: **Table A2. Qualitative Risk Assessment – Côte d'Ivoire**

				Qualitative risk assessment			
List of active ingredients	Chemical family	Pesticide category	Authorized	a) probability of exposure	b) severity if exposed	Risk score= a * b	Risk
2,4 D	Phenoxyalkanoic acids	Herbicide	Yes	5	4	20	Severe
Chlorpyrifos	Organophosphates	Insecticide	Yes	4	4	16	Severe
Metalaxyl M	Acylalanine	Fungicide	Yes	4	4	16	Severe
Glyphosate	Organophosphates	Herbicide	Yes	5	3	15	Severe
Profenofos	Organophosphates	Insecticide/Nematicides/ Acaricides	Yes	3	4	12	High
Dimethomorph	Morpholine	Fungicide		4	3	12	High
Imidacloprid	Neonicotinoid	Insecticide / Acaricides	Yes	5	2	10	High
Acetamiprid	Neonicotinoid	Insecticide	Yes	5	2	10	High
Mancozeb	Carbamates	Fungicides/Insecticides	Yes	5	2	10	High
Maneb	Ethylene bisdithiocarbamates	Fungicides/Insecticides	Yes	5	2	10	High
Zineb	Ethylene bisdithiocarbamates	Fungicides/Insecticides	Yes	5	2	10	High
Triadimenol	Triazoles	Fungicide	Yes	3	3	9	High
Dimethoate	Organophosphates	Insecticides	Yes	2	4	8	High
Paraquat	Bipyridylium	Herbicide	No	2	4	8	High
Triclopyr	Pyridine	Herbicide	Yes	4	2	8	High
Cycloxydim	Oxime	Herbicide	Yes	4	2	8	High
Propanil	Phenylamides	Herbicide	Yes	4	2	8	High
Atrazine	Triazines	Herbicide	No	2	4	8	High
Pyrazosulfuron	Triazines	Herbicide	Yes	4	2	8	High
Diuron	Substituted ureas	Herbicide	Yes	4	2	8	High
Haloxyfop-R Methyl	Aryloxyphenoxypropionate	Herbicide	Yes	4	2	8	High
Nicosulfuron	Substituted ureas	Herbicide	Yes	4	2	8	High
Cupric oxide	Inorganic compound	Fungicide	Yes	4	2	8	High
Carbofuran	Carbamates	Insecticide	No	2	3	6	Medium
Thiametoxam	Neonicotinoids	Insecticide	Yes	5	1	5	Medium
Cypermethrin	Pyrethroid	Insecticides/Acaricides	Yes	5	1	5	Medium
Lamda Cyhalothrin	Pyrethroid	Insecticides/Acaricides	Yes	5	1	5	Medium
Bifenthrin	Pyrethroid	Insecticides/Acaricides	Yes	5	1	5	Medium
Deltamethrin	Pyrethroid	Insecticides/Acaricides	Yes	5	1	5	Medium
Cyphenothrin	Pyrethroid	Insecticides/Acaricides	Yes	5	1	5	Medium
Tetramethrin	Pyrethroid	Insecticides/Acaricides	Yes	5	1	5	Medium
Terbufos	Organophosphates	Insecticide/Nematicides	Yes	1	4	4	Medium
Temephos	Organophosphates	Insecticides	Yes	1	4	4	Medium
Pirimiphos methyl	Organophosphorothioate	Insecticides	Yes	1	4	4	Medium
Fipronil	Phenylpyrazole	Insecticides	Yes	3	1	3	Medium
TCMB (Thiophanate-Methyl)	Carbamate	Fungicide	Yes	1	3	3	Medium
Pyraclostrobin	Carbanilate	Fungicide	Yes	1	3	3	Medium
Chlothianidin	Neonicotinoid	Insecticide	Yes	1	2	2	Low
Prochloraz	Imidazole	Fungicide	Yes	2	1	2	Low
Novaluron	Benzoylphenyl urea	Insecticide	Yes	1	1	1	Low
P,P-DDT	Organochlorine	Insecticides	No	0	5	0	Null
Malathion	Organophosphates	Insecticides	No	0	4	0	Null
Fenitrothion	Organophosphates	Insecticides	No	0	4	0	Null
Fenthion	Organophosphates	Insecticides	No	0	4	0	Null
Aldicarb	Carbamates	Insecticides	No	0	5	0	Null
Diniconazol	Conazole	Fungicide	No	0	4	0	Null

Source: Authors based on information compiled from the panel expert workshop.

Appendix 4. **Table A3. Qualitative Risk Assessment Ghana**

				Qualitative risk assessment		
List of active ingredients	**Chemical family**	**Pesticide category**	**Authorized**	**a) Probability of exposure**	**b) Severity if exposed**	**Risk score= a * b**
Paraquat	Bipyridylium	Herbicide	Yes	4	4	16
Chlorpyrifos	Organophosphates	Insecticide	Yes	3	4	12
Lamda cyhalothrin	Pyrethroid	Insecticide	Yes	3	4	12
Aluminium Phosphide	Inorganic compound	Insecticide*	Yes	2	5	10
Glyphosate	Organophosphates	Herbicide	Yes	4	2	8
Mancozeb	Carbamate	Fungicide	Yes	2	3	6
Imidacloprid	Neonicotinoid	Insecticide	Yes	2	2	4
2,4 D	Phenoxyalkanoic acids	Herbicide	Yes			
Carbofuran	Carbamates	Nematicide	Yes			
Dimethoate	Organophosphate	Insecticide	Yes			
Fenvalerate	Pyrethroid	Insecticide	Yes			
Pirimiphos-methyl	Organophosphate	Insecticide	Yes			

Source: Authors based on information compiled from the panel expert workshop.
Note: * storage