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Research Article

Impacts of Pesticide Use on Market Gardening Crops in Mokolo Municipality

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Abstract

The study aims to assess the impacts of the use of pesticides in market gardening on crops, human health and the environment in Mokolo, Far North Region of Cameroon. Pesticides use is a common practice to protect crops, driven by personal beliefs and challenges faced by farmers in the area. Although this practice improves yields, it has both positive and negative effects on farmers, crops and the environment. Data for this study was collected through questionnaires administered to 158 farmers and 15 officials from the locality, NGOs and other stakeholders. The questionnaires, structured to assess the impacts of pesticides on crops, the environment, the economy, and health were administered across 13 market gardening sites. Data collected were analyzed using Kobo Collect, Excel, and Quantum Geographic Information System (QGIS) for spatialization. The findings indicate that pesticide use has harmful consequences on farmers, crops health and environment. Pesticides residues on crops was very high as reported by 88.7% on parsley, 59% on celery, and 73.7% on peppers, cabbage, and onions). Health issues reported among farmers was also very high: 88% for respiratory cases and 72% for skin irritations. There was significant financial losses due to high costs of pesticide purchase (80,000 to 90,000 FCFA). The results reveals a gap in effective pesticides use. It also underscores an urgent need of regulations that promote integrated pest management as well as the use of sustainable alternatives (bio-pesticides) to preserve a healthy ecosystem and protect public health.

Keywords

Pesticides, Market Gardening, Impact, Sustainability, Environment

1. Introduction

Man, in his quest for food self-sufficiency and sustainable development, has established various plant protection mechanisms. Thanks to technological advances, powerful chemical processes have been developed to combat pests of crops like rice, cotton, market gardening crops, sugarcane, etc, thereby increasing national pesticide consumption [9, 14]. Weeds, diseases, and pests - capable of causing production losses of up to 30% - can now be controlled. According to [12], yield losses due to weed competition can reach 20 kg/ha per day. To mitigate such losses, particularly in intensive crops such as sugarcane and market gardening crops, producers resort to chemical control through pesticide use, which remains a key factor in agricultural development in the face of demographic pressure.

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In Western countries, pesticide use is more intensive, raising major concerns for public health and the environment, particularly biodiversity loss, pollinator decline, and soil health degradation. This underlines the need to rethink agricultural practices, reduce chemical dependence, and promote sustainable alternatives [19]. African countries, facing rapid demographic growth and an alarming food crisis, are not exempt. For example, in Ivory Coast, 85% of vegetable growers have no agricultural training, and 59% have never received guidance on the use of synthetic pesticides, resulting in significant consequences [7] and Cameroon is no exception. According to the Sustainable Alternative Development Organization [24], until 1989 the Cameroonian government subsidized pesticide acquisition, leading to high consumption. Between 1982 and 1992, Cameroon imported an average of 4.6 tons of pesticides annually, at a cost of 8 billions CFA francs. In 1991, pesticide sales amounted to 3.6 billion CFA francs, rising to 12.2 billion in 2000. Little thought was given to the crucial challenges posed by pesticide use. The widespread application of pesticides in market gardening contributes to soil degradation and water pollution, highlighting the importance of sustainable farming practices [23].

Cameroon's agricultural policy focused on crop protection between 1960 and 1980 shifted after the economic crisis of the 1990s, when the state withdrew from pesticide distribution. Product quality and farmer training ceased to be priorities [10]. In 2004, this responsibility was transferred to the Ministry of Agriculture and rural Development (MINADER) by Law No. 2003/003 of April 21, 2003. Since then, agriculture has represented about 44% of Cameroon's GDP and remains the main occupation of the labor force (56%), although only 15.4% of land is arable. Despite achieving more than 80% food self-sufficiency and stimulating exports to neighboring countries around the same period, poor land management and the isolation of arable areas have hindered local economic growth [15].

Constant agricultural evulation incorporates new methods such as mechanization and chemical use. While mechanization has advantages, it does not fully address the needs of local populations, most of whom depend on subsistence farming and face limitations due to land morphology. Pesticides, often considered affordable, are widely used to overcome these challenges [20].

According to Cameroon's National Profile on Chemical Management (2012), seven out of the country's ten regions hold pesticide stocks, with the Far North Region accounting for the largest share (0.6 tons, nearly 23%). The most common pesticides include lindane (55%) and endosulfan (37%). In Mokolo Municipality, located in the Far North Region, pesticides are used for various crops such as maize, millet, and vegetables mainly to reduce labor time and effort [5]. However, this practice generates environmental, social, and economic effects, including species mortality and skin diseases.

Here, pesticide use particularly in market gardening is widespread, with significant annual tonnage posing risks to environmental health, farmers' and consumers' health, as well as weakening the local economy [16]. Misuse, often driven by yield demands and lack of training, exacerbates these risks. While nearly 95% of pesticides are used for agricultural purposes, human exposure also results from the direct use of antiparasitic products and obsolete or banned chemicals [2].

The Far North Region like the rest of Cameroon has a remarkable expansion of market gardening [21], with cultivated areas ranging between 5,000 and 15,000 hectares depending on climatic conditions and years. This growth is fueled by population increase driven in part by the influx of refugees and internally displaced persons as well as the rising demand for condiments. Mokolo Municipality is well known for the quality of its condiments and food crops, which extend beyond its borders. In villages such as Mandaka, Mokong, Boula, Gouloua, Minglia, Mayo-Lade, and Gawar, about 80% of the population is engaged in market gardening. At every stage of production, chemical products are applied to control weeds, fight insects, and maintain crop health. However, this practice is inseparably linked to pesticide use, contributing to an alarming increase in diseases [8].

The impacts of pesticides on vegetable production are now a major concern and a growing source of anxiety at the local level. Soil fertility is maintained only through chemical inputs, and crops deteriorate quickly when treatments are reduced. Moreover, due to their toxicity, pesticides further degrade residential lands and gardens, thus posing heightened risks to the health of both rural and urban inhabitants. The abusive and often uncontrolled use of these substances also increases the likelihood of both short- and long-term diseases [25].

To effectively address this issue, it is essential to establish an inventory of the different types of pesticides in use, in order to analyze their effects on local farming systems. The purpose of this article is therefore to identify and evaluate the impacts of pesticides on crop production, as well as their environmental, economic, and health-related consequences.

2. Materials and Methods

2.1. Study Area Location

The study area is focused on Mokolo Municipality, located in the Far North Region of Cameroon. Mokolo lies between 10°28' N and 13°56' E and 10°54' N and 14°45' E, and is bordered to the north by the municipalities of Koza and Mozogo, to the east by Gazawa and Soulede-Roua, to the west by Nigeria and Bourha, and to the south by Mogode and Hina. Its Sudano-Sahelian climate, diversified soils, and dense hydrographic network make it a favorable zone for the cultivation of sweet potatoes, fruit trees, and market gardening crops. With an estimated population of 531,799 inhabitants in 2023, 42% men and 58% women alongside 73,887 residents in the Minawao Camp, the Municipality represents a major market for both the production and consumption of food crops in the Region (Figure 1).

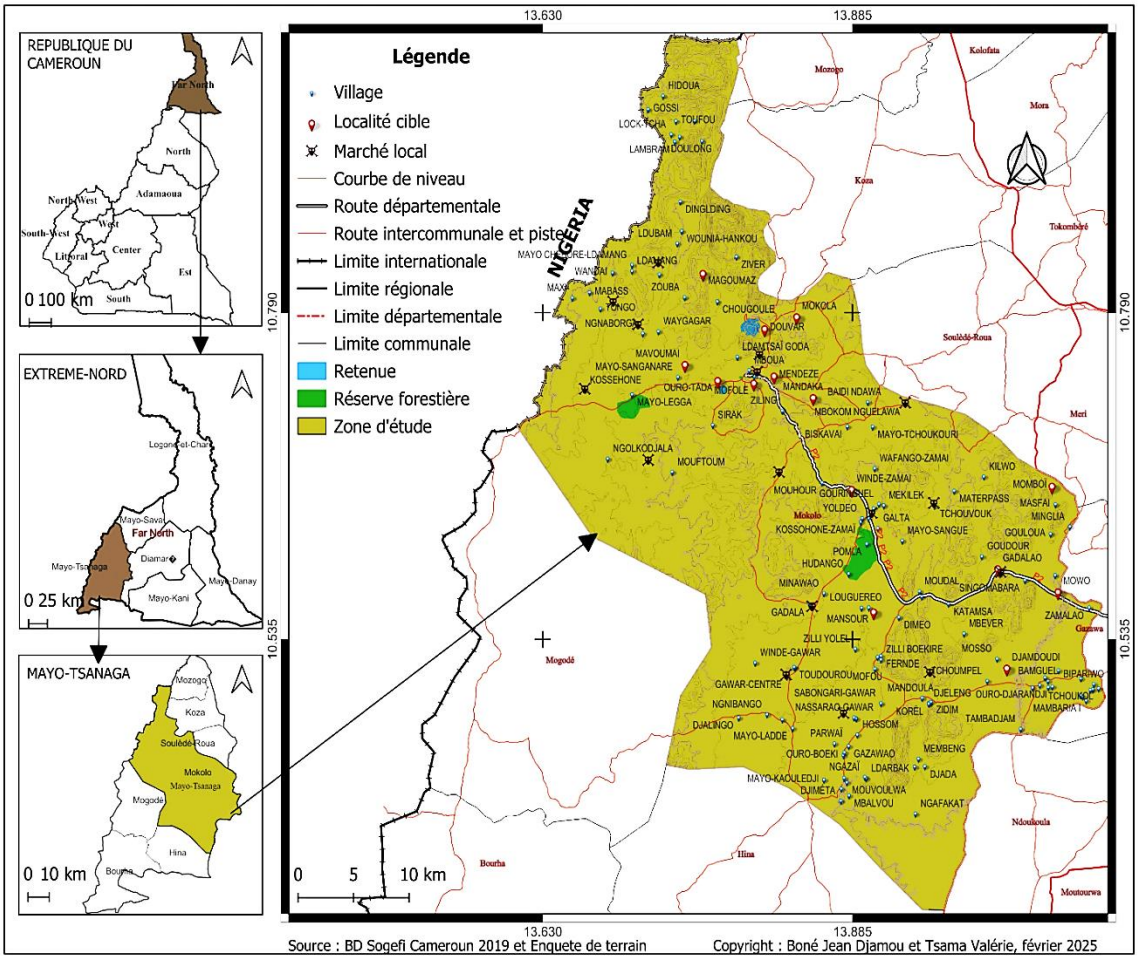


Figure 1. *Map of the study site.*

The study area, illustrated in Figure 1, is characterized by the cultivation of various vegetables such as parsley, celery, tomato, onion, cabbage, chili, lettuce, eggplant, okra, carrot, bell pepper, zucchini, and cucumber. It stands as one of the major production centers in the region, supported by several local markets that drive the municipality's socio-economic life.

2.2. Sampling

This study is based on a rigorous methodological approach combining field surveys and interactions with key actors in market gardening. Farmers were selected according to two predefined criteria: regular practice of market gardening and pesticide use on site. The sample size was determined using Slovin's formula:

$$n = \frac{N}{1+Ne^2}$$

Where, n = sample size, N = population size, and e = margin of error (e.g., 5% = 0.05).

For a population of 260 farmers, the calculated sample was 158, distributed across 13 localities (≈12 per locality).

$$n = \frac{260}{1+260\ x\ (0{,}05)^2} = 157{,}58$$

The activity is largely driven by youth, with 40% of respondents aged 25–35. Education levels remain low: 35% have only primary education, 34% have no schooling, 26% completed secondary school, and only 5% hold a university degree. Over half of the respondents reported 2–4 years of experience in market gardening.

Sixteen local markets supply pesticides, reflecting wide accessibility and significant chemical use. In addition, qualitative interviews were conducted with Municipal authorities, NGOs, policy makers, and development partners to assess their initiatives, engagement, and influence on farming practices. The sample included farmers in Common Initiative Groups (CIG), traders, retailers, intermediaries, transporters, economic interest groups, consumers, and institutional representatives (DDADER, the Municipality, and the Cereal Board), as well as development partners such as Center for Self-Help for Sustainanable development (CAPROD) and Programme for the Improvement of Compititiveness of Fam-

ily Agro-pastoral Farms (ACEFA) (Table 1).

Table 1. *Key Informants.*

Category	Frequency	%
Farmers (market gardeners)	108	52.2
Crop resellers	67	32.4
Retailers & intermediaries	5	2.4
Pesticide traders	5	2.4
Consumers (households & restaurants)	5	2.4
Transporters	5	2.4
Local organizations (CIG)	7	3.4
Municipal officials	2	1.0
DDADER officials	1	0.5
Project/Program managers	3	1.4

Source: Field survey, 2025

The sample is largely composed of farmers (52.2%) and resellers (32.4%), who play a central role in the production and marketing chain. Retailers, pesticide traders, and consumers are underrepresented (2.4% each), while institutional and local organization representatives account for only 5.3%, reflecting limited involvement in sustainable agricultural management.

Data analysis relied on Kobo Collect and Excel for processing quantitative and qualitative survey data, while Quantum Geographic Information System (QGIS) was used for spatializing georeferenced information. The primary objective was to assess the impacts of pesticide use on market gardening crops in Mokolo Municipality.

3. Results and Discussion

The results of study are presented in three main sections: the farmers' motivations for using pesticides, the types and application methods of these products, and the immediate harmful effects associated with their use.

3.1. Farmers' Motivations for Pesticide Use

The use of pesticides is driven by personal beliefs and the challenges faced by farmers, aiming to support labor and improve crop yields.

3.1.1. Crop Protection Against Pests

Insect pests are perceived as a threat to crops and human well-being, causing significant damage and potentially spreading diseases. To protect their harvests, farmers use insecticides to reduce pest populations (Figure 2).

Source: Field surveys, 2025

Figure 2. *Sorting of Insect-Affected Crops in Mandaka.*

This figure (Photos above) vividly illustrates the sorting of crops damaged by insects in Mandaka, highlighting the extent of post-harvest losses. It reflects the constant pressure pests place on market gardening, forcing farmers to discard part of their harvests before sale and/or resort to insecticide use.

3.1.2. Insect Proliferation

The data indicate a high infestation of pests primarily affecting tomatoes, peppers, cabbage, carrots, parsley, and celery, with up to 68% of crops impacted. Key pests include

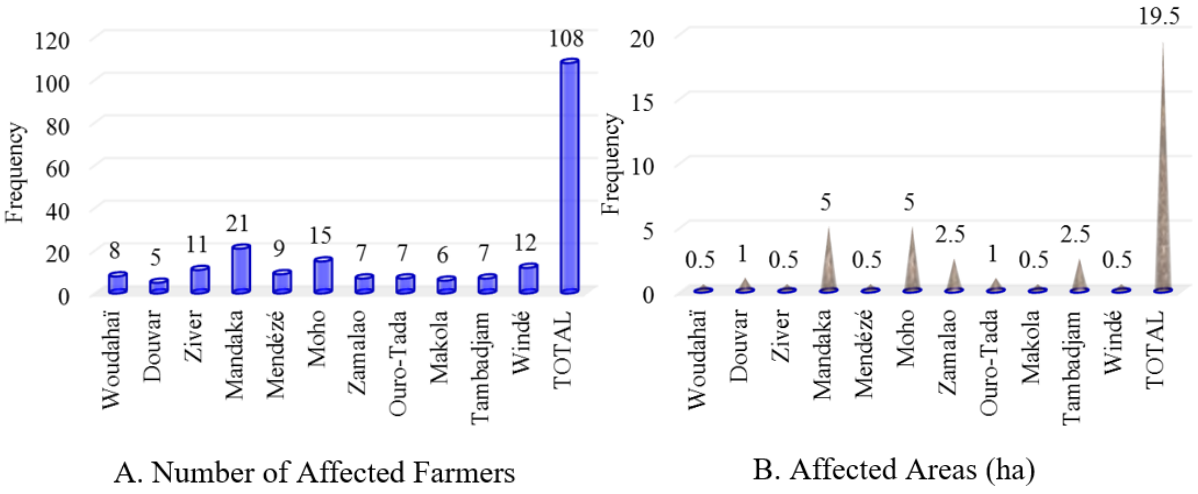
Tuta absoluta (tomato leafminer) and *Bemisia tabaci* (virus-carrying whitefly) for tomatoes; *Aphis* spp. on parsley and celery; *Helicoverpa armigera* and thrips on peppers; *Plutella xylostella* and *Pieris rapae* on cabbage; *Nasonovia ribisnigri* and *Thrips tabaci* on lettuce; and *Thrips tabaci* along with *Delia* spp. flies damaging onion roots and bulbs (Figure 2).

The data reveal a severe pest infestation affecting mainly tomatoes, peppers, cabbage, carrots, parsley, and celery, with the latter two impacted by 68%. Major pests include *Tuta absoluta* (tomato leafminer) and *Bemisia tabaci* (virus-transmitting whitefly) on tomatoes; *Aphis* spp. on parsley and celery; *Helicoverpa armigera* and thrips on peppers; *Plutella xylostella* and *Pieris rapae* on cabbage; *Nasonovia ribisnigri* and *Thrips tabaci* on lettuce; and *Thrips tabaci* with *Delia spp*. flies damaging onion roots and bulbs (Figure 3).

Source: Field surveys, 2025

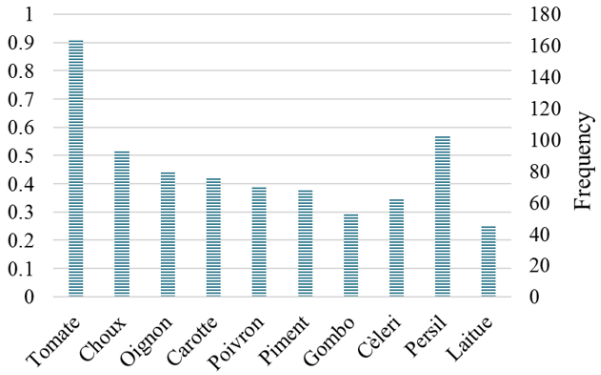
Figure 3. *Damage to Curly Parsley by Aphis spp. and Delia spp. in Mandaka.*

Figure 3 shows the damage caused to curly parsley by the harmful flies *Aphis spp.* and *Delia spp.* in Mandaka. The white spots (highlighted in red) represent plants attacked by these tiny insects, clearly illustrating their impact in weakening foliage and compromising crop growth. Such damage not only affects the quality of agricultural products but also reduces their market value. The following matrix summarizes the crop infestations (Figure 3).



A. Number of Affected Farmers

B. Affected Areas (ha)



C. Affected Crops

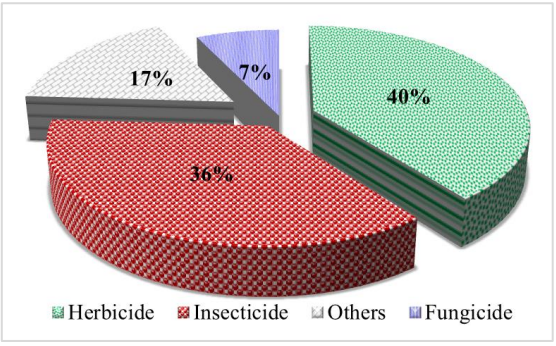
Source: Field Survey, 2025

Figure 4. *Pest Damage by Locality.*

The extent of pest damage across different localities is significant, as shown (Figure 4) by the number of affected farmers (108), the crops impacted, and the total area concerned (19.5 ha). Crops such as tomato, parsley, cabbage, and lettuce are among the most frequently targeted. Mandaka stands out with the highest number of affected farmers (21) over 5 ha, indicating severe damage intensity in this area and underscoring the regional importance of the problem.

3.1.3. Weeding

Farmers use herbicides for weeding to boost production while saving time and money compared to manual tillage. Direct seeding with herbicides is more efficient and less labor-intensive, especially for those cultivating at least 1.5 hectares, notably onion producers (Figure 5).



Source: Field Survey, 2025

Figure 5. *Herbicide Usage Rate in Onion Farming.*

Figure 5 shows the use of herbicides in onion cultivation in 2025. It indicates that many growers use herbicides to control weeds and increase yields. There are regional differences in herbicide use, reflecting varied agricultural practices in the Far North Region of Cameroon.

3.2. Types of Pesticides Used

Numerous pesticides identified based on the needs of growers in Mokolo were sold in the markets (Figure 6). These include Glyphosate, Atrazine, 2,4-D Amine salt, Cypermethrin, Imidacloprid, and Emamectin. Some banned pesticides, such as Paraquat and "Dragon", are also in circulation.

Figure 6. *Some pesticides for sale at the Mokolo market.*

Source: Field surveys, 2025
X: 13,8064 Y: 10,74386 Z: 809 Field survey 2025

Figure 6 shows an assortment of pesticides on display. During this survey, it was observed that vendors lacking a government-approved license. Currently, the unregulated sale of these products is prohibited in Cameroon, and these sellers have no knowledge of the products' composition. Their primary motivation is to make money, driven by high demand for pesticides from farmers.

The pesticides in the target localities each have a specific purpose, as indicated by their trade names, as highlighted in Table 2.

Table 2. Types of Pesticides Used by Growers in the Target Localities.

Pesticides family	Commercial Names	Frequency of Use	Role of Pesticides on Crops
Herbicides	Glyphosate	High	Non-selective herbicide, eliminates weeds before cultivation.
	2,4-D Amine Salt	Medium	Selective herbicide against broadleaf weeds (dicots).
	Runtup	High	Non-selective herbicide, eliminates weeds before cultivation.
	Atrazine	Medium	Selective herbicide used for corn and other crops.
	Oxadiazon	Low	Pre-emergence herbicide to control grasses and broad-leaf weeds.
	Diuron	Low	Long-lasting herbicide, used pre- and post-emergence.
	Nicosulfuron	Medium	Selective herbicide against grasses and some broadleaf weeds.
Insecticides	Chlorpyrifos-Ethyl	Medium	Broad-spectrum insecticide against soil-borne and aerial pests.
	Acetamiprid	High	Systemic insecticide against aphids and whiteflies.
	Cypermethrin	High	Contact insecticide against caterpillars, thrips, and beetles.
	Deltamethrin	High	Broad-spectrum insecticide against flying and crawling insects.
	Imidacloprid	Medium	Systemic insecticide against aphids and whiteflies.
	Lambda-cyhalothrin	Medium	Contact insecticide against foliar pests.
	Permethrin	Low	Contact and ingestion insecticide against caterpillars and beetles.
Fungicides	Copper Hydroxide	Medium	Preventive fungicide against fungal and bacterial diseases.
	Mancozeb	High	Preventive fungicide against downy mildew and early blight (Alternaria).
	Metalaxyl + Copper Oxide	Medium	Systemic fungicide against downy mildew and soil-borne diseases.
	Dimethomorph + Copper Oxide	Medium	Preventive and curative fungicide against downy mildew.

Source: Field Survey, 2025

Table 2 shows pesticides used by growers, their use and frequency of use. Herbicides, insecticides, and fungicides, are broadly employed by farmers to protect crops in the Municipality of Mokolo. For instance, the herbicides Glyphosate and Runtup, are the most widely used to eliminate weeds before cultivation in the fields. It was observed that some products are more popular than the others due to their efficacy or cost.

3.2.1. Herbicides

Growers use herbicides to eliminate weeds in their fields. Their effectiveness depends on the dosage, the method of application, and the timing of the treatment. Different herbicides, such as Glyphosate, are available. Some target only weeds, while others destroy all vegetation before sowing. Ganava, a grower in Woudaha ï uses herbicides based on the weather, cost, and the size of his farm (Figure 7).

A B

Figure 7. *Some Herbicides Found in Local Markets.*

Source: Field surveys, 2025
X: 13,8064 Y: 10,74386 Z: 809 Field Survey 2025

This figure displays herbicides found in the markets of the Mokolo municipality. These include, among others, Supercot, Super Machete, and a post-emergence liquid herbicide called Finish. Most of these pesticides have Glyphosate as their active ingredient.

Foliar herbicides kill plants by being absorbed through the leaves, while soil-acting herbicides prevent weeds from growing. Growers in Mokolo use them extensively, though their usage depends on the cultivation area (Figure 8).

Figure 8 shows that large farms use more herbicides to control weeds, while small farms prefer alternative methods or use less. This difference is due to the need for effective weed management over large areas, where manual weeding is not cost-effective.

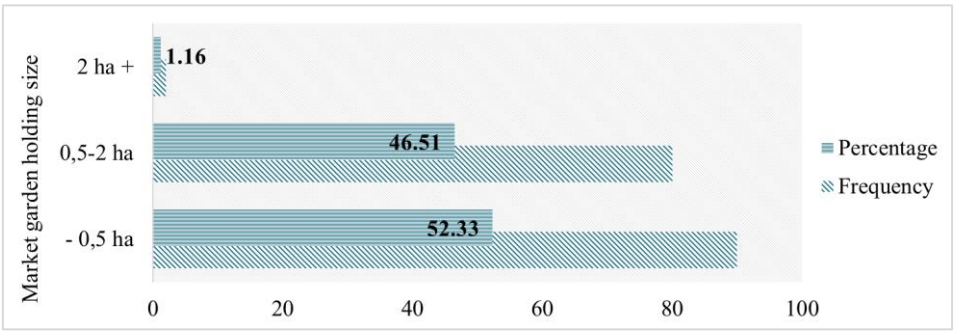


Figure 8. *Farm size and herbicide use by Market Gardeners.*

Access to chemical products depends on the growers' resources. However, banned herbicides, often of dubious quality, are sold illegally in local markets. Some, like glyphosate, are widely used despite the fact that the Ministry of Agriculture and Rural Development (Table 3) do not approve them.

Table 3. *Illegal Herbicides Discovered for Sale.*

No.	Trade Name	Active Ingredient	Herbicide Type	Remarks
01	Dragon	Paraquat Dichloride	Contact Herbicide	Highly toxic, banned in several countries
02	Glyspring	Glyphosate	Systemic Herbicide	Used for total weed control
03	Kill Off	Glyphosate	Systemic Herbicide	Non-selective action on plants

No.	Trade Name	Active Ingredient	Herbicide Type	Remarks
04	Pentagon	Paraquat Dichloride	Contact Herbicide	Fast-acting but hazardous to health
05	Amino Force	2,4-D Amine Salt	Selective Herbicide	Used against broadleaf weeds (di-cots)
06	Buffalo 80	Glyphosate	Systemic Herbicide	Used to eliminate weeds

Source: SODECOTON Mokolo sector and field surveys, 2025

Unapproved herbicides, such as glyphosate and paraquat, pose risks to health and the environment. Paraquat, which is highly toxic and banned in many countries, is still sold under brand names like Dragon and Pentagon. Herbicides are divided into two categories: contact herbicides, which act on the exposed parts of plants, and systemic herbicides, which are absorbed to destroy the entire plant.

Selective herbicides target certain plants without harming others, but they often escape regulation, particularly liquid herbicides (Figure 9).

Figure 9. *Unapproved Pesticides Found on the Market.*

Source: Field surveys, 2025
X: 13,8064 Y: 10,74386 Z: 809 February 2025

Figure 9 shows that banned liquid herbicides remain available on the market, particularly those containing paraquat dichloride, a highly toxic substance prohibited in many countries. Sellers claim their primarily source and supplies is from Nigeria and sometimes from Douala. However, 90% of the stakeholders surveyed are unaware that these products are unapproved, given their toxicity. This poses a danger to the population as we still find unapproved pesticides in the markets

3.2.2. Insecticides

Insecticides, designed to eliminate insects, larvae, and eggs, are divided into organic (such as organophosphates, carbamates, and pyrethroids) and inorganic types. Some have been withdrawn due to their toxicity, leading to a search for eco-friendly solutions. Biological control methods are also available. Various insecticides, including traditional products, pyrethroids, and new formulations, are used against different pests such as bollworms (Table 4).

Table 4. Typology of Insecticides Used by Growers.

Active Ingredient	Trade Names	Pioneer Localities	Targets
Cypermethrin Ibis 360 EC Cigogne	Cypalm 360 EC Ibis 360 EC Cigogne	Mandaka, Mokola, Zamalao, Mendeze, Ouro-Djarendji, Gadalao	Boring and sucking caterpillars
Emamectin + Teflubenzuron	Tema 135 WDG	Mandaka, Mombo ï	Boring caterpillars
Emamectin Emacot 100 WDG Emacot Pro	Expert 50WG Emacot 100 WDG Emacot Pro	Mokola, Mendeze, Moho, Djamdoudi, Mandaka, Mokolo, Zamalao, Mendeze	Boring caterpillars
Rynaxypyr Prevathon 5SC	Coragen 20SC Prevathon 5SC	Mandaka, Mokola, Zamalao, Mendeze, Woudaha ï	Caterpillars, sucking pests, and birds
Spinetoram + Acetam-iprid	Cobra 120EC	Galta	Boring caterpillars, whiteflies
Cyhalodiamide	Imperator	Galta	Boring caterpillars
Indoxacarb Moran 30 DF Indoxan 150 EC	Patriot 150 EC Moran 30 DF Indoxan 150 EC	Mandaka, Ouro-Tada, Mokolo	Boring caterpillars
ACARICIDES			
Acetamiprid Benji 700 WG Kriss 200 SL	Optimal 20 SP Benji 700 WG Kriss 200 SL	Woudaha ï, Ziling, Mowo	Whiteflies

Source: Field surveys, 2025

This table shows the insecticides used by growers, highlighting the diversity of active ingredients, brand names, and target pests. This variety underscores the importance of pest control in local market gardening, but raises questions about pesticide use and the associated environmental risks. Dichlorvos is recommended for eliminating ants and other harmful insects.

3.2.3. Fungicides Used Primarily for Seed Treatment

Fungicides are phytosanitary products designed to control, repel, or eliminate harmful fungi to crops by combating diseases such as downy mildew and molds. They are divided into two categories: preventive and curative. Among the best-known brands are Fungiforce, Metazeb Cotomil, Cotzeb, Eagrowcare, Fungioff, Kalao, and Mancozeb, each with specific areas of use (Table 5).

Table 5. Typology of Fungicides Used by Farmers.

Fungicide Classes	Trade Names	Zones	Number of Growers	Application Area
Metalaxyl + Copper Oxide	Cotomil, Fungioff, Fungiforce	Mandaka	45	Seed and carrot nursery treatment
Copper Hydroxide	Kalak	Mowo	30	Onion seed treatment

Fungicide Classes	Trade Names	Zones	Number of Growers	Application Area
Mancozeb	Manco-Sam, Metazeb, Cotzeb	Mowo, Zamalao	50	Seed treatment and market gardening
Dimethomorph + Copper Oxide	Eagrowcare	Woudaha ï Oura	40	Seed treatment and market gardening

Source: Field surveys, 2025

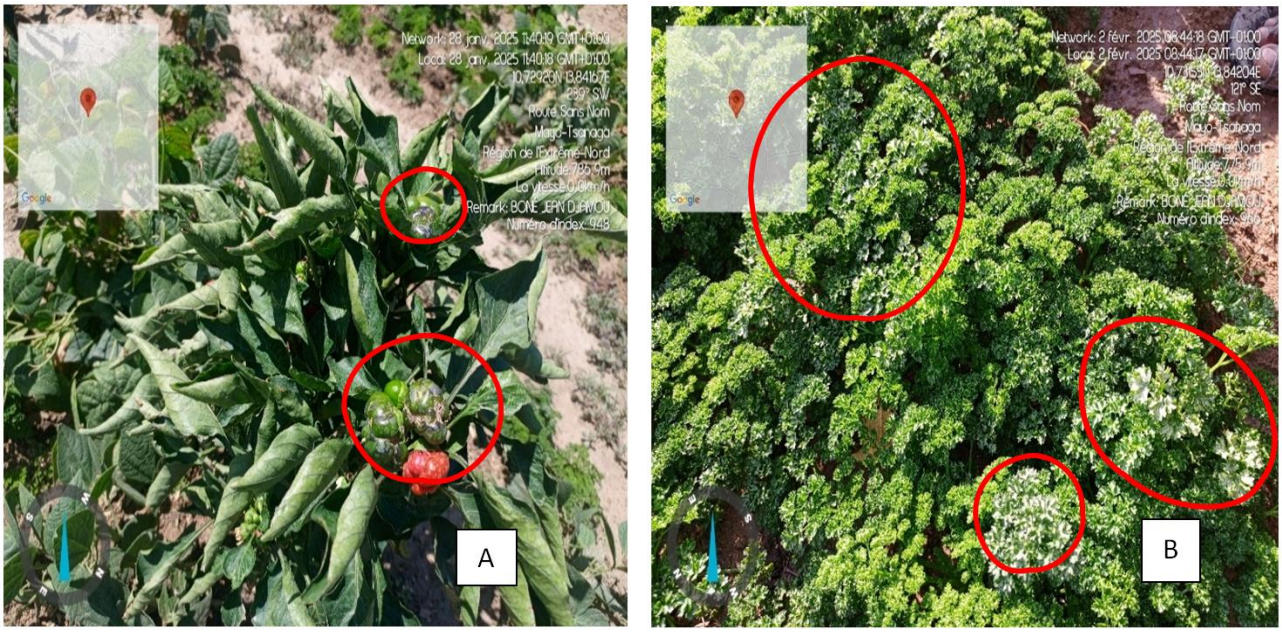
The diversity of fungicides varies by locality. In Mandaka, 45 growers use Metalaxyl and Copper Oxide. In Mowo, 50 prefer Mancozeb, while 30 use Copper Hydroxide. In Woudaha ï 40 producers choose Dimethomorph. These choices reflect the specific phytosanitary needs of each region.

3.3. Acute Effects of Pesticides

The use of pesticides in market gardening is a common practice to ensure crop protection against pests, diseases, and weeds. However, this practice has multiple consequences, which can be both positive and negative.

3.3.1. Impacts of Pesticides on Crops

Excessive or inappropriate use of pesticides leads to crop damage, including reduced growth and product quality, as well as increased dependence on pesticides. This promotes the emergence of resistance in pests, necessitating more expensive and concentrated products (Figure 10).



Source: Field surveys, 2025

Figure 10. *Crop Damage by Resistant Insects.*

Pests gradually develop resistance, making pesticides less effective. This forces producers to use higher doses or formulations that are more potent, thereby increasing production costs. This phenomenon exacerbates farmers' financial vulnerability and influences the sustainability of agricultural systems.

Collected data show that direct application of products on vegetables leaves at least one directly detectable pesticide residue, notably in 88.7% of parsley samples, 59% of celery, and 73.7% of peppers, cabbages, and onions. These residues impact human health.

3.3.2. Environmental Impacts

Pesticide accumulation in soils severely affects the chemical and biological composition of plots. Some products containing toxic substances persist for long periods, affecting

soil organisms and reducing natural fertility (Figure 11).

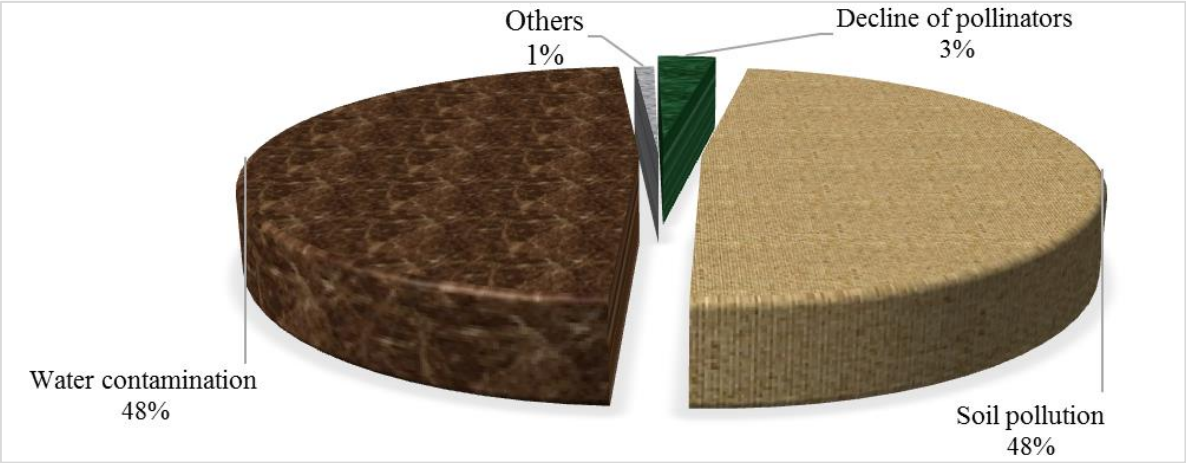


Figure 11. *Major Environmental Challenges Related to Pesticide Use.*

Soil pollution and water contamination each account for 48% of the environmental effects resulting from pesticide use in the surveyed regions. The decline of pollinating agents, though less frequently cited (11%), remains a critical issue for biodiversity. Only 3% of responses mentioned other environmental impacts (Figure 11). These results highlight the urgent need to implement sustainable pesticide management measures to mitigate their harmful effects.

These chemicals, leached by rainfall or irrigation, contaminate groundwater and water bodies, threatening water quality and aquatic ecosystems.

At the local level, pollution of water sources is a significant concern, accounting for over 36% of identified causes. This pollution stems from the proximity of seasonal riverbeds and wells to agricultural areas. The situation is worsen by spills of hydrocarbons used for pumping nearby rivers. These water quality issues pose serious threats to the health of local communities, including waterborne diseases and intestinal parasitic infections.

3.3.3. Economic Impacts

Proper use of approved pesticides reduces costs and increases yields for producers, while excessive or inappropriate use leads to additional expenses (Figure 12).

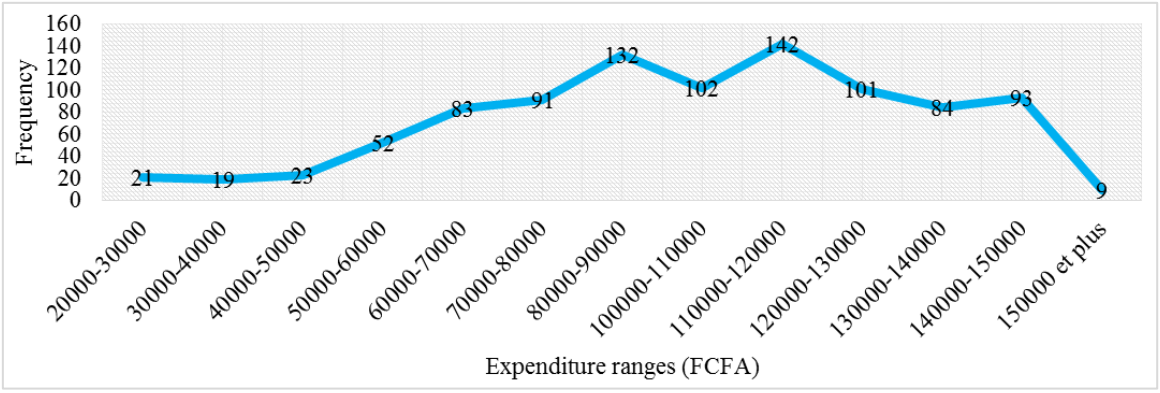


Figure 12. *Farmers' expenditures related to pesticide purchases.*

The trend curve of farmers' expenditures on pesticide purchases reveals a strong concentration of spending in the higher ranges, particularly between 80,000 and 90,000 FCFA, and between 110,000 and 120,000 FCFA. In contrast, the lower ranges (20,000–30,000 to 70,000–80,000 FCFA) show much lower frequency, indicating that most farmers invest significant amounts in pesticides.

This highlights the importance of production costs linked to pesticide use, making vegetable farming mainly accessible to individuals with substantial financial means, as emphasized by the President of the Condiment Producers' Cooperative of Mandara.

3.3.4. Social and Health Impacts

Pesticide using farmers face health risks such as skin irritations and respiratory disorders, exacerbated by a lack of training and protective equipment. Pesticide residues on fruits and vegetables also harm consumer health. Some farmers report endocrine disorders and neurodegenerative diseases, underscoring the urgent need to safeguard food quality. Figure 13 presents the results of farmers reporting side effects related to pesticide use.

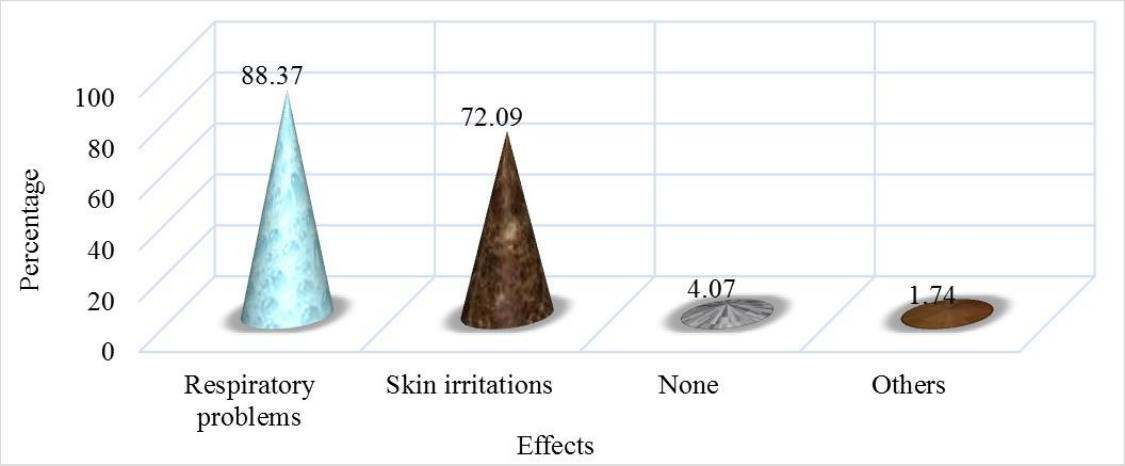


Figure 13. *Health effects of pesticides.*

This bar chart reveals that exposure to pesticides mainly leads to respiratory problems, reported by more than 88% of the farmers surveyed, as well as skin irritations in 72% of them. Only 4% of participants reported no side effects, while 1% mentioned other less common effects. These findings highlight the significant health impact associated with pesticide use, underscoring the need for greater vigilance and protective measures to minimize these adverse effects.

4. Discussion

Heavy pest and disease pressure, worsened by drought and high temperatures that weaken crops, mainly drive the intensive use of pesticides in vegetable farming in Cameroon's Far North Region. Similar findings by [1, 13] indicate that 87% of farmers rely on pesticides to reduce economic losses, particularly in high-value crops such as tomato and onion [23]. Limited access to training on biological alternatives and the influence of neighbors' practices, along with aggressive marketing by pesticide vendors [4], reinforce this dependence.

Pesticides used fall into three categories: insecticides, fungicides, and herbicides. According to the World health organisation [17], insecticides account for about 65% of use, dominated by highly toxic organophosphates (Chlorpyrifos) and pyrethroids (Lambda-Cyhalothrin). Fungicides (25%), such as mancozeb and chlorothalonil, are suspected to act as endocrine disruptors [6]. Herbicides (10%) include glyphosate, which is banned in neighboring countries like Chad, Guinea, and Gabon yet is suspected to cause respiratory problems [3, 22, 25]. Nearly 70% of these pesticides are obsolete or banned in the European Union (EU) member countries but still marketed in Cameroon due to weak regulation [3, 22].

Application methods, mainly manual spraying, often ignore prescribed doses and combine three to five products, increasing toxicity, especially when mixing insecticides and fungicides. Lack of training leads to overuse or usage outside the manufacturer's recommendation, with nearly 90% of farmers applying pesticides without gloves, masks, or boots. Mismanagement of empty containers further pollutes soils and water [3, 8, 22], who report frequent dumping of pesticide waste into fields and streams.

The impacts are multidimensional: environmentally, pesticides reduce pollinators and contaminate soil and water resources. Even [17] notes Chlorpyrifos residues in wells reaching 0.8 mg/L, far above the recommended 0.01 mg/L, while bee populations in farming zones have dropped by 40% [26, 27]. Economically, high pesticide costs and health consequences undermine long-term profitability.

Health effects are significant, with farmers commonly suffering from respiratory problems, skin irritations, and acute poisoning [11]. Kidney cancer cases have been reported in Maroua [18]. This dependency fosters both food and financial insecurity, hindering the adoption of sustainable practices. Moreover, health burdens and water contamination risks can exacerbate tensions between villages.

5. Conclusion

This study examined the effects of pesticides used in vegetable farming in the Municipality of Mokolo, in Cameroon's Far North Region. The findings from the field surveys tar-

geted interviews and observations clearly show that pesticide use in Mokolo municipality has alarming environmental, health, and socio-economic consequences. Soils and water sources are contaminated, agents of pollination are gradually disappearing, and farmers are exposed to toxic substances, threatening not only ecosystem sustainability but also public health. Moreover, reliance on pesticides increases production costs and limits sustainable alternatives, keeping producers in a state of economic vulnerability.

In light of these challenges, it is essential to promote agroecological practices, strengthen regulations on the import and use of pesticides, and raise awareness among farmers as well as local populations about environmentally friendly and health-conscious alternatives.

Abbreviations

ACEFA	Programme for the Improvement of Compititiveness of Family Agro-pastoral Farms
CAPROD	Center for Self-Help for Sustainanable Development
CIG	Common Initiative Groups
CNPS	National Social Insurance Fund
EU	European Union
MINADER	Ministry of Agriculture and rural Development
NGOs	Non-Governmental Organizations
QGIS	Quantum Geographic Information System
SODECOTON	Cotton development Company of Cameroon
WHO	World Health Organisation

Conflicts of Interest

The authors declare no conflicts of interest.

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