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Assessment of Vegetable Agrosystem of Kodéni in Bobo-Dioulasso, Burkina Faso: Balancing Pest Pressure and Smallholder Phytosanitary Practices

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Authors' contributions

This work was carried out in collaboration among all authors. Authors HM, FT, and RAO conducted the tests and collected the data. Authors HM and FT analyzed the data and wrote the initial draft of the manuscript. Authors HM, RAO, JTY, BT, SB, and FT revised the manuscript. Author TCZ oversaw the entire project. All authors read and approved the final manuscript.

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Abstract

Vegetable growing plays an economic, social, and ecological role in the city of Bobo-Dioulasso, Burkina Faso. However, large-scale urbanization, ongoing ecosystem degradation, and intense pest pressure are undermining the productivity and profitability of vegetable growing in Bobo-Dioulasso. Given this situation, an assessment of smallholder farming practices is necessary to enhance the sustainability of the agrosystem vegetables of Kodéni in the city of Bobo-Dioulasso. Accordingly, a survey of smallholder practices was conducted among 30 farms at the site. Soil samples were collected to determine the soil's sanitary and physicochemical quality. The results revealed that vegetable farmers practiced intercropping and crop rotation on small plots (1,235 $m^2 \pm 684.84$ m^2). The pests identified were caterpillars, mites, and snails. The soil health analysis revealed a high prevalence of soil-borne fungal pathogens, with major species including *Fusarium oxysporum* (100%), *Fusarium solani* (48.7%), *Fusarium equiseti* (41.2%), and *Colletotrichum dematium* (37.3%). The physicochemical analysis of the soil showed a high level of fertility (pH = 6.83 ± 0.52; organic matter = 1.38 ± 0.47) compared to the general level of soil fertility in Burkina Faso. In response to pest pressure, vegetable farmers applied a variety of pesticide products, 33.33% of which are not registered for vegetable cultivation, and half of these pesticides are classified as highly hazardous. Producers also used excessive doses of chemicals, with a phytosanitary treatment frequency (IFT) reaching 34, 30,14, and 13 (doses/ha) for tomatoes, cabbage, peppers, and lettuce, respectively. For the sustainable management of the Kodéni vegetable-growing area, it would be necessary to provide guidance to producers on the responsible use of pesticides and to initiate a new focus on agroecology.

Keywords: Vegetable farming; pest pressure; pesticide misuse; soil-borne pathogens; farming practices; agricultural sustainability; Bobo-Dioulasso.

1. Introduction

Agriculture plays a vital role in the socioeconomic development of communities (Yarou *et al.*, 2017). It employs 86% of the labor force, accounts for 45% of household income and 30% of GDP, and generates 70% of export earnings (FAO, 2019). Vegetable farming plays a prominent role in the agricultural sector by providing a large portion of the food supply and contributing significantly to people's incomes (Loumedjinon et al., 2021). Economically, vegetable farming contributes to foreign exchange earnings for the country's economy, with total production estimated at 936,519 tons in 2018. It remains one of the most profitable agricultural activities in the country (Nabie, 2018). However, this sector faces numerous challenges that threaten its sustainability. It is constrained by several factors, such as the reduction of arable land due to increasing urbanization, soil nutrient depletion resulting from overexploitation, and the vulnerability of crops to pests. The main soil-borne pests are pathogenic fungi, bacteria, gall nematodes, and viruses.

In an effort to combat pests and maximize yields, farmers often resort to indiscriminately using pesticides (Ouédraogo, 2019). This practice raises growing concerns about its effects on soil quality, particularly regarding microbial biodiversity, soil structure, and long-term fertility. Studies have shown that pesticides, including herbicides, insecticides, and fungicides, can enter the soil through various pathways. There, they reduce microbial biomass and the diversity of mycorrhizal fungi. This disrupts the ecosystem services these organisms provide (Riedo et al., 2021). Most vegetable growers periodically apply synthetic chemical pesticides without adhering to the recommended dosage (Son et al., 2017; Romba et al., 2020). Only 40 to 45% of encountered pesticides are registered for vegetable farming (Ouédraogo, 2019). Most vegetable farmers use pesticides intended for cotton cultivation, which are not recommended for vegetable farming due to their high toxicity and persistence in crops (Kaboré et al., 2025).

These poor practices have resulted in the development of pesticide-resistant pests and the accumulation of pesticide residues in plant tissues (Babu et al., 2020). They have also led to the persistence of applied pesticides in the tissues of protists, microarthropods, and unfertilized eggs (Hans & Farooq, 2000). Over the decades, pesticide use has increased, impacting soil physicochemical properties (Mishra et al., 2023) through changes in parameters such as organic carbon, available phosphorus, and soil acidification (Merouani et al., 2025), as well as pH, conductivity, cation exchange capacity, organic matter content, and biological parameters (Bensaci et al., 2025). These practices pose enormous and alarming risks to public health and the environment (Atieno et al., 2020). In this context, agroecology appears to be a credible alternative for improving productivity whilst reducing environmental impacts. These approaches are based on the use of organic fertilisers, integrated pest management and the utilisation of local resources (FAO, 2019). In addition to their agronomic benefits, they offer economic opportunities such as reducing dependence on chemical inputs and improving the market quality of produce. In Bobo-Dioulasso, nearly all farmers use chemical pesticides on their crops, particularly in urban and peri-urban vegetable farming (Ouédraogo et al., 2019). These pesticides are often used intensively and do not adhere to recommended dosages (Naré et al., 2015). Thus, it became clear that assessing the current state of smallholder farming practices in the Kodéni market garden area was essential. The study aimed to provide scientific and technical knowledge to improve the sustainability and productivity of the Kodéni site.

Specifically, the objectives were:

- to assess the health status of the Kodéni vegetable-growing area;
- to evaluate the soil fertility of the Kodéni vegetable-growing area;
- to characterize smallholder agricultural and plant protection practices in the Kodéni vegetable-growing area.

2. Materials and Methods

2.1 Study Area

The study was conducted in the city of Bobo-Dioulasso, located in western Burkina Faso and the capital of Houet Province, with an estimated population of 904 920, representing 16.9% of the country's urban population (INSD, 2022). The Kodéni market garden area is located on the outskirts of the city of Bobo-Dioulasso (Burkina Faso) along the Bobo-Dioulasso–Banfora road and situated near the industrial zone (Fig. 1). The site is located at an elevation of 285 meters, 10°21'0'' north latitude, and 5°4'60'' west longitude.

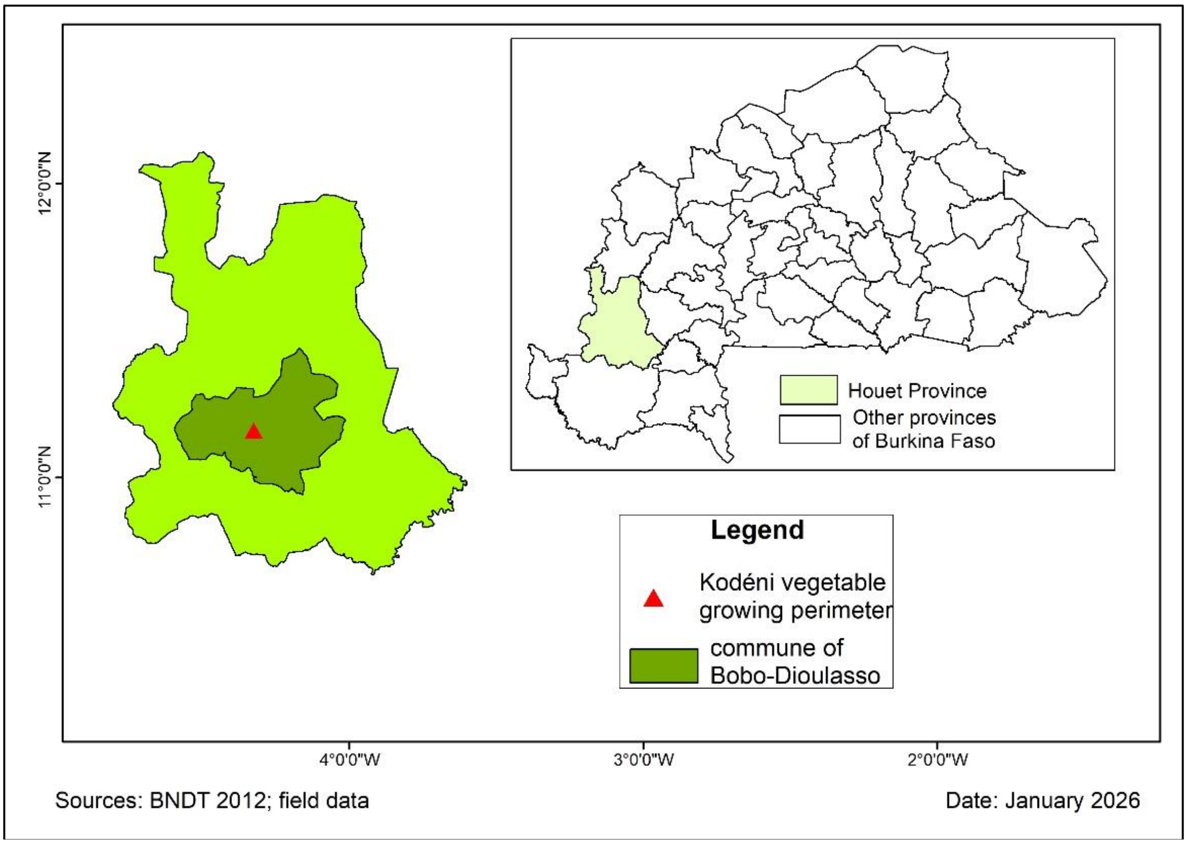

Fig. 1. Overview of the study area

2.2 Survey Procedure and Soil Sampling

Thirty plots were randomly selected using Google Earth in the Kodéni market gardening area (Fig. 2). Soil samples were collected and surveys were conducted on the 30 selected plots.

The survey of smallholder farming practices was conducted in accordance with ethical principles, using a participatory and respectful approach, without intrusion.

Prior to data collection, the research protocol, survey form and consent form were submitted for approval to the managers of the Kodéni market gardeners' cooperative. Each producer was provided with clear information on the objectives of the study, the duration of the interview, the nature of the questions to be asked and the purpose of the data. To maintain confidentiality, the data were anonymised using codes, personal information was separated from other data, and the results were presented using codes only. No information that could directly identify a farmer, their farm or their household will be published. The information collected covered: (i) identification of farmers; (ii) farm characteristics; (iii) cropping and plant protection practices; and (iv) the main symptoms and pest observed. Subsequently, soil samples were taken from each plot along a diagonal line, at a depth of 0 to 20 cm. One (1) composite sample was taken from each plot, resulting in a total of thirty (30) composite samples.

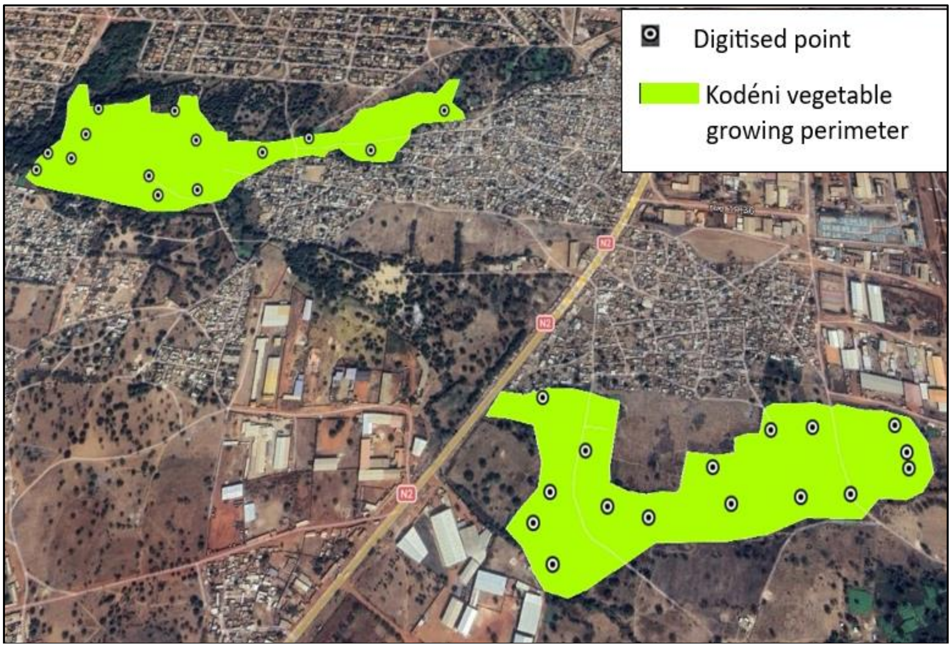

Fig. 2. Digitisation of study plots

2.3 Physicochemical Analysis of Soil in the Kodéni Vegetable-Growing Area

All soil samples were dried in the shade and transported to the Soil-Water-Plant Laboratory at the Institute of Environment and Agricultural Research (INERA) in Farakô-ba for analysis. The dried soil samples were ground and sieved using a 2 mm diameter sieve. The fine fraction (less than 2 mm) was used to determine total carbon using the Walkley-Black method, total nitrogen using the Kjeldahl method, available phosphorus using the Bray I method, and total potassium using spectrophotometry. pH was measured using a pH meter on a compost-water suspension. The Robinson pipette method was used to determine the particle size fractions (sand, silt, and clay), and the ammonium acetate method was used to determine the cation exchange capacity.

2.4 Analysis of the Fungal Flora in the Soil of the Kodéni Vegetable-Growing Area

Another portion of the soil samples was used to catalog soil fungal agents (Pereira e Silva et al., 2012). First, 11.7 g of potato dextrose agar (PDA) and 3.6 g of agar were dissolved in 300 mL of distilled water. The resulting medium was sterilized at 120°C under 2 bars of pressure. The medium was allowed to cool in a sterilized laminar flow hood. Then, 0.15 g of streptomycin sulfate (an antibiotic) was added to the medium, which was distributed into 30 Petri dishes. The dishes were inoculated with 1 g of the composite sample. Sprinkling was performed under sterile conditions in a laminar flow hood. After sprinkling, all 30 Petri dishes were incubated in an incubation chamber at 20 °C. The colonies that developed were observed seven to eight days after incubation. They were examined first with a binocular magnifying glass and then with an optical microscope after being mounted between a slide and a coverslip. The fungal agents were identified using Mathur and Kongsdal's (2003) identification key.

2.5 Data Analysis

The Treatment Frequency Index (TFI) is an indicator used in agriculture to measure the intensity of pesticide use and represents the number of reference doses applied per hectare (Son, 2018). The TFI is calculated using the following formula:

$$IFT = \sum_{i=1}^{n} \left(\frac{Dose_i}{Dose_{ref,i}} \right)$$

With Dose_i: applied to treatment i
Dose_(ref,i): approved dose for this treatment

The analyses were performed using XLSTAT software (version 2016). Microsoft Excel (2016) was used to generate the graphs.

3. Results and Discussion

3.1 Results

3.1.1 Socio-Professional Profile of Market Gardeners

Surveys have shown that farmers range in age from 20 to 70 years old, with an average age of 43. The population is exclusively male, and the majority (62.5%) have no formal education. Only 20.83% have completed primary school, 12.5% have completed secondary school, and 4.17% have completed university (Fig. 3).

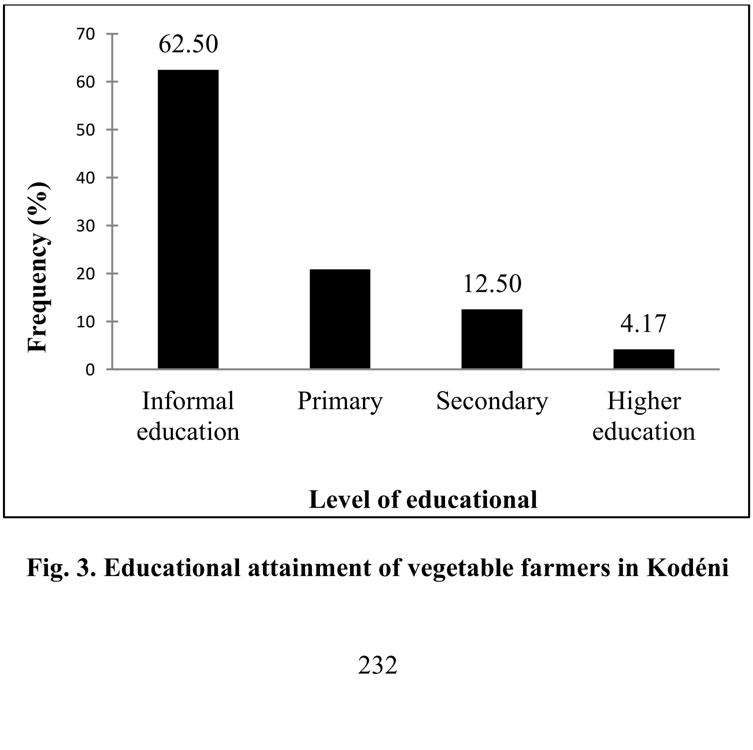

Fig. 3. Educational attainment of vegetable farmers in Kodéni

3.1.2 Characteristics of Smallholder Farming Practices

3.1.2.1 Average Farm Size

The farmers engaged in vegetable farming throughout the year and cultivated small plots, with an average size of 1,235 m² ± 1,055 m² (Fig. 4).

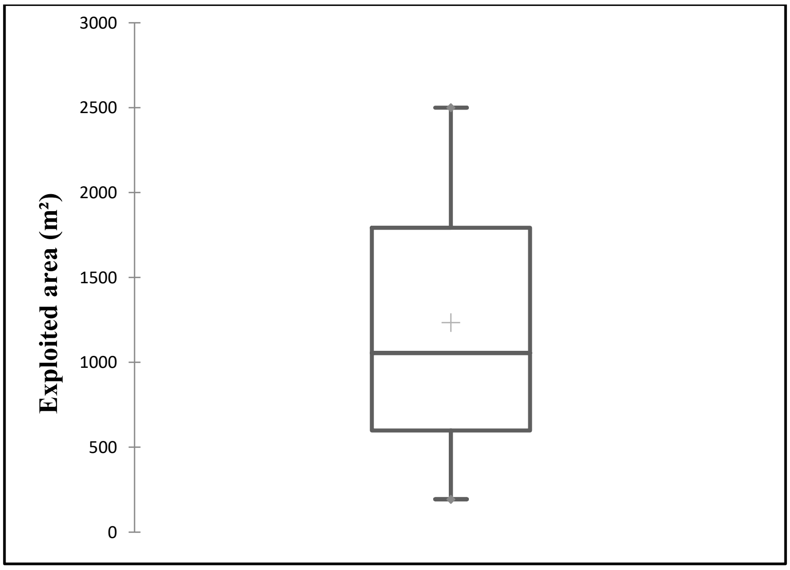

Fig. 4. Average farm size of vegetable growers

3.1.2.2 Vegetable Crops Grown

The vegetable crops grown by market gardeners are diverse at the Kodéni site (Fig. 5). All market gardeners produced lettuce (100%), bell peppers (97%), tomatoes (90%), cabbage (80%), green beans (73%), local eggplant (67%), and leafy vegetables (60%).

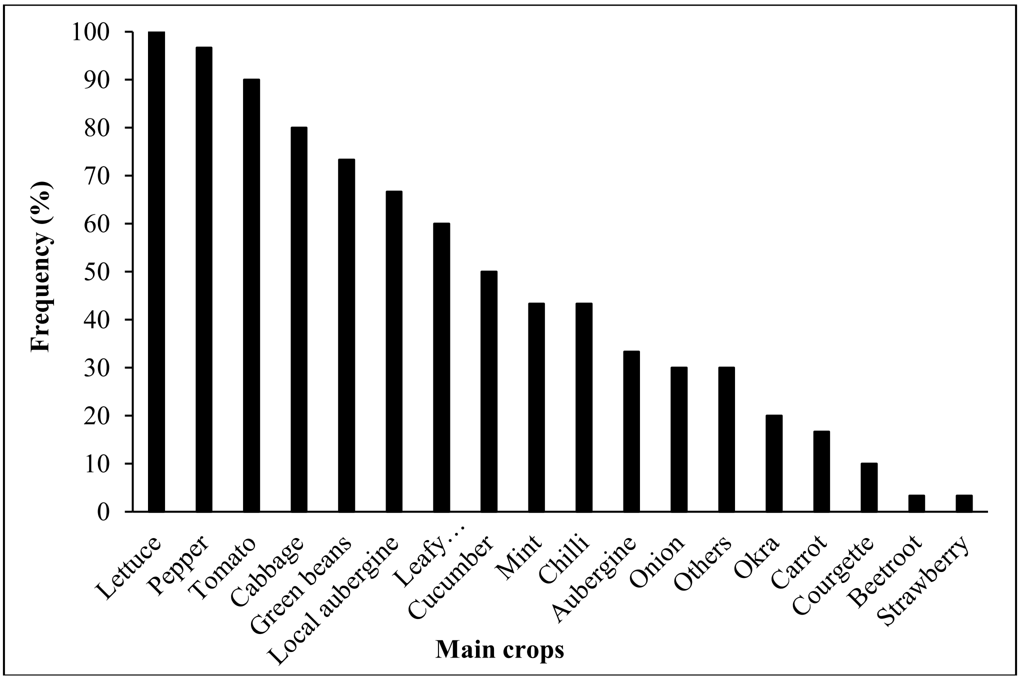

Fig. 5. Percentage of vegetable farmers by crop type at the Kodéni site

3.1.2.3 Application of Inorganic and Organic Fertilizers

Vegetable farmers in Kodéni use both inorganic (NPK and urea) and organic fertilizers. The application rates of these fertilizers varied greatly from farmer to farmer. On average, they applied 1,414.55 ± 1,082.93 kg of NPK, 572.42 ± 333.97 kg of urea, and 1,872.76 ± 1,200.13 kg of organic matter (see Fig. 6).

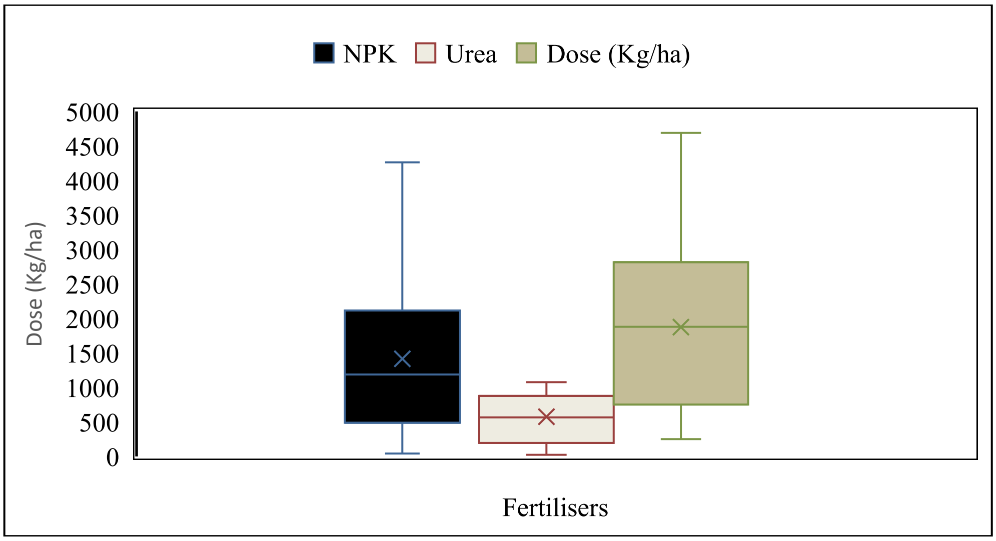

Fig. 6. Different fertilizer rates

3.1.3 Chemical Characteristics of Soils in Vegetable Farms in Kodéni

Table 1 presents the physicochemical characteristics of the soil samples. The soils were sandy-clay loam with a sand content of 61% and a relatively high silt content of 12%, according to the particle size distribution analysis. The soils were chemically slightly acidic (pH 6.83) with an organic matter content of 2.38%. The total nitrogen content of the soils remained low at approximately 0.13%. Nutrient levels were low, at 53.67 and 83.14 mg/kg for available phosphorus and potassium, respectively. The cation exchange capacity (CEC) was also relatively low, at 10 cmol C.kg^{-1}.

Table 1. Physicochemical parameters of the soils at the Kodéni vegetable-growing site

Variable	Mean ±SD	Median	Minimum	Maximum
pH-E	6.83±0.52	6.69	5.69	7.66
CO (%)	1.38±0.47	1.24	0.52	2.23
OM (%)	2.38±0.81	2.14	0.89	3.84
TN (%)	0.13±0.05	0.13	0.04	0.23
C/N	10.50±0.62	10.61	9.29	11.88
TP (mg/kg)	807.30±316.52	728.87	169.36	1507.64
AP (mg/kg)	53.67±22.67	50.04	12.26	91.80
TK (mg/kg)	1432.17±344.86	1329.68	997.26	2160.72
K+ (mg/kg)	83.14±40.06	74.98	25.65	195.34
CEC (cmol/kg)	10.55±3.60	9.71	2.76	18.44
Sand (%)	61.67±8.61	62.75	44.12	75.49
Clay (%)	12.55±3.56	12.75	7.84	22.55
Silt (%)	25.78±8.37	23.53	5.88	45.10

SD: Standard deviation; pH-E: pH-eau; TC: Total Carbon; OM: Organic Matter (%); TN: Total; Nitrogen percentage of total nitrogen (%); C/N: Carbon on Nitrogen; TP: Total Phosphorus;AP: Assimilable Phosphorus; TP: Total Potassium (mg/kg); K+: Assimilable potassium(mg/kg); CEC: Cation Exchange Capacity (cmol/kg)

3.1.4 Crop Intercropping and Crop Rotation in Kodéni

One hundred percent of vegetable farmers in Kodéni practice crop intercropping, and 96.67% practice crop rotation. These practices are motivated by the desire for immediate income and limited space. For these producers, crop rotation and intercropping are ways to diversify crops while seeking favorable production and sales periods.

3.1.5 Characterization of Pests and Associated Symptoms

3.1.5.1 Symptoms of Pest Attacks

The main symptoms encountered by more than 80% of vegetable farmers were leaf, stem, and root rot; yellowing; drying out; wilting; flower drop; and seedling blight. The identified pests were insects, primarily caterpillars, followed by mites and snails (Fig. 7).

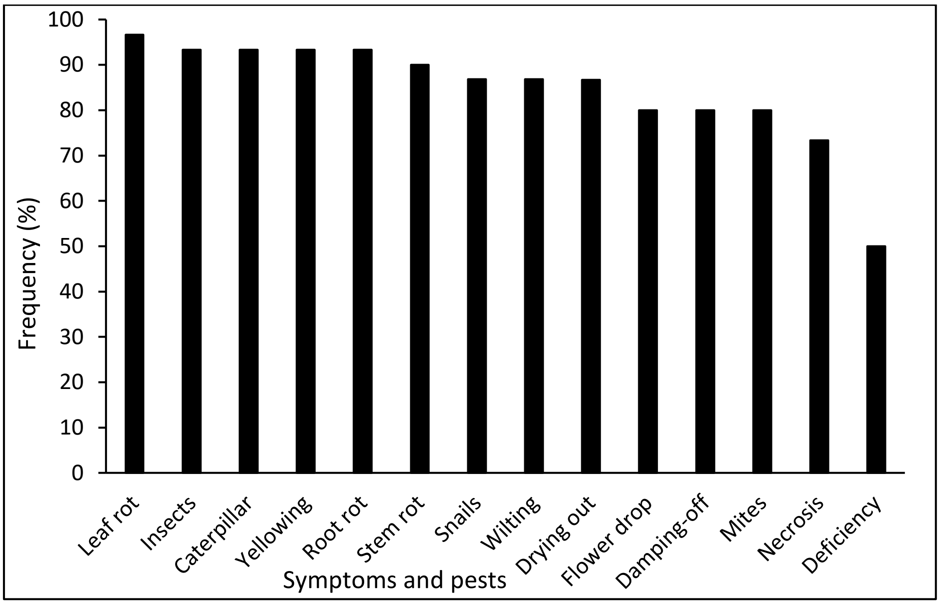

Fig. 7. Farmers' recognition of the main symptoms of diseases and pests

3.1.5.2 Inventory of Pathogenic Fungal Flora in the Soils of Kodéni

Ten fungal species were identified in the Kodéni soil samples. The most dominant species associated with collar and root rot were from the *Fusarium* genus, including *F. oxysporum* (100%), *F. solani* (48.7%), and *F. equiseti* (41.2%). Important species associated with post-harvest losses were also identified: *Colletotrichum lindemuthianum* (37.3%) and *Rhizoctonia solani* (13.33%) (Fig. 8).

3.1.6 Pest Control Measures Adopted by Vegetable Farmers in Response to High Pest Pressure

3.1.6.1 Groups of Pesticides Used by Vegetable Farmers

Given the high pest pressure at the Kodéni site, pest control measures rely primarily on chemical control. All producers used synthetic chemical pesticides. The most commonly used pesticides at the Kodéni vegetable-growing site were Acarius (50%), Bomec (36%), and Savahaler (26%) (Fig. 9A). Of these pesticides, 89% belong to the acaricide group, 36% to the insecticide group, 12% to the herbicide group, and 10% to the fungicide group (Fig. 9B), formulated as emulsifiable concentrate (EC), wettable powder (WP), and water-dispersible granules (WG).

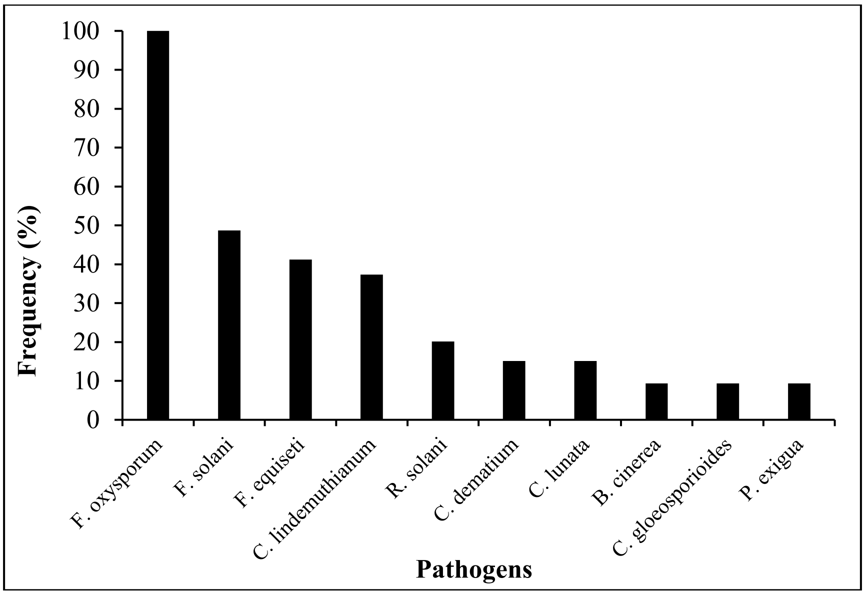

Fig. 8. Frequency of fungal pathogens identified in the soil of vegetable farms in Kodéni

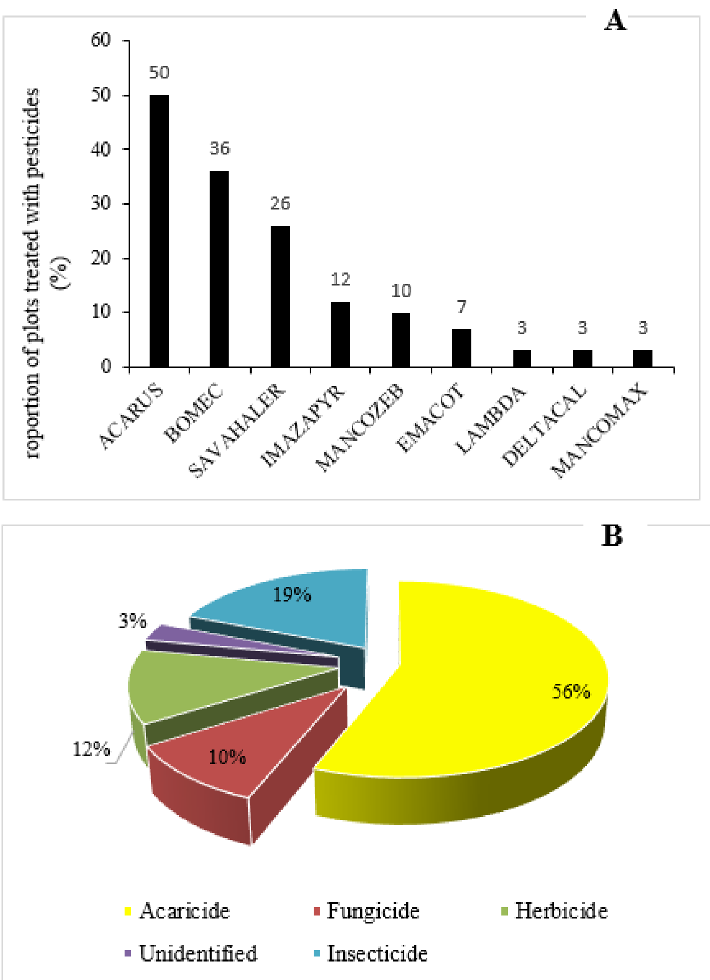

Fig. 9. Types and categories of pesticides used in Kodéni

A) Different types of pesticides; B) Categories of pesticides used at the Kodéni site

Approximately 66.67% of the pesticides used are moderately hazardous (WHO Class II) and 33.33% are highly hazardous (Class I). These products belong mainly to the families of avermectins, neonicotinoids, pyrethroids, acetamiprids, carbamates, organophosphates, dithiocarbamates, and imidazolinones. The main active ingredients in these pesticides are abamectin, lambda-cyhalothrin, profenofos, deltamethrin, emamectin benzoate, methomyl, imazapyr, and mancozeb (Fig. 10). Referring to the list of registered pesticides published in July 2023 by the Sahelian Pesticides Committee (CSP), it is noted that 33.33% of the pesticides used at this vegetable farm in Kodéni are not registered, while 10% are registered, but for cotton cultivation (Table 2).

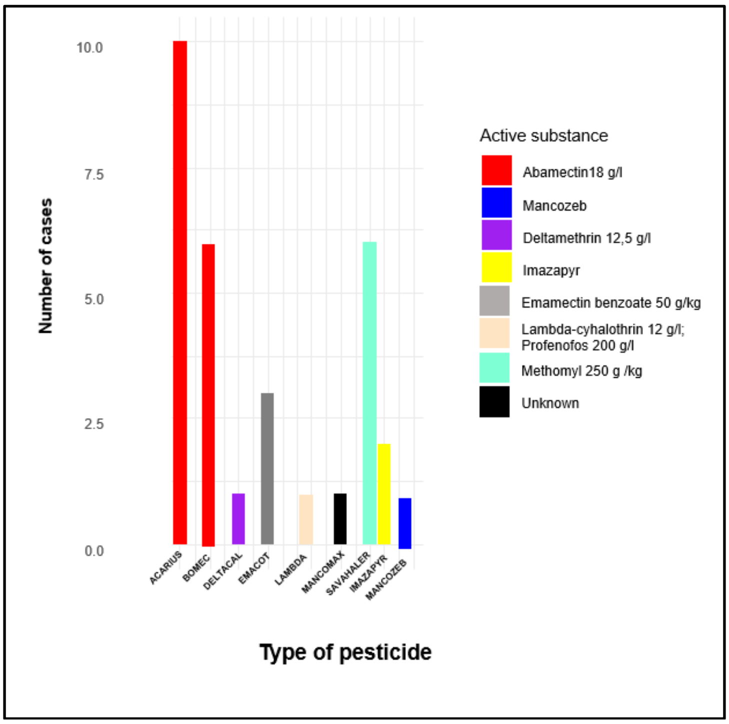

Fig. 10. Types of pesticides and their active ingredients used in Kodéni

3.1.7 Classes of Chemical Pesticides and Their Toxicity Levels

Of the active ingredients listed in Fig. 8, 50% are on the Highly Hazardous Pesticides (HHP) list (PAN, 2021) and are banned in European Union countries. One such pesticide is abamectin (18 g/l), which 86% of vegetable growers at the Kodéni site use. The WHO considers abamectin (18 g/l) very hazardous and lethal if inhaled under the Globally Harmonized System (GHS) of the European Union and Japan. It is also highly toxic to bees.

Table 2. Hazard level of pesticides used at the Kodéni site (PAN-HHP classification, 2023)

Active ingredients	Chemical families	Product category	Area of application	CSP accreditation for vegetable growing	Toxicity class	PAN-HHP
Abamectin (18 g/l)	Avermectins	Acaricides	Vegetables	Yes	II	-
Deltamethrin (12,5 g/l)	Pyrethroids	Insecticides	Vegetables	Yes	II	-
Emamectine benzoate (50 g/kg)	Avermectins	Insecticides	Cotton	No	III	Highly persistent in water and soil; highly toxic to bees
Lambda-	Pyrethroids	Insecticides	Vegetables	No	II	Fatal if inhaled;

Active ingredients	Chemical families	Product category	Area of application	CSP accreditation for vegetable growing	Toxicity class	PAN-HHP
cyhalothrin (25g/l)						carcinogenic, highly toxic to bees
Methomyl (250 g/kg)	Carbamates	Insecticides	Vegetables	Yes	II	-
Profenofos 200g/l	Organophosphates	Insecticides	Cotton	No	II	Harmful to ecosystem services
Mancozeb	Dithiocarbamates	Fungicides	Vegetables	Yes	II	-
Imazapyr	Imidazolinones	Fungicides	Cereals	No	III	Moderately persistent, low bioaccumulation potential, low toxicity to bees and fish

II = Moderately hazardous; III = Slightly hazardous; CSP = Sahelian Pesticides Committee

3.1.8 Intensity of Pesticide Applications at the Kodéni Site

In light of the intensification of vegetable farming, growers have been using excessive amounts of pesticides. Analysis of the treatment frequency index (TFI) revealed that tomato plots received an average of 34 doses of insecticides per hectare, followed by cabbage plots at 30 doses/ha, bell pepper plots at 14 doses/ha, and lettuce plots at 13 doses/ha (Fig. 11).

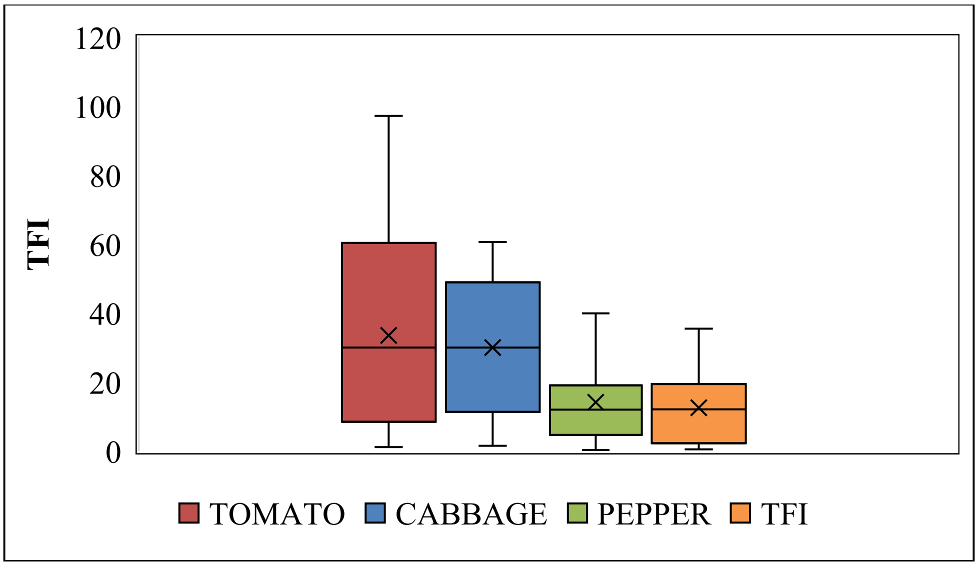

Fig. 11. Pesticide treatment frequency index (TFI) for the most common crops

3.2 Discussion

3.2.1 Socio-professional Profile

The study revealed that vegetable farming in Bobo-Dioulasso was dominated by men. Similarly, Ouédraogo (2019) found that 97–99% of vegetable farmers in Houet Province were male. Women, meanwhile, were primarily involved in marketing market garden produce (Koffie-Bikpo & Adaye, 2014). The study showed that vegetable farmers at the Kodéni site had a low level of education. Very few had completed secondary school, as previously observed by Ouédraogo (2019), who concluded that most vegetable farmers lacked a high level of education.

3.2.2 Characterisation of Smallholder Farming Practices

Vegetable farmers in Kodéni cultivated relatively small plots, averaging 1,235 m² per plot. This reduction in plot size had also been noted in studies by Ouattara (2016) and Naré et al. (2015). Kodéni is located in an urban area of Bobo-Dioulasso and faces intense land pressure and large-scale urbanisation. The study highlighted the continued presence of market gardening activities at the Kodéni market garden site. According to Robineau (2013), this can be explained by the fact that market gardening is the main source of income for farmers. Furthermore, a wide variety of crops were found, including lettuce, bell peppers, tomatoes, green beans, cabbage, local aubergines and leafy vegetables. All of the vegetable farmers at the site grew lettuce. This could be explained by lettuce's low water requirements and relatively short growth cycle (30–50 days) (Nabie, 2018). Crop rotation and intercropping are agricultural practices employed by vegetable farmers on small plots. Crop rotation, practised by most vegetable farmers, appears to be a strategy for rapidly producing short-cycle crops in order to capitalise on market demand while reducing pest populations. Ouédraogo (2019) concluded from his research that short-cycle crops requiring fewer inputs (such as lettuce, green beans, amaranth and sorrel) are prioritised in crop rotation in order to generate income quickly for purchasing the seeds of major vegetable crops (such as peppers, cabbages and tomatoes), which are costly to maintain due to their long growing cycles and high water and input requirements. Physicochemical analysis of the soil reveals high organic matter levels (average pH = 6.93, average C/N ratio = 10.50, and average organic matter content = 2.38), in contrast to the general level of fertility of soils in Burkina Faso, which have low organic matter content (less than 2%). The high level of organic matter of soil of Kodéni is attributed to the extensive use of organic fertilisers (1,872.76 ± 1,200.13 kg/ha) (Pouya et al., 2013; Saba, 2023; Bassolé, 2024).

Although the results of soil analyses indicate a high level of organic matter compared to the average in Burkina Faso, the soil in the Kodéni vegetable-growing area is becoming sandier (61% sand), which is a sign of depletion due to continuous and intensive cultivation (Huang & Hartemink, 2020). Furthermore, almost 83.33% of vegetable farmers do not treat their seeds before sowing them in the nursery, and they largely produce their own seeds. Vegetable farming techniques in Bobo-Dioulasso remain traditional, with seeds often being self-produced (Ouédraogo et al., 2019). According to the FAO, the use of untreated seeds can lead to an increase in pest pressure. Seeds can serve as a vector for the transmission of Fusarium spp. (Blanco & Aveling, 2018).

3.2.3 Pest Pressure Associated with the Intensification of Vegetable Farming

The survey revealed a predominance of Fusarium species, including *F. oxysporum* (100%), *F. solani* (48.7%) and *F. equiseti* (41.2%), associated with the intensification of vegetable farming. In the Kodéni vegetable-growing area, farmers left crop residues on production plots after harvest. However, the work of Blancard et al. (2009) showed that *F. oxysporum*, a soil-borne pathogen, persists in the soil through infested crop residues and can also be transmitted via seeds. Certain species important for post-harvest losses were also identified: *Colletotrichum lindemuthianum* (37.3%) and *Rhizoctonia solani* (13.3%). According to Padder & Sharma (2017), *C. lindemuthianum* is a fungal pathogen responsible for anthracnose, which can result in yield losses of up to 90–100%. Rhizoctonia solani is responsible for root rot, collar rot and other necrotic symptoms and can cause significant yield losses in many crops. According to Padder & Sharma (2017), *Colletotrichum lindemuthianum* is a fungal pathogen that causes anthracnose and can result in yield losses of up to 90–100%. Rhizoctonia solani, which causes root rot, collar rot and other necrotic symptoms, can also result in significant yield losses in many crops. Vegetable growers often rely on chemical interventions (pesticides) to control pests and diseases and optimise yields (Soro et al., 2018; Kumar et al., 2024).

3.2.4 Phytosanitary Responses to Pest Pressure

The study revealed that all producers used chemical pesticides to protect their crops and optimise their yields. This finding is consistent with Ouattara's (2016) research, which found that 96.87% of vegetable farmers in the Bobo-Dioulasso area use chemical pesticides. For vegetable farmers, synthetic chemical pesticides act quickly and are effective at controlling diseases and pests. According to Ahouangninou (2013), the systematic use of chemical pesticides can be explained by the fact that most vegetable farmers believe they can limit the damage caused by pests and produce sufficient quantities of vegetables of an acceptable quality for the market. Analyses revealed a strong predominance in the use of a pesticide based on a single active ingredient (abamectin 18 g/l). This focus on a single product may reflect vegetable farmers' heavy reliance on chemical control, likely due to the product's effectiveness or availability. However, the prolonged use of this specific product carries risks, including the development of pest resistance, as well as increased environmental and health impacts (South & Hastings, 2018; Sonhafouo-Chiana et al., 2022).

The study revealed that some of the pesticides used at the Kodéni site were intended for the cultivation of cereals or cotton, rather than vegetables. Pesticides that were not registered with the CSP were also found at this site, thus confirming the findings of Son et al. (2017). The majority of the pesticides used were insecticides, acaricides, herbicides and fungicides. Half of these were classified as highly hazardous and banned in the European Union. The heavy use of pesticides in vegetable production can be partly explained by the large number of pesticide distributors in Burkina Faso's cities (Yaméogo 2021; Romba et al., 2020), as well as the absence of monitoring and guidance for producers from advisory support services. Although Burkina Faso has a pesticide regulatory framework based on Law No. 026-2017/ AN, which has been strengthened in recent years through the adoption of implementing decrees and a national strategy to combat the misuse of pesticides, as well as through enhanced market surveillance and the establishment of regional harmonisation frameworks (Ministry of Agriculture, 2021; CILSS/COAHP, 2023), porous borders, the high cost of registered pesticides and poverty among producers could also explain the use of unregistered pesticides at this vegetable farm. These poor practices could have harmful impacts on living organisms, including animals, humans and plants. Certain active ingredients, such as abamectin, deltamethrin, lambda-cyhalothrin and methomyl, are considered highly hazardous by the WHO and lethal if inhaled (GHS). They are also carcinogenic and highly toxic to bees.The pesticide treatment frequency indicator (IFT) showed high average values for tomatoes (34) and cabbage (30). This indicates the heavy use of synthetic chemical pesticides on these crops, with application rates averaging 30 times the recommended dose. Heavy pest pressure forces producers to use pesticides without adhering to recommended doses or usage standards. In the long term, this could lead to the pollution of the three environmental compartments (water, soil and air) (Scholtz et al., 2002), as well as the deterioration of the health of producers and consumers, and of biodiversity (Son et al., 2017).

3.2.5 Sustainable Management of the Agrosystem Vegetables of Kodéni

The study revealed an intensive production system in Kodéni. Vegetable growers cultivate small plots of 1,235 ± 1,055 m², and the small size of these plots leads to the excessive use of organic matter (1,872.76 ± 1,200.13 kg/ha), NPK (1,414.55 ± 1,082.93 kg/ha) and urea (572.42 ± 333.97 kg/ha), in an attempt to increase yields. The site is also infested with crop pests. To combat these pests, growers use various plant protection products, some of which are harmful to the environment and human health. In light of these findings, it would be beneficial to establish or strengthen the monitoring of chemical pesticides, and to raise awareness among vegetable growers of the need to use these pesticides only as a last resort. In addition, the use of high-quality organic fertilisers, such as compost enriched with beneficial microorganisms (*Trichoderma harzianum*, mycorrhizae, etc.), should be encouraged for more effective pest management. Appropriate crop rotation and intercropping systems should also be promoted, and guidance provided to producers on the judicious use of pesticides. A new focus on agroecology should also be initiated. Kpadenou et al. (2020) propose intercropping and crop rotation as pest control techniques in the context of pest management in vegetable farming. However, farmers should be trained to identify which types of crop rotation and intercropping effectively control pests. According to Sawadogo et al. (2025), applying compost enriched with *Trichoderma harzianum* significantly increases crop yields and improves certain soil chemical parameters (e.g. organic matter, nitrogen and phosphorus). Converting crop residues left on the ground by farmers after harvest into compost could help reduce the proliferation of pathogens while improving soil fertility (Coulibaly *et al.*, 2020; Gnankambary *et al*., 2022).

4. Conclusion

Vegetable production improves household living conditions and ensures a food supply for urban residents. However, pest infestations are a problem for the industry, leading farmers to use synthetic chemical pesticides. Our study involved assessing production systems in order to characterise vegetable farming practices and operations with a view to sustainable pest management.

Our research revealed that vegetable farming at the Kodéni site is predominantly carried out by men who are largely illiterate. These producers work on small plots of land and use excessive amounts of chemical fertilisers

(NPK and urea) and synthetic chemical pesticides, primarily from the avermectin, neonicotinoid, pyrethroid, acetamiprid and carbamate families. The main active ingredients in these products are abamectin (18 g/L), lambda-cyhalothrin (25 g/L), deltamethrin (12.5 g/L) and methomyl (250 g/kg). These ingredients are toxic to human health, the environment and bees, and are mostly banned internationally. The values of the pesticide treatment frequency indicator (IFT) reflect non-compliance with the recommended application rates among my vegetable growers. In fact, for tomato and cabbage crops, these rates can be up to 30 times higher than the recommended dose, which could have long-term adverse effects on the environment. This heavy use of synthetic chemical pesticides is linked to the high prevalence of various pests, primarily fungal pathogens dominated by the genus Fusarium, which is present in all plots. Analysis of soil chemical parameters indicates an important concentration of chemical elements in the soil due to regular use of organic fertilisers. However, the use of high-quality organic manure should be promoted by recycling crop residues through composting and enriching the compost with beneficial microorganisms. A sound crop rotation and intercropping system should also be implemented for sustainable and agroecological pest management in vegetable farming. Further research is needed to quantify the identified pathogens and determine the effects of soil physicochemical characteristics on pathogen incidence, in order to inform the efficient management of soil-borne pests in vegetable-growing areas.

5. Study Limitations

This study had significant limitations that may restrict the generalisability of its conclusions, notably the small sample size of just 30 plots. Furthermore, the absence of control sites prevents robust comparisons from being made. The study was conducted during the dry season (March–April), largely based on farmers' self-reports, whereas pesticide use can vary depending on the production period and self-reports may introduce a self-reporting bias. The identification of soil born pathogens was based on the morphological characterization of fungi. It would be useful (i) to assess the soil's infectious potential through fungal counts, (ii) to consider other pathogens, namely bacteria and nematodes, and (iii) to combine these morphological identifications with a molecular and pathological characterization of soil born pathogens. Despite these limitations, the results provides important information on the phytosanitary practices of smallholder farming farmers and provides a basis for more in-depth research in the future.

Consent

Free and informed consent was obtained before the questionnaire was administered. For participants who were illiterate, verbal consent was obtained.

Disclaimer (Artificial Intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

Competing Interests

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Ahouangninou, C. C. A. (2013). *Durabilité de la production maraîchère au sud-Bénin : un essai de l'approche écosystémique* [Sustainability of vegetable production in southern Benin: An exploration of the ecosystem approach] [Doctoral dissertation, University of Abomey-Calavi]. https://agritrop.cirad.fr/572410/

Atieno, M., Herrmann, L., Nguyen, H. T., Phan, H. T., Nguyen, N. K., Srean, P., Than, M. M., Zhiyong, R., Tittabutr, P., Shutsrirung, A., Bräu, L., & Lesueur, D. (2020). Assessment of biofertilizer use for sustainable agriculture in the Great Mekong Region. *Journal of Environmental Management, 275*, 111300. https://doi.org/10.1016/j.jenvman.2020.111300

Babu, S., Singh, R., Avasthe, R. K., Yadav, G. S., Das, A., Singh, V. K., Mohapatra, K. P., Rathore, S. S., Chandra, P., & Kumar, A. (2020). Impact of land configuration and organic nutrient management on productivity, quality and soil properties under baby corn in Eastern Himalayas. *Scientific Reports, 10*, 16129. https://doi.org/10.1038/s41598-020-73072-6

Bassolé, Z., Gansanore, R. N., & Yanogo, P. I. (2024). Farmers' Strategies for Soil Fertility Management Around Lowlands in the Commune of Réo (Burkina Faso). *African Journal on Land Policy and Geospatial Sciences, 7*(2), 467–487. https://doi.org/10.48346/IMIST.PRSM/ajlp-gs.v7i2.43313

Bensaci, E., Bakhti, F. Z., & Zouggaghe, F. (2025). Impact of pesticide on the physical and chemical agricultural soil in a semi-arid region of Algeria (M'Sila). *Journal of Agriculture and Applied Biology, 7*(1), 1–13. https://doi.org/10.11594/jaab.07.01.01

Blancard, D., Laterrot, H., Marchoux, G., & Candresse, T. (2009). *Tomato Diseases: Identify, Understand, Control. Éditions Quae*. https://www.quae.com/produit/213/9782759203284/les-maladies-de-la-tomate

Blanco, R., & Aveling, T. A. S. (2018). Seed-borne *Fusarium* pathogens in agricultural crops. *Acta Horticulturae, 1204*, 161–170. https://doi.org/10.17660/ActaHortic.2018.1204.21

Coulibaly, S. S., Touré, M., Kouamé, A. E., Kambou, I. C., Soro, S. Y., Yéo, K. I., & Koné, S. (2020). Incorporation of crop residues into soil: A practice to improve soil chemical properties. *Agricultural Sciences, 11*(12), 1186–1198. https://doi.org/10.4236/as.2020.1112078

Food and Agriculture Organization of the United Nations. (2019). *Le devenir de l'élevage au Burkina Faso: Opportunités et défis face aux incertitudes*. FAO. https://www.fao.org/documents/card/en/c/CA4952FR/

Gnankambary, Z., Pouya, M. B., Sanon, S. B., Sigu, H., Sedogo, P. M., & Kiba, D. I. (2022). Differences in smallholder farmers' compost pits in terms of production and quality across Burkina Faso: The case of Eastern Region. *African Journal of Agricultural Research, 18*(11), 946–955. https://doi.org/10.5897/AJAR2022.16152

Hans, R. K., & Farooq, M. (2000). Dissipation and accumulation kinetics of lindane in soil and earthworm (*Pheretima posthuma*). *Pollution Research, 19*(3), 407–409. http://www.envirobiotechjournals.com/article_abstract.php?aid=4345&iid=146&jid=4

Huang, J., & Hartemink, A. E. (2020). Soil and environmental issues in sandy soils. *Earth-Science Reviews, 208*, 103295. https://doi.org/10.1016/j.earscirev.2020.103295

Institut National de la Statistique et de la Démographie. (2022). *Fifth General Census of Population and Housing (5th RGPH): Final Results. National Institute of Statistics and Demography*. https://www.insd.bf/5e-rgph

Inter-State Committee for Drought Control in the Sahel (CILSS). (2023). *Third session of the West African Pesticide Registration Committee (COAHP): Towards regional harmonisation of pesticide management in West Africa*. Institut du Sahel. https://cilss.int/index.php/2023/11/08/3eme-session-du-comite-ouest-africain-dhomologation-des-pesticides-vers-une-harmonisation-regionale/

Kaboré, K. H., Tougma, M., Ouéda, N., Sawadogo, W. M., Diallo, A., Nabié, B., Sondo, M., Lankoandé, B., & Kassankogno, A. I. (2025). Pratiques phytosanitaires et contamination des légumes et eaux d'irrigation par les pesticides dans les zones maraîchères des régions des hauts-bassins et du centre-sud du Burkina Faso [Pesticide practices and contamination of vegetables and irrigation water by pesticides in market gardening areas of the Hauts-Bassins and Centre-Sud regions of Burkina Faso]. *International Journal of Current Research, 17*(12), 35679–35686. https://doi.org/10.24941/ijcr.49879.12.2025

Koffie-Bikpo, C. Y., & Adaye, A. A. (2014). Agriculture commerciale à Abidjan : le cas des cultures maraîchères. *Pour, 224*, 141–149. https://doi.org/10.3917/pour.224.0141

Kpadenou, C. C., Tama, C., Tossou, B. D., & Yabi, J. A. (2020). Facteurs d'adoption de la gestion intégrée des ravageurs en production maraîchère dans la vallée du Niger au Bénin. *European Scientific Journal, 16*(3), 101–120. https://doi.org/10.19044/esj.2020.v16n3p101

Kumar, A., Ojha, P. K., & Roy, K. (2024). The first report on the assessment of maximum acceptable daily intake (MADI) of pesticides for humans using intelligent consensus predictions. *Environmental Science: Processes & Impacts, 26*(5), 870–881. https://doi.org/10.1039/D4EM00059E

Loumedjinon, E. V. S., Ayeni, G. A., Issaka, K., Agani, F. O., & Yabi, A. J. (2021). Déterminants de l'adoption du compost à base de la jacinthe d'eau par les producteurs de tomate au Sud Bénin [Determinants of the adoption of water hyacinth-based compost by tomato growers in southern Benin]. *Afrique Science, 18*(5), 52–65. http://www.afriquescience.net/revue/18/5/4.pdf

Mathur, S. B., & Kongsdal, O. (2003). *Common laboratory seed health testing methods for detecting fungi* (1st ed.). International Seed Testing Association (ISTA). https://www.seedtest.org/en/publications/bookstore/handbooks.html

Merouani, I., Ketif, A., Draidi, K., Habbachi, W., & Roubal, A. (2025). Effect of pesticide molecules on the physico-chemical properties of soil cultivated by *Brassica napus* rapeseed (flowering stage and rosette stage). *Applied Ecology and Environmental Research, 23*(2), 3525–3539. https://doi.org/10.15666/aeer/2302_35253539

Ministère de l'Agriculture, des Aménagements Hydro-agricoles et de la Mécanisation. (2021). *National Strategy to Combat the Unregulated Sale and Misuse of Pesticides (SNLUAP)*. Gouvernement du Burkina Faso. https://www.aib.media/burkina-pesticides-le-gouvernement-veut-mieux-organiser-le-secteur/

Mishra, S. K., Tripathi, K. M., & Pandey, S. (2023). Effect of chemical pesticides on soil health and its physio-chemical properties. In *Novel Perspectives of Geography, Environment and Earth Sciences* (Vol. 8, pp. 156–167). B P International. https://doi.org/10.9734/bpi/npgees/v8/6115E

Nabie, B. (2018). *Analysis of Phytosanitary Practices and Factors Influencing the Adoption of Integrated Pest Management in Urban and Peri-urban Vegetable Production in Burkina Faso: The Case of Ouagadougou* [Master's thesis, Université de Liège]. https://matheo.uliege.be/handle/2268.2/5071

Naré, R. W. A., Savadogo, P. W., Gnankambary, Z., Nacro, H. B., & Sedogo, M. P. (2015). Analyzing risks related to the use of pesticides in vegetable gardens in Burkina Faso. *Agriculture, Forestry and Fisheries, 4*(4), 165–172. https://doi.org/10.11648/j.aff.20150404.13

Ouattara, Z. A. (2016). *Characterization of Market Gardening Production Systems and Analysis of the Determinants of Soil Fertility under Market Garden Crops in the Houet Province (Burkina Faso)* [Engineering thesis, Université Polytechnique de Bobo-Dioulasso]. https://www.beep.ird.fr/collect/upb/index/assoc/IDR-2016-OUA-CAR.dir/IDR-2016-OUA-CAR.pdf

Ouédraogo, R. A. (2019). *Impact of Soil Fertility Management Practices on Soil Quality under Vegetable Crops in Bobo-Dioulasso (Burkina Faso)* [Doctoral dissertation, Université catholique de Louvain]. https://hdl.handle.net/2078.5/94140

Ouédraogo, R. A., Kambiré, F. C., Kestemont, M. P., & Bielders, C. L. (2019). Characterizing the diversity of vegetable farms in the Bobo-Dioulasso region in Burkina Faso to facilitate their agro-ecological transition. *Cahiers Agricultures, 28*, 20. https://doi.org/10.1051/cagri/2019021

Padder, B. A., Sharma, P. N., Awale, H. E., & Kelly, J. D. (2017). *Colletotrichum lindemuthianum*, the causal agent of bean anthracnose. *Journal of Plant Pathology, 99*(2), 317–330. https://doi.org/10.4454/jpp.v99i2.3867

Pereira e Silva, M. C., Dias, A. C. F., van Elsas, J. D., & Salles, J. F. (2012). Spatial and temporal variation of archaeal, bacterial and fungal communities in agricultural soils. *PLoS ONE, 7*(12), e51554. https://doi.org/10.1371/journal.pone.0051554

Pouya, M. B., Bonzi, M., Gnankambary, Z., Traoré, K., Ouédraogo, J. S., Somé, A. N., & Sédogo, M. P. (2013). Current Soil Fertility Management Practices and Their Effects on Cotton Production and Soil in Cotton-Farming Systems in Central and Western Burkina Faso. *Cahiers Agricultures, 22*(4), 282–292. https://doi.org/10.1684/agr.2013.0643

Riedo, J., Wettstein, F. E., Rösch, A., Herzog, C., Banerjee, S., Büchi, L., Charles, R., Wächter, D., Martin-Laurent, F., Bucheli, T. D., Walder, F., & van der Heijden, M. G. A. (2021). Widespread occurrence of pesticides in organically managed agricultural soils—The ghost of a conventional agricultural past? *Environmental Science & Technology, 55*(5), 2919–2928. https://doi.org/10.1021/acs.est.0c06405

Robineau, O. (2013). *Making a Living from Agriculture in the African City: A Geography of Arrangements Between Actors in Bobo-Dioulasso, Burkina Faso* [Doctoral dissertation, Université Paul-Valéry Montpellier 3]. https://doi.org/10.70675/a72a267eza131z447fz99b6z9bf16680488a

Romba, R., Drabo, S. F., Kaboré, A. B. Z., Sawadogo, S., & Gnankiné, O. (2020). Assessment of risks associated with vegetable growers' plant protection practices and identification of resistance in the whitefly *Bemisia tabaci* (Hemiptera: Aleyrodidae) in the municipalities of Ouagadougou and Loumbila in Burkina Faso, West Africa. *Sciences de la vie, de la terre et agronomie, 8*(2), 90–99. https://lecames.org/revue_ramres/index.php/SVT/article/view/615

Saba, F. (2023). *Study of the Effects of the Combined Use of Biochar and Microdose Fertilization on the Agro-Pedological Properties of the Western and North-Central Zones of Burkina Faso* [Doctoral dissertation, University of Liège]. ORBi. https://orbi.uliege.be/handle/2268/304071

Sawadogo, J., Kaboré, H. F. M., Traoré, M., Sanon, S. B., Soma, F., & Coulibaly, A. (2025). Effects of Increasing Doses of Trichoderma harzianum-Enriched Compost on Sorghum (Sorghum bicolor L.) Yield and Soil Chemical Properties in West Africa, Burkina Faso. *Afrique SCIENCE*. https://www.afriquescience.net/parutions/vol27/n1/6-Effets-de-doses-croissantes-du-compost-enrichi-au-Trichoderma-harzianum-sur-le-rendement-du-sorgho-Sorghum-bicolor-L-et-sur-les-proprietes-chimiques-du-sol-en-Afrique-de-l-Ouest-Burkina-Faso

Scholtz, M. T., Voldner, E., McMillan, A. C., & Van Heyst, B. J. (2002). A pesticide emission model (PEM) Part I: Model development. *Atmospheric Environment, 36*(32), 5005–5013. https://doi.org/10.1016/S1352-2310(02)00570-8

Son, D. (2018). *Analysis of the risks associated with pesticides use and measurement of integrated pest management performance in tomato crops in Burkina Faso* [Doctoral dissertation, University of Liège]. https://orbi.uliege.be/handle/2268/223341

Son, D., Somda, I., Legrève, A., & Schiffers, B. (2017). Phytosanitary practices of tomato growers in Burkina Faso and risks for health and the environment. *Cahiers Agricultures, 26*(2), 25005. https://doi.org/10.1051/cagri/2017010

Sonhafouo-Chiana, N., Nkahe, L. D., Kopya, E., Awono-Ambene, P. H., Wanji, S., Wondji, C. S., & Antonio-Nkondjio, C. (2022). Rapid evolution of insecticide resistance and patterns of pesticides usage in agriculture in the city of Yaoundé, Cameroon. *Parasites & Vectors, 15*(1), 186. https://doi.org/10.1186/s13071-022-05321-8

Soro, G., Koffi, N. M., Kone, B., Kouakou, Y. E., M'Bra, K. R., Soro, P. D., & Soro, N. (2018). Utilisation de produits phytosanitaires dans le maraîchage autour du barrage d'alimentation en eau potable de la ville de Korhogo (nord de la Côte d'Ivoire) : risques pour la santé publique [Use of plant protection products in market gardening around the drinking water supply dam for the city of Korhogo (northern Côte d'Ivoire): Risks to public health]. *Environnement, Risques & Santé, 17*(2), 155–163. https://doi.org/10.1684/ers.2018.1147

South, A., & Hastings, I. M. (2018). Insecticide resistance evolution with mixtures and sequences: A model-based explanation. *Malaria Journal, 17*(1), 80. https://doi.org/10.1186/s12936-018-2203-y

Yaméogo, J. (2021). Perceptions of Environmental and Health Risks Associated with Pesticide Use in Urban Market Gardening in Koudougou (Burkina Faso): An Index-Based Approach. *Revue Interdisciplinaire Resol-Tropiques, 2*(3), 1–18. https://publication.georesbio.org/index.php/rirt/article/view/118

Yarou, B. B., Silvie, P., Assogba Komlan, F., Mensah, A. C., Alabi, T., Verheggen, F., & Francis, F. (2017). Pesticidal plants and vegetable crop protection in West Africa: A review. *Biotechnologie, Agronomie, Société et Environnement, 21*(4), 288–304. https://doi.org/10.25518/1780-4507.16175

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