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Mercury Levels, Soil Properties and Farming Practices in Cabbage-Growing Farms of Buguias, Benguet: A Monitoring Report for Semi-Temperate Conventional Farming in Northern Philippines

Cristy R. Cadiogan*, Alexander W. Fagyan, Carlito P. Laurean, and Gennie B. Soyon

College of Agriculture, Benguet State University, Philippines
*Corresponding author email address: cristycadiogan@gmail.com DOI: https://doi.org/10.70884/mjsir.v86i1.611

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Abstract

Semi-temperate conventional farming has been documented to have adversely affected the soil properties, including mercury accumulation, in the Cordillera Administrative Region (CAR), Northern Philippines. However, the monitoring of this adverse phenomenon had been alarmingly sparse amidst its potential health and environmental implications vis-à-vis the economic significance of the semi-temperate vegetable production in the region. To address this, the study reassessed the mercury (Hg) levels, soil properties, and farming practices in selected agricultural farms in Nan-agto, Natubleng, Buguias, Benguet, 15 years after mercury concentrations were reported to exceed threshold levels in soil, water, and crops in 2007. Results revealed that mercury was no longer detectable in 12 of the 15 soil samples and in all cabbage head samples, suggesting a significant decline in Hg levels. Favorable soil pH (5.81–6.97), marginal to adequate OM, and high CEC may have contributed to reduced Hg mobility and bioavailability. Interviews revealed adherence to good agricultural practices (GAP), such as the use of non-mercury-containing pesticides and the application of lime and organic matter. The absence of Hg in crop and soil is attributed to the banning of mercury-based agrochemicals and the possible phytoremediation effect of cabbage. This study underscores the need to maintain good agricultural practices (GAP) and reinforces the importance of long-term environmental monitoring for the important and iconic semi-temperate vegetable farming of CAR.

Introduction

Agriculture remains a foundational pillar of the Philippine economy, utilizing approximately 13.32 million hectares of land (Miraflor, 2020). Within the Cordillera Administrative Region (CAR), Benguet stands as a primary agricultural hub, second only to mining, and serves as the nation's "Salad Bowl" by contributing the vast majority of the country's semi-temperate crops, such as cabbage (Philippine Statistic Authority [PSA], 2017). The historical development of this industry dates back to the early 1900s during the American colonial period, when the introduction of temperate seed varieties, coupled with the region's high-altitude, cool climate, transformed the mountainous terrain into a highly specialized agricultural landscape. Today, this high-altitude vegetable production system is iconic to CAR; a global overview via Google Scholar reveals that while localized semi-temperate vegetable studies exist in select high-altitude zones of India and Australia, CAR remains the predominant global focus for this specific type of tropical-montane agroecosystem.

However, a critical gap exists in the current body of literature: the overwhelming majority of these regional studies focus strictly on maximizing crop yield and production economics, largely disregarding the severe environmental consequences, such as soil degradation, intensive pesticide runoff, and heavy metal accumulation, that threaten the long-term sustainability of this unique ecosystem.

The extensive use of agrochemicals, including fertilizers, pesticides, and insecticides, to ensure high crop yields has led to environmental concerns, particularly heavy metal contamination. Mercury (Hg), a toxic heavy metal, can accumulate in soil, leach into groundwater, and enter the food chain via plant uptake (Rice et al., 2014; World Health Organization [WHO] & Food and Agriculture Organization of the United Nations [FAO], 2025). It is highly persistent in the environment, showing a slow degradation rate (Turull et al., 2018; Kimura & Miller, 1964), while its bioaccumulative nature poses long-term threats to ecosystems and human health (Valenti et al., 2005; Harada et al., 1999). It is known to cause neurological, digestive, and reproductive damage, especially in vulnerable populations (WHO, 2017; Gworek et al., 2020). For plants, Hg negatively impacts growth, enzymatic activity, and microbial populations essential for soil fertility (Hamim et al., 2019; Schaller & Diez, 1991).

In 2007, Laurean courageously revealed the elevated mercury levels in soil, water, and vegetables that exceed threshold limits in the region, specifically in Natubleng, Buguias, Benguet. However, after that baseline study, no follow-up monitoring had been conducted, which is very alarming amidst mercury's potential health and environmental implications vis-à-vis the economic significance of the semi-temperate vegetable production in CAR. Recent environmental monitoring of heavy metals in the region includes the study of Napaldet and Buot (2020), who monitored lead (Pb) and mercury (Hg) levels in the Balili River, a major agricultural irrigation source traversing Baguio City and La Trinidad, and evaluated local aquatic macrophytes for their phytoremediation potential amidst persistent heavy metal risks.

These limited studies on heavy metal contamination in the region, particularly those in semi-temperate vegetable farms, highlight the immediate need to monitor their levels, given their health and environmental significance, as a basis for the development of heavy metal policy in the region. Given the 15-year gap since the previous assessment, this study aims to reassess Hg levels in the cabbage-growing area in Natubleng, Buguias, Benguet, and investigate factors that could have influenced the mercury levels, including soil properties, farming practices, and crop interactions. The study could help elucidate how mercury levels change over time in long-term farming areas and aims to support better decisions in agriculture and environmental health, particularly in the under-monitored yet iconic semi-temperate vegetable farming landscape of CAR.

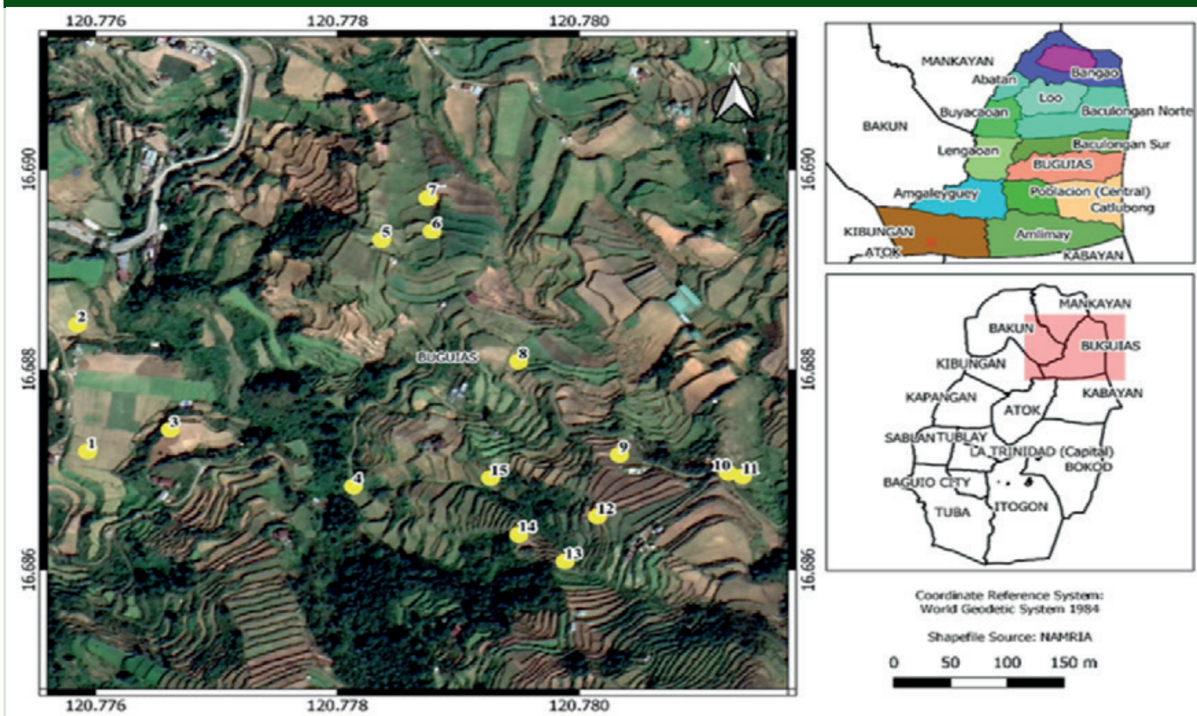
Materials and Method

The study was conducted in Nan-agto, Natubleng, Buguias, Benguet (Figure 1), a known vegetable-producing area in the Cordillera region. Sampling and analysis were carried out from July to October 2022. This site was previously assessed by Laurean (2007), who reported elevated mercury concentrations in soil and crops. However, the absence of georeferenced data in the 2007 study precluded the exact replication of the original sampling sites. Consequently, the present study selected 15 representative farms within the same vicinity, characterized by long-term cabbage cultivation, to ensure comparability in terms of cropping history and elevation.

A total of 15 composite soil samples were collected from 15 different farms. Each composite sample was derived from 10 sub-samples per farm taken from the topsoil (20–30 cm depth), where the majority of cabbage roots are concentrated (FAO, 2005). The sample size was determined based on the actual number of farms planted with cabbage during the sampling period; at the time of data collection, only 15 farms met the study

Figure 1

Location of Sampling Sites in Nan-agto, Natubleng, Buguias, Benguet, Philippines



criteria within the selected area. Approximately 1 kg of soil per composite sample was collected using a stainless-steel shovel and stored in clean plastic bags. Soil samples were immediately brought to the Benguet State University Soil Science Laboratory for air-drying, sieving, and analysis of physicochemical properties, while a separate portion was sent to CRL Environmental Corporation (Pampanga) for mercury testing using Cold Vapor Atomic Absorption Spectroscopy (CVAA). This method (CVAAS) is a widely recognized method for trace mercury analysis in soil and plant tissues due to its high sensitivity and selectivity. The technique allows detection of mercury at very low concentrations (typically in the μg/kg range) and provides reliable results. It uses the External Standard Calibration Method (also known as the external calibration curve) for mercury (Hg) analysis in soil and plant samples (U.S. Environmental Protection Agency, 2007)

Simultaneously, cabbage heads from the same 15 sampling locations were harvested. Only the marketable portions (i.e., cabbage heads) were collected, excluding roots. Each cabbage sample weighed approximately 300–500 grams and was stored in clean paper bags inside an icebox. These were also submitted to CRL Environmental Corporation for mercury analysis via CVAA.

Soil and Plant Analysis

Soil texture was determined using the pipette method as described by Gee and Bauder (1986). Soil pH was measured using the potentiometric method, with a 1:1 soil-to-water ratio and a calibrated pH meter. The organic matter (OM) content was analyzed using the Walkley-Black method, while the cation exchange capacity (CEC) was determined through the Ammonium Acetate method. For mercury analysis, concentrations in both soil and cabbage samples were measured using Cold Vapor Atomic Absorption Spectroscopy (CVAA), a technique well-suited for detecting trace levels of mercury in environmental and agricultural matrices.

The collected data on mercury content in soil and plant samples, as well as the soil's physical and chemical properties, were analyzed using descriptive statistics. These results were then compared with the maximum allowable mercury concentration standards and used in reference to the baseline established by Laurean (2007). To quantify environmental shifts over the fifteen-year interim, the pollution reduction efficiency (R%) was calculated using the following equation:

$$R(\%) = \frac{C_{2007} - C_{present}}{C_{700}} \times 100$$

While Laurean (2007) reported alarming mercury concentrations of up to 5.40 mg/kg in the soil, the present study recorded a maximum level of 0.1 mg/kg. This represents a 98.15% pollution reduction efficiency over the fifteen years, indicating significant temporal attenuation or shifting agricultural practices in the area.

Farmer Survey and Farming Practice Documentation

To document farming practices, structured interviews were conducted with the same 15 farmers from the sampled farms. A standardized questionnaire was developed and translated into the local dialect (Kankana-ey) to ensure clarity and cultural appropriateness. The survey collected information on farmers' demographics, crop management, pesticide and fertilizer usage, and historical practices. Interviews were conducted in person, with responses recorded immediately during farm visits.

Results and Discussion

Mercury Content of Soil

Fifteen years after the 2007 study by Laurean, which reported mercury concentrations of up to 5.40 mg/kg in soil, the present study recorded markedly lower mercury levels. Among the 15 farms sampled, only three exhibited detectable mercury at the reporting limit of 0.1 mg/kg, whereas the remaining 12 had no detectable Hg (Table 1). The findings suggest an apparent decline in soil mercury levels over time.

Several factors may account for the observed decline or non-detection of mercury in the soil after 15 years. One key factor is the ban on mercury-based agrochemicals by the Fertilizer and Pesticide Authority (FPA) in 2008, effectively limiting new sources of mercury contamination (FPA, 2020). Commonly used pesticides in Benguet, such as Tamaron, Endosulfan, DDT, Aldrin, and Gramoxone, were also prohibited along with other red-label pesticides, removing them from local markets (Lu, 2010; Billig, 2022). Additionally, international regulatory actions have contributed to reduced global availability. For instance, Thailand banned the production, use, import, and export of mercury-containing pesticides in 2005, followed by China in 2010, Japan in 2013, India in 2018, and Australia in 2020 (Schneider, 2021).

Cabbage production through the years may also have contributed to the phytoremediation of Hg. Continuous cropping over 15 years may have resulted in the gradual uptake and removal of trace amounts of Hg. Several studies show that Brassica species can uptake metals and retain them largely in their roots. These metals can then be transported throughout the plant, including to the head, which is the edible part (Li et al., 2017; Patra & Sharma, 2000). Brassica species, including cabbage, are known to uptake a variety of heavy metals, including cadmium (Cd), chromium (Cr), and lead (Pb), and other heavy metals, which may include mercury (Małecka et al., 2019). A study on Brassica juncea demonstrated its capacity to accumulate zinc and copper, confirming the genus' general aptitude for heavy-metal uptake (Islam et al., 2020).

Possible leaching of mercury in the soil can also be considered, particularly given the predominance of sandy loam soils in the study area with good drainage, which allows greater water infiltration (Jaja, 2016). High rainfall in the region may have facilitated Hg transport to lower horizons or nearby water bodies (Punia, 2020; Wuana & Okieimen, 2011). Volatilization may also play a role in mercury reduction in soil. Mercury can be converted into elemental mercury (Hg^0), a volatile form, especially under slightly acidic to neutral pH conditions and in the presence of certain microbial activity (Stefanowicz et al., 2014). The observed soil pH levels (5.81–6.97) and marginal to moderate organic matter content could support such microbial processes.

In addition, the adoption of proper application of organic and inorganic fertilizers by farmers in the area and the application of lime resulted in a favorable soil pH of the agricultural farms, which may have reduced or eliminated the mercury content of the soil fifteen years after

Table 1

Mercury Content of Soil (mg/kg) in Selected Agricultural Farms Grown with Cabbage in Nan-agto, Natubleng, Buguias, Philippines, 2022.

SAMPLE	RESULT
1	Not Detected
2	Not Detected
3	Not Detected
4	Not Detected
5	Not Detected
6	0.1 mg/kg
7	Not Detected
8	Not Detected
9	0.1 mg/kg
10	Not Detected
11	Not Detected
12	Not Detected
13	0.1 mg/kg
14	Not Detected
15	Not Detected
Reporting limit	0.1 mg/kg
Soil Mercury level (Laurean, 2007)	5.40 mg/kg
Reporting limit	0.60 mg/kg

the first assessment. At high pH, Hg tends to form barely soluble phosphates and carbonates (Olaniran et al., 2013), compared to a low pH, it exists in more bioavailable free ionic forms, and thus the mobility will increase (Sintorini et al., 2020).

Overall, the results imply that the use of non-mercury-containing pesticides, phytoremediation, leaching, volatilization, and the favorable soil properties may have resulted in the non-accumulation of mercury in the soil. These results carry profoundly positive implications for the region. Economically, the verified reduction of soil mercury safeguards the reputation of the Cordillera Administrative Region (CAR) as the premier hub for semi-temperate vegetable production, ensuring the continued marketability of its crops. More importantly, from a public health perspective, the minimal mercury levels directly translate to a significantly lower risk of toxic heavy metal bioaccumulation in the food chain, guaranteeing that the vegetables reaching national consumers are safe for consumption. However, while these results are highly encouraging, they underscore the necessity of continuous monitoring to ensure that current soil management practices remain sustainable over time.

Mercury Content of Cabbage

Based on the plant tissue analysis, mercury (Hg) was not detected in any of the collected cabbage heads (Table 2). This notable absence directly aligns with the low or non-detectable levels of Hg observed in the soil (Table 1), indicating that the concentration of the metal in the substrate is insufficient to trigger plant bioaccumulation. While this study utilized only the consumable cabbage heads, historical baseline data from Laurean's (2007) assessment, alternate highland crops such as potato and broccoli exhibited high contamination, with an average mercury content of 1.91 mg/kg, a value that

Table 2

Mercury Content of Cabbage (mg/kg) Grown in Selected Agricultural Farms in Nana-agto, Natubleng, Buguias, Benguet, Philippines, 2022

SAMPLE	RESULT
1	Not Detected
2	Not Detected
3	Not Detected
4	Not Detected
5	Not Detected
6	Not Detected
7	Not Detected
8	Not Detected
9	Not Detected
10	Not Detected
11	Not Detected
12	Not Detected
13	Not Detected
14	Not Detected
15	Not Detected
Reporting limit	0.1 mg/kg

exponentially exceeded the maximum allowable consumer concentration of 0.04 mg/kg.

In addition, the favorable soil pH may have made the mercury less bioavailable and, therefore, cannot be absorbed by the cabbage crop. At high pH, metals tend to form barely soluble phosphates and carbonates (Sandrin & Hoffman, 2007), and at low pH, these are highly mobile in the soil (University of Massachusetts, 2011). The non-use of pesticides containing mercury may have contributed to the non-detection of mercury in cabbage heads.

The moderate amount of OM content of the soil may have helped immobilize the Hg from being absorbed by the plant. This is because carboxyl and hydroxyl groups in organic matter lower heavy metal toxicity by complexing and adsorbing it (Li et al., 2021).

The non-detection of mercury in the current cabbage samples carries profoundly positive implications, specifically for regional food safety. Cabbage is a high-value crop distributed from the Benguet trading centers to markets nationwide. The fact that Hg levels remain safely below limits and are completely undetected guarantees that these commercial vegetables present zero heavy metal toxicity risks to consumers, effectively validating local efforts toward safer agricultural production.

Physical and Chemical Soils Properties

Soil Texture

As presented in Table 3, 13 out of the 15 farms sampled had sandy loam textures, while one farm exhibited loamy sand and another sandy clay loam. These predominant textures suggest that the study area is generally well-drained, which can facilitate the leaching of mercury. Moreover, since Hg^{+} is a positively charged ion, and sandy soils possess relatively fewer negatively charged sites, mercury is less likely to be adsorbed and more likely to be transported through percolating water. Fine-textured soils with higher silt and clay content have a greater capacity to retain heavy metals like mercury due to their larger surface area and higher cation exchange capacity (Yao et al., 2015). In contrast, coarse-textured soils such as sandy loam are less effective at immobilizing mercury, allowing greater infiltration and potential leaching.

Soil pH

Soil pH across the sampled farms ranged from 5.82 to 6.97, falling within the recommended range for agricultural production (Philippine Council for Agriculture, Forestry and Natural Resources Research and Development [PCARRD], 1982). This moderately acidic to near-neutral pH can be attributed to the common farming practice of applying lime, which neutralizes acidity by reacting with hydrogen ions in the soil (Anderson et. al., 2013; United States Department of Agriculture [USDA], 1999). This pH range is also favorable for the formation of barely soluble mercury compounds, such as phosphates and carbonates, thus limiting mercury mobility and bioavailability (Olaniran et al., 2013).

Soil Organic Matter

The application of chicken manure by farmers contributes significantly to the organic matter (OM) content of the soil. Chicken manure is known to be rich in nutrients such as nitrogen, potassium, phosphorus, and calcium, and its decomposition gradually releases these elements into the soil (Zublena et al., 1993; Adeyemo et al., 2019). As shown in Table 3, the OM content ranged from 3.0% to 3.76%, within the optimal range of 3% to 6% for agricultural soils (Fenton et al., 2008; PCARRD, 1982). Organic matter plays a critical role in mercury immobilization by providing functional groups such as carboxyl and hydroxyl, which can bind with Hg^{+} to form stable organo-metallic complexes, thereby reducing its toxicity and availability in the soil (Li et al., 2021).

Cation Exchange Capacity (CEC).

Table 3 indicates that the CEC values across the farms were favorable, exceeding 20 meq/100g soil, which is considered adequate for crop production (PCARRD, 1982). The high CEC can be attributed to the combined effects of favorable pH and sufficient organic matter, both of which enhance the development of negatively charged sites on soil colloids (Efretuei, 2016; FAO, 2005; UGA Extension, 2014; Wolf, 1999). A higher CEC increases the soil's ability to adsorb positively charged ions such as mercury, thereby reducing its mobility. According to Mengel (2014), soils with high CEC exhibit enhanced retention of heavy metals like Hg^{+}, helping to mitigate environmental contamination risks.

Table 3

Soil Texture, Soil pH, Organic Matter Content, and Cation Exchange Capacity of Selected Agricultural Farms Grown with Cabbage, Nan-agto, Natubleng, Buguias, Benguet, Philippines, 2022.

FARM	SOIL TEXTURE	SOIL pH	ORGANIC MATTER CONTENT (%)	CATION EXCHANGE CAPACITY m.e./100 g SOIL
1	Sandy loam	6.38	3.57	21.23
2	Sandy loam	5.81	3.76	21.20
3	Sandy loam	6.63	3.61	20.36
4	Sandy loam	6.57	3.53	21.50
5	Sandy loam	6.48	3.50	20.06
6	Loamy Sand	6.97	3.11	21.73
7	Sandy loam	6.69	3.11	21.60
8	Sandy loam	6.94	3.19	24.76
9	Sandy loam	6.92	3.32	21.63
10	Sandy loam	6.74	3.36	22.80
11	Sandy loam	6.30	3.15	22.73
12	Sandy loam	6.75	3.13	23.23
13	Sandy clay loam	5.94	3.28	20.73
14	Sandy loam	6.63	3.23	23.40
15	Sandy loam	6.74	3.02	23.50
Soil Fertility Index:			Values	Values
			>4.5	>20
			2.1-4.5	10-20
			<2.0	<10
pH RANGE				
Very strongly acidic	<4.0			
Strongly acidic	4.0-4.9			
Moderately acidic	5.0-5.9			
Slightly acidic	6.0-6.5			
Neutral	6.6-7.4			
Slightly basic	7.5-7.9			
Moderately basic	8.0-8.9			
Strongly basic	9.0			

When compared to other regional agronomic literature, these properties demonstrate a significant deviation from the classic baseline characteristics of heavily cultivated highland soils in Benguet. Historically, long-term intensive vegetable farming in the region has triggered severe soil degradation and acidification, with studies in La Trinidad and Atok, Benguet recording strongly acidic soil profiles ranging from pH 4.5 to 5.5 due to aggressive ammoniacal nitrogen fertilization (Advincula & Padrones, 2023). Therefore, the recorded pH values above 5.81 in this study indicate a highly favorable neutralization of soil acidity, likely driven by successful regional extensions advocating for regular lime applications and balanced fertilization. Furthermore, while sandy loam textures are typical for well-drained montane agroecosystems, the 3% OM and high CEC 20 m.e./100g soil are superior to the marginal ranges (often <1%) typical of over-cultivated, erosion-prone sloping lands in CAR.

Current Farmers Practice

Soil Nutrient Management

Kind and Amount of fertilizer. Figure 2 shows that the majority of the farmers use complete (14-14-14) fertilizer. This is followed by Yara Liva Nitrabor (15.4 % N-25.9% CaO -0.3% B) and Yara Mila (15-09-20), respectively, and Nitrabor has nitrogen, boron, and calcium, which are involved in the cell wall structure. Boron facilitates the movement of calcium into and within plants and, at the same time, helps increase soil pH (Al Mayahi, 2019). This was followed by Urea (46-0-0), and only one farmer used ammonium sulfate (21-0-0).

The data show that farmers applied inorganic fertilizers within the recommended rate at 240-60-60 kg NPK/ha, which may have prevented the accumulation of mercury in the soil. The result supports the findings of Zhao and Wang (2010) that mercury has been found in agricultural fertilizers, and excessive inorganic fertilizer application can contribute to Hg accumulation in soil (Zhong et al., 2016).

Chicken Manure and Lime Application. Most of the farmers apply chicken manure before planting at 5000-6000kg/ha for cabbage (Figure 3). Chicken manure as an organic amendment is essential in improving soil productivity and crop production as it enhances soil fertility, organic matter, aeration, buffering of soil reaction, water holding capacity, cation exchange capacity, and microbial activities (Adeyemo et al., 2019; Dikinya & Mufwanzala, 2010).

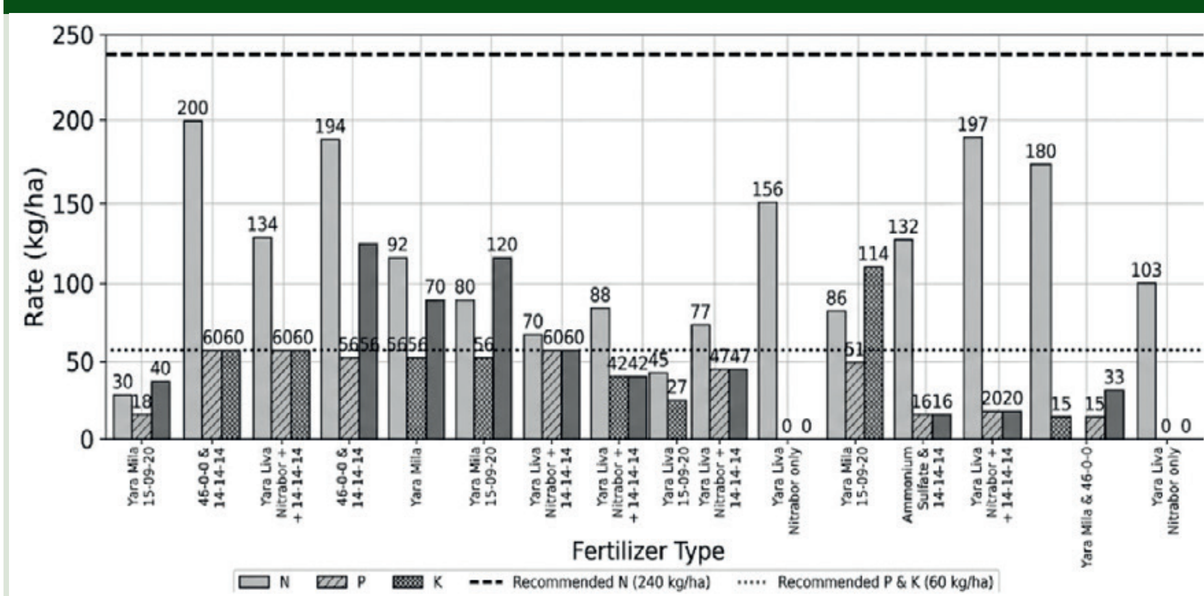
Results also show that farmers applied lime in their farms at a rate of 8001-9000kg/ha before planting. This liming practice corroborates the findings in this study that soil pH is favorable for plant growth. Also, liming improves soil pH, which results in the unavailability of Hg (Fageria & Moreira, 2011). The recommended application rate for chicken manure is 5,000–6,000kg/ha (Marquez et al., 2007), while lime is typically applied at 5,900–8,880kg/ha (Laurean et al., 2015), indicating that the farmers' current practices fall within or near the recommended ranges for soil fertility management.

Pest and Disease Management

Kinds of Pesticides Used & Rate of Application Insecticide. Figures 4 and 5

Figure 2

Kinds and Amounts of Inorganic Fertilizers Applied by Farmers in Selected Agricultural Farms Grown with Cabbage, Nan-agto, Natubleng, Buguias, Benguet, Philippines, 2022



summarize the insecticide management practices among the surveyed cabbage farmers. The survey results indicate that the majority (53%) of farmers predominantly utilize Imidacloprid, applying it at a rate of 25-75 tbsp/ha. This is followed by the co-formulation of Chlorpyrifos + Cypermethrin and Tolfenpyrad, both of which are distributed at a higher field rate of 50-75 tbsp/ha. Other commonly applied insecticides include Indoxacarb, Chlorantraniliprole, and Lambdacyhalothrin, which are managed within a field rate of 25-75 tbsp/ha. Additionally, Chlorpyrifos and Spinetoram are introduced at rates ranging from 50-75 tbsp/ha. A minority of local growers also supplement their pest management regimens with Bifenthrin + Novaluron, Cartap Hydrochloride, Cypermethrin, and Pyrethrins, all maintained within a consistent application range of 25-75 tbsp/ha.

Insecticides are generally applied every 7 to 10 days as needed, adhering to standard crop protection intervals. Importantly, the data reveal that farmers consistently follow the recommended dosage for these chemical inputs. Furthermore, none of the insecticides used contain mercury as an active ingredient, thereby ruling out any contribution to mercury accumulation in soil and crops. This is consistent with the continuing regulatory measures of the Fertilizer and Pesticide Authority (FPA), which has prohibited the use of agricultural pesticides containing mercury (FPA, 2020).

Fungicide. Among the fungicides reported, Mancozeb is the most widely utilized, applied at an estimated field rate of 25-75 tbsp/ha. This is followed by Difenoconazole, which is administered within a comparable dosage range of 75 tbsp/ha. Similar to the observed insecticide application patterns, fungicides are sprayed at a frequent 7- to 10-day interval as needed following the recommended dosage. Notably, none of the fungicides used by the surveyed farmers contain mercury as an active ingredient. This compliance directly aligns with Fertilizer and Pesticide Authority (FPA) regulations, which strictly ban the integration of mercury-containing fungicides in domestic agricultural practices (Billig, 2022).

Pesticide active ingredients used by farmers in cabbage production. Figure 6 shows the active ingredients of the pesticides used by farmers. The data show that all of the pesticides being used by farmers have no mercury as one of the active ingredients that may have caused the non-accumulation of mercury in the soil and plant as a result of the banning of pesticides containing mercury by the FPA, including all other red-label pesticides in 2008, making them unavailable in the market (Billig, 2022).

The farming practices observed in the study generally reflect the principles of Good Agricultural Practices (GAP), as farmers applied inorganic fertilizers, chicken manure, lime, insecticides, and fungicides within or near the recommended

Figure 3

Chicken Manure and Lime Applied by Farmers in Selected Agricultural Farms Grown with Cabbage, Nan-agto, Natubleng, Buguias, Benguet, Philippines, 2022.

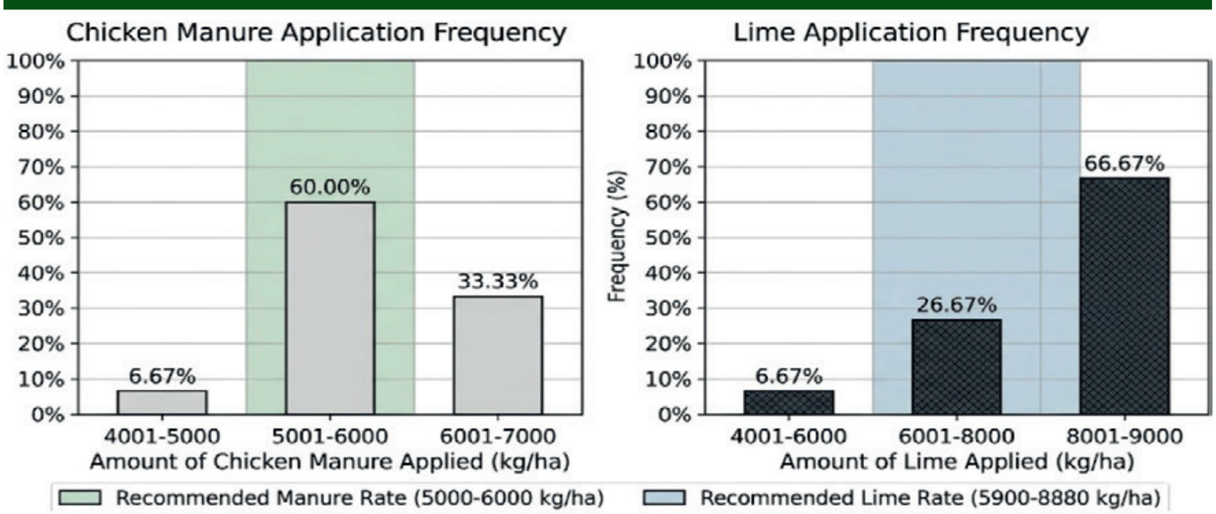
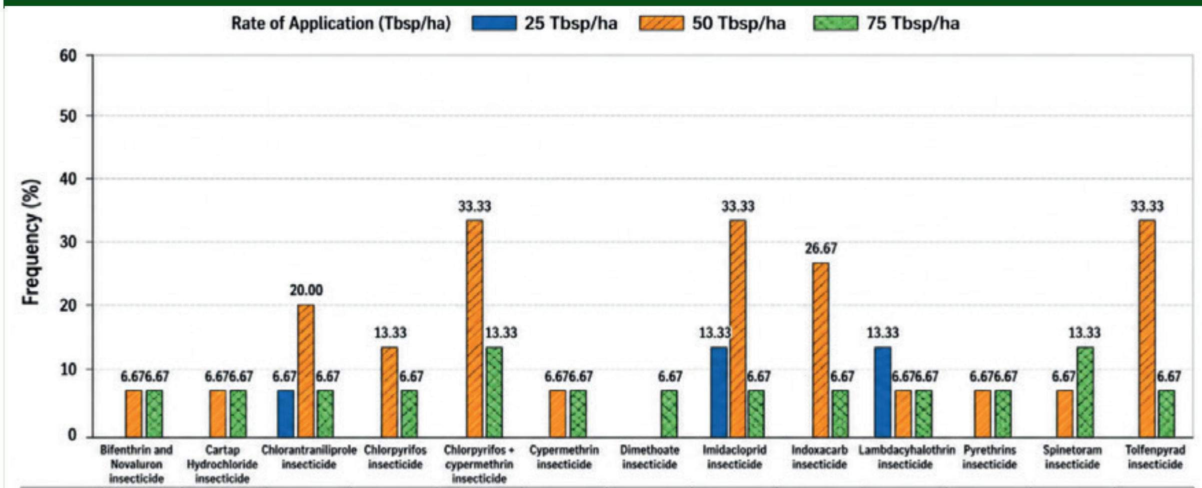


Figure 4

Kinds and Rates of Insecticides Used by Farmers in Selected Agricultural Farms Grown with Cabbage, Nan-agto, Natubleng, Buguias, Benguet, Philippines, 2022.

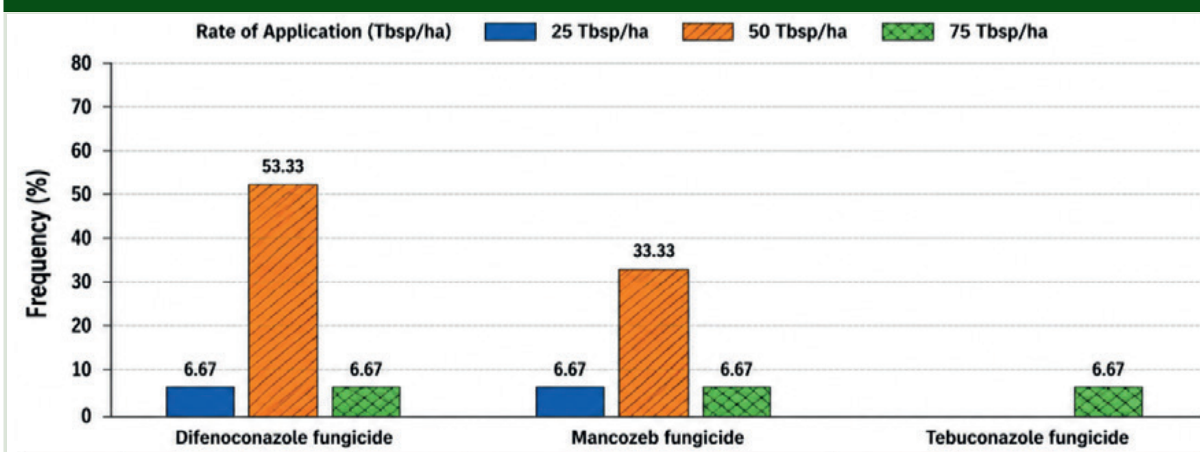


	Bifenthrin and Novaluron insecticide	Cartap Hydrochloride insecticide	Chlorantraniliprole insecticide	Chlorpyrifos insecticide	Chlorpyrifos + cypermethrin insecticide	Cypermethrin insecticide	Dimethoate insecticide	Imidacloprid insecticide	Indoxacarb insecticide	Lambdacyhalothrin insecticide	Pyrethrins insecticide	Spinetoram insecticide	Tolfenpyrad insecticide
Total Frequency (%)	13.33	13.33	33.33	20.00	46.66	13.33	6.67	53.33	33.33	26.67	13.33	20.00	40.00
Number (Frequency)	2	2	5	3	7	2	1	8	5	4	2	3	6
Rank	7	7	4	6	2	7	8	1	4	5	7	6	3

*Recommended dosage: 50–75 tablespoon/ha   Recommended dosage range (50–75 Tbsp/ha)

Figure 5

Kinds and Rates of Fungicides Used by Farmers in Selected Agricultural Farms Grown with Cabbage, Nan-agto, Natubleng, Buguias, Benguet, Philippines, 2022.



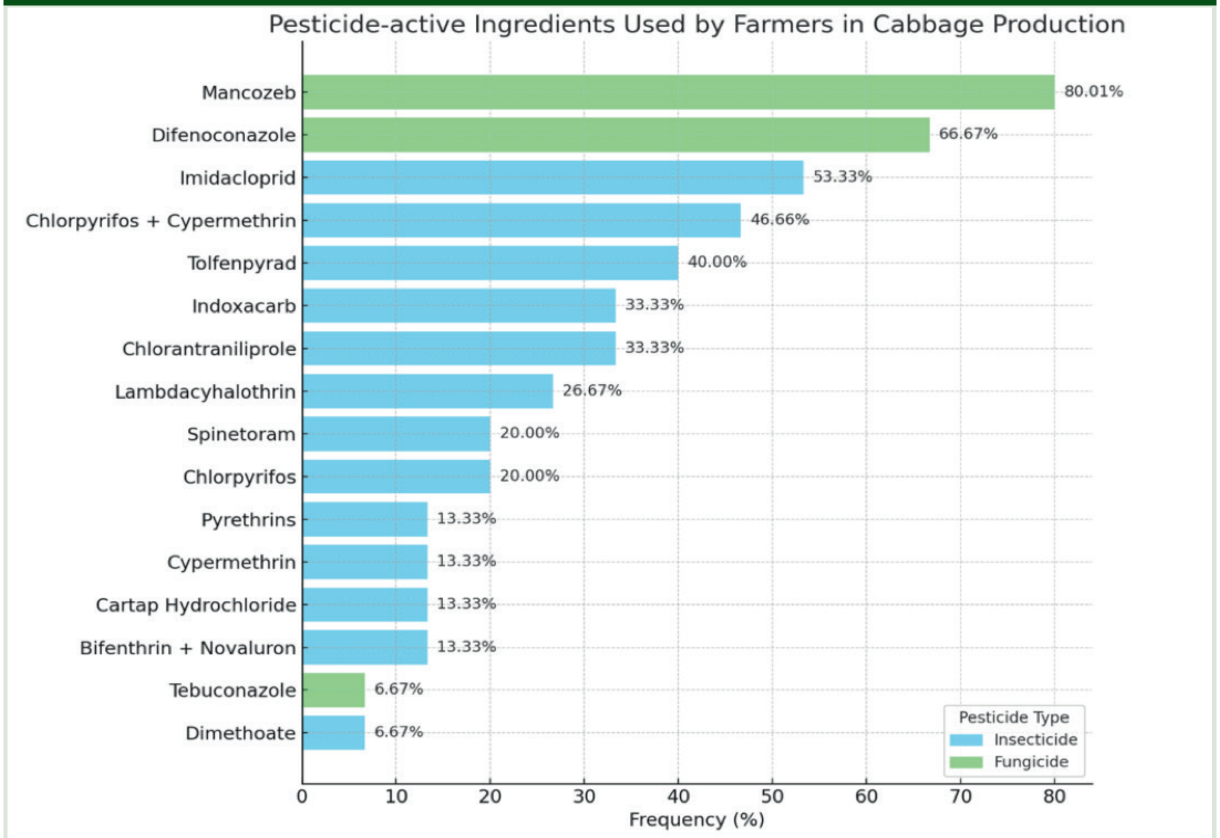
	Difenoconazole fungicide			Mancozeb fungicide			Tebuconazole fungicide		
Total Frequency (%)	6.67	53.33	6.67	6.67	33.33	6.67	—	—	6.67
Number (Frequency)	1	8	1	1	10	1	—	—	1
Rank	—	1	—	—	1	—	—	—	2

*Recommended dosage: 50–75 tablespoon/ha   Recommended dosage range (50–75 Tbsp/ha)

rates and application schedules. Such practices contribute to sustainable soil fertility management by maintaining favorable soil conditions necessary for crop production. This is particularly important in semi-temperate vegetable production systems such as those in Benguet, where intensive and continuous cultivation of high-value vegetables is common. Compared with conventional farming

Figure 6

Pesticide-Active Ingredients Used by Farmers in Selected Agricultural Farms Grown with Cabbage, Nan-agto, Natubleng, Buguias, Benguet, Philippines, 2022.



systems that often rely on excessive agrochemical inputs, the balanced use of fertilizers, organic amendments, and lime observed in this study may help sustain soil productivity while minimizing potential environmental impacts.

Furthermore, the farmers' adherence to recommended input rates likely contributed to the non-accumulation of mercury (Hg) in both soil and cabbage samples. The absence of mercury-containing pesticides, in compliance with Fertilizer and Pesticide Authority (FPA) regulations, eliminated a potential source of Hg contamination. In addition, favorable soil properties such as adequate organic matter content and suitable soil pH may have reduced mercury mobility and bioavailability in the soil. Organic matter can adsorb heavy metals, while liming increases soil pH and decreases Hg solubility, thereby limiting its uptake by plants. These findings suggest that proper soil and crop management practices not only support productive vegetable farming but also help minimize the risk of mercury contamination in agricultural soils and crops.

Conclusions

The reassessment of mercury levels in selected cabbage-producing farms in Nan-agto, Natubleng, Buguias, Benguet, conducted 15 years after the baseline study by Laurean (2007), demonstrated a notable reduction in soil mercury concentrations, from 5.40mg/kg to non-detectable levels in 12 out of 15 sampling sites. Likewise, mercury was not detected in any of the cabbage head samples analyzed. These findings indicate a substantial improvement in both soil and crop quality within the study area and minimize bioaccumulation hazards. While further study is needed to ascertain the cause of the presence and eventual reduction of the residues in this study's samples, the positive trend may be attributed to several contributing factors: the discontinuation of mercury-based agrochemicals as enforced by current regulatory policies, natural leaching and volatilization of mercury from the soil, improved nutrient management practices, and the presence of favorable soil properties such as near-neutral pH, sufficient organic matter content, and high cation exchange capacity (CEC). Additionally, the potential role of cabbage in mercury phytoremediation may have further supported the observed reduction in mercury levels.

Recommendations

The Fertilizer and Pesticide Authority (FPA) needs to sustain and intensify the monitoring of agricultural inputs to prevent the reintroduction of mercury-containing pesticides and fertilizers into farming systems. This includes stricter regulations on product labeling and importation. On the other hand, farmers need to maintain current soil management practices, particularly the regular application of lime and organic matter, which help in improving soil pH and structure, potentially reducing the mobility of heavy metals. Continued adherence to the use of recommended pesticide dosages that are certified to be free from mercury content is essential to ensure food safety and environmental protection. The conduct of soil analysis at least every two years to monitor soil health and provide appropriate lime recommendations is also recommended. This will help maintain optimal soil pH and minimize the potential mobilization of any residual heavy metals. In addition, the study recommends that regular training programs be conducted for farmers on safe and sustainable agricultural practices, including the proper handling and disposal of agrochemicals. Future studies are encouraged to monitor long-term trends of mercury and other heavy metals in similar agricultural areas and to evaluate the effectiveness of phytoremediation and volatilization processes in mitigating soil contamination.

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