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Assessment of pest management practices in the wilaya of El tarf (Algeria): Agricultural intensification, patterns of herbicide use, and environmental impacts

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Abstract:

Driven by the global push for higher yields since the 1950s, agricultural intensification in the El Tarf province of northeastern Algeria has led to a heavy reliance on chemical pesticides. Known as the "orchard of the East," this highly fertile region encompasses an agricultural area of 84,000 hectares, with irrigated lands projected to expand to 20,000 hectares by 2026. 70% of local farming is commercial and profit-driven, focusing heavily on market garden vegetables, industrial tomatoes, and fruits. Due to the area's high humidity and rainfall, which frequently exceeds 1,000 mm/year, fungal diseases are a constant threat; consequently, fungicides account for 54% of local chemical use, followed by insecticides at 37%, and herbicides at 9%. Local farmers strongly prefer selective and systemic herbicides applied to foliage and roots to efficiently eliminate weeds. While these chemical practices have successfully ensured crop production, they pose documented environmental risks—particularly to aquatic ecosystems, where leached herbicides bioaccumulate, resulting in significantly higher toxicity in fish compared to birds and bees. Ultimately, the study highlights the urgent need to adopt sustainable plant protection practices to safeguard human health and preserve the region's vital ecosystems.

Keywords Herbicide, agricultural, environmental, toxicity, El Tarf.

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Introduction

Since the 1950s, the intensification of agricultural systems—driven by the need to increase crop yields and ensure food security for growing populations—has been accompanied by a marked expansion in the production and application of synthetic pesticides. What began as the targeted use of a limited number of fungicides and insecticides against specific pests has evolved into the widespread deployment of thousands of active ingredients across multiple chemical classes, including organochlorines, organophosphates, carbamates, pyrethroids, neonicotinoids, and diverse herbicidal and fungicidal chemistries. This diversification reflects both advances in agrochemical research and the shifting pest pressures associated with monoculture, intensified cropping systems, and global trade (Aimeur, 2017).

Globally, the geographic distribution of pesticide consumption has also changed. Historically concentrated in high-income countries, nearly one-quarter of global pesticide use now occurs in developing countries, mirroring the mechanization and intensification of agriculture that often accompany economic growth and changing dietary demands (Aimeur, 2017). According to FAO and other assessments, chemical pest control has contributed substantially to crop protection: estimates indicate that pesticide use has helped avert losses amounting to roughly 20–30% of potential global agricultural production, thereby supporting food availability (Oerke, 2006; FAO, 2007). This productivity gain, however, has been achieved alongside a dramatic increase in input intensity some studies report a 15- to 20-fold escalation in pesticide application over the latter half of the twentieth century and a concomitant sevenfold rise in synthetic fertilizer use (Oerke, 2006; Lamberth et al., 2013).

The environmental and human-health consequences of this intensification have become increasingly evident. Many pesticide active ingredients are persistent, bioaccumulative, or possess modes of action that affect non-target organisms, resulting in ecological disruption—declines in beneficial insects (including pollinators), soil biodiversity loss, and contamination of aquatic ecosystems through runoff and leaching. Pesticide residues also enter the human food chain, representing a primary exposure pathway for the general population through consumption of contaminated fruits, vegetables, and cereals; additional exposure occurs via drinking water, inhalation of spray drift or volatilized compounds, and occupational contact among applicators and farmworkers (WHO, 2022).

Materials and Methods

Milk sampling

The adoption of chemical pesticides in modern agriculture has generally contributed to higher crop productivity and reduced crop losses. However, these agronomic benefits are accompanied by significant concerns regarding acute and chronic toxicity to humans, non-target organisms, and broader ecosystem integrity. To inform a comprehensive risk assessment of agricultural practices and their products, we carried out a mixed-stakeholder survey in the wilaya of El Tarf. The survey targeted primary actors in the pesticide supply and use chain local farmers, agrochemical retailers, and public health and phytosanitary authorities (Direction des Services Agricoles, DSA to document pesticide choice and use patterns.

Description of the Study Area

Located in the far northeast of Algeria, the wilaya of El Tarf, often referred to as the "green lung" or the "orchard of the East" is a strategic agricultural region characterized by high productivity and a wide variety of crops. This performance is primarily due to particularly favorable natural conditions, such as high rainfall frequently exceeding 1,000 mm/year, as well as the availability of significant water resources provided by dams such as Mexa and Cheffia and the presence of wetlands, including El Kala National Park. Added to these assets is a Utilized Agricultural Area of approximately 84,000 hectares, a growing portion of which is irrigated, with the irrigated area projected to increase from 14,000 to 20,000 hectares by 2025–2026 due to the development of boreholes. These soil and climate conditions, combined with the fertility of the Bouteldja, Besbes, and Dréan plains, foster the development of high-quality agricultural sectors. Among these, industrial tomato production plays a leading role, supported by an agro-industrial processing network specializing in double-concentrated tomato paste and helping to supply the domestic market. At the same time, fruit growing—particularly citrus fruits such as oranges, lemons, and mandarins—benefits from a favorable microclimate in the western plains, strengthening the region's agricultural specialization and competitiveness. Thus, the interplay between natural resources, water infrastructure, and production diversification gives the wilaya of El Tarf a major role in the Algerian agricultural system (DSA, 2024–2026).

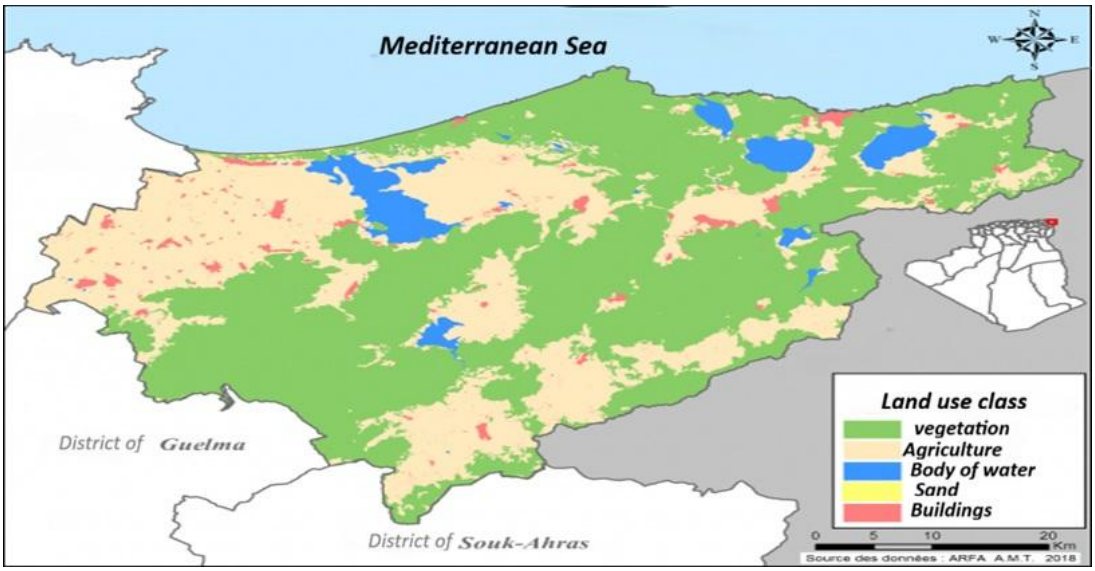


Figure 1. Land-use map of the El Tarf province produced by BNEDER in 2011 (ARFA, 2019)

Results

1. Types of Farmers in the El Tarf Province:

In the El Tarf province, agriculture is predominantly market-oriented, with 70% of farmers engaged in commercial farming, compared to 30% involved in subsistence farming. This distribution highlights an agricultural model predominantly geared toward profitability and market development.

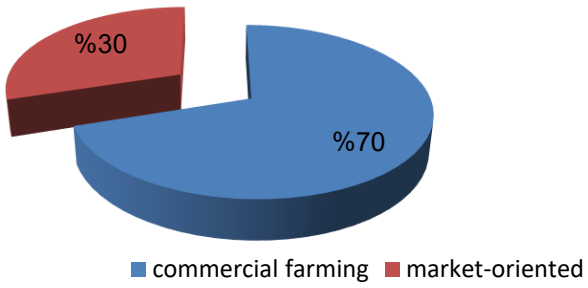


Figure 2. Types of farmers in the El Tarf region

2. Common types of agriculture in the El Tarf region

The histogram shows that vegetable and fruit crops are by far the most common in El Tarf, while citrus fruits, grains, and olives are less prevalent.

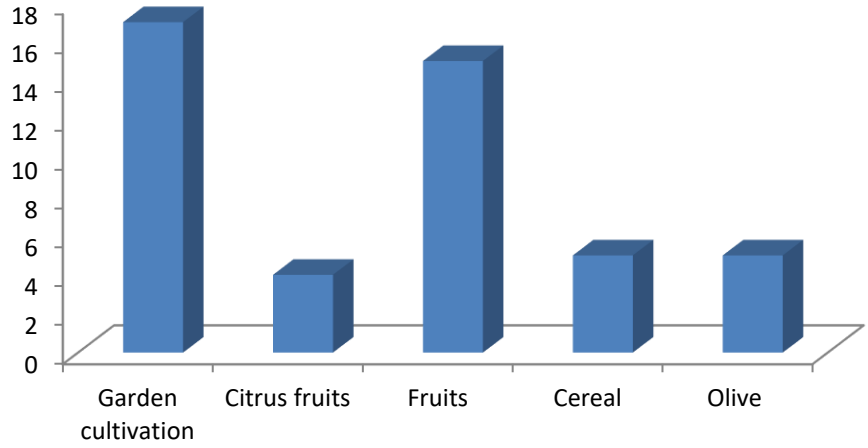


Figure 3. Common types of agriculture in the El Tarf province

3. Different types of pesticides in the El Tarf region

The pie chart presents the distribution of the three principal pesticide categories identified in the survey. Fungicides constitute the dominant group, representing 54% of all pesticide products, indicating their widespread application in crop protection. Insecticides account for 37% of the total, making them the second most prevalent category. Herbicides, by comparison, represent only 9% of the pesticides recorded. The proportional size of each sector reflects the frequency of application of the different pesticide groups and highlights their relative contribution to the plant protection strategies adopted by farmers.

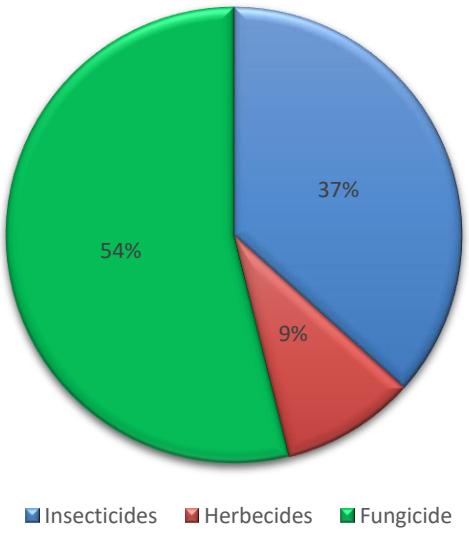


Figure 4: Different Types of Pesticides Used in the El Tarf Region

4. Mode of Penetration of Herbicides Used in the El Tarf Province

With regard to Histogram 4, which illustrates the mode of herbicide penetration in the El Tarf province, most herbicides primarily penetrate through the foliage and roots, while stem penetration is rather rare.

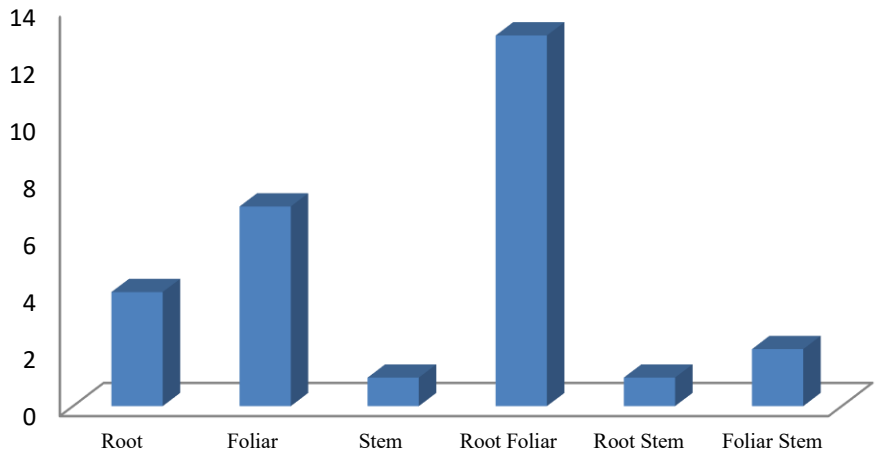


Figure 5. Herbicide application methods used in the wilaya of El Tarf

5. Types of herbicides used in the wilaya of El Tarf

Farmers prefer to use selective herbicides, followed by systemic herbicides, while contact herbicides are less common.

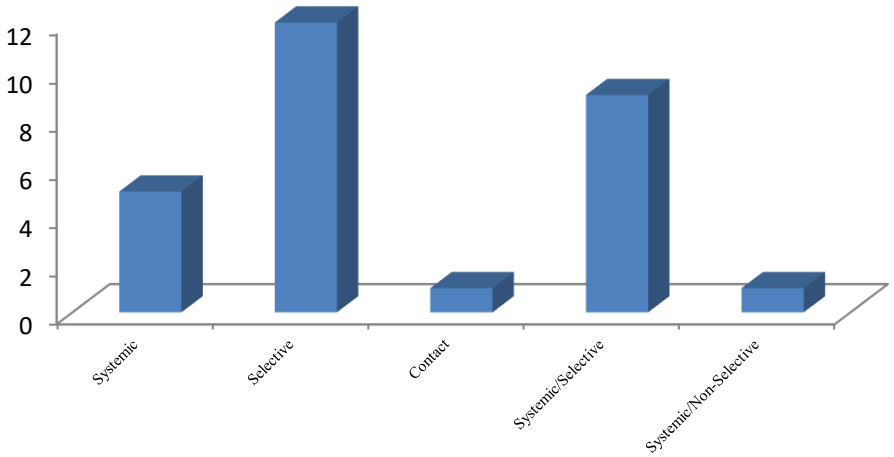


Figure 6. Types of herbicides used in the wilaya of El Tarf

6. Adverse effects of herbicides on other non-target organisms

According to Figure 7, the adverse effects on bees are mostly minor. Herbicides affect birds, with mild effects being most common. It appears that the effects of herbicides vary considerably among fish. This variability influences the

observed effects, which include moderately frequent occurrences in some cases, high and low toxicity, and less frequent or even mild effects.

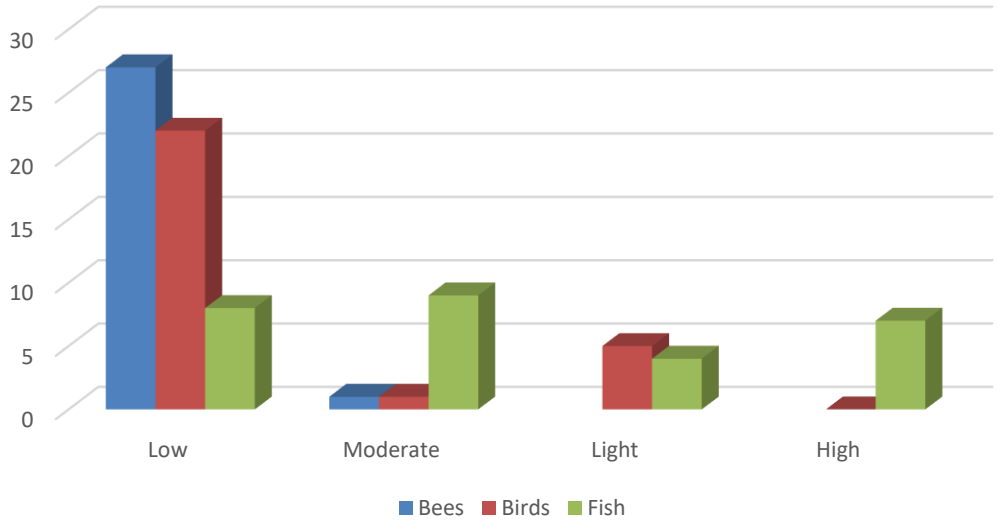


Figure 7. The side effects of herbicides on non-target organisms

Discussion

An analysis of a survey of 47 farmers in the province of El Tarf reveals that 70% of farmers favour commercial farming, whilst 30% focus on subsistence farming. This distribution indicates a prevalence of market-oriented production systems, reflecting a fairly significant involvement of farms in sales channels. The emphasis on commercial farming may be due to the agricultural potential of the wilaya of El Tarf. Indeed, this area benefits from significant natural resources, relatively high rainfall and fertile soils that favour the expansion of crop cultivation and livestock farming. Research conducted in the wilaya highlights that agriculture is one of the major pillars of local development and benefits from government support programmes aimed at optimising farm production and profitability (Hadjeris & Garoui, 2023; Labed Brinis & Chebli, 2025). These findings are also consistent with Barrett's (2008) study, which highlights that the involvement of small-scale producers in agricultural markets tends to result in higher incomes and better utilisation of productive resources. Ogutu, et al., (2019) also demonstrate that agricultural marketing plays a role in reducing multidimensional poverty and improving the living conditions of rural households. The predominance of commercial farming in the sample can also be understood by linking it to the structural changes in agriculture in Algeria. According to Adair et al. (2022), the agricultural reforms undertaken over many years have encouraged a gradual transition towards a more market-oriented form of agriculture, focused on improving productivity, profitability and national food security. However, the 30% proportion of farms focused on self-consumption highlights the continuing importance of subsistence farming in rural families'

plans. This situation is common on family farms where a portion of production is allocated to meeting domestic food needs, whilst minimising the risks associated with fluctuations in agricultural prices. A number of studies indicate that the combination of market-oriented production and production for self-consumption represents a strategy for resilience and economic adjustment for farmers (Jaleta et al., 2009; Carletto et al., 2017).

Vegetable and fruit farming are the most widespread forms of agriculture in the wilaya of El Tarf, while citrus fruits, cereals, and olive trees are less prevalent. This predominance can be attributed to the region's favorable agroclimatic conditions, notably its humid Mediterranean climate and fertile soils, which favor high-economic-value horticultural production. These findings are consistent with the observations of Balouli (2018), who highlights the importance of vegetable and fruit crops in Algeria's most productive agricultural regions. Similarly, Matallah and Matallah (2023) report that the environmental conditions of the El Tarf region favor the development of diversified agricultural systems dominated by horticultural crops. Conversely, the low representation of cereals confirms the findings of Benniou et al. (2014), which show that this crop is more widely grown in the semi-arid areas of eastern Algeria than in the humid coastal regions. As for olive and citrus trees, their low prevalence could be linked to the technical requirements and investments needed for their cultivation, as also noted by Mansouri and Menani (2017). Overall, these findings highlight an agricultural focus primarily geared towards vegetable and fruit cultivation, in line with El Tarf's natural characteristics and the trends observed in other regions of northern Algeria.

The prevalence of fungicides can be explained by the region's humid climate, which is conducive to the development of fungal diseases affecting vegetable and fruit crops. These findings are consistent with the observations of Matallah and Matallah (2023), who highlight that high humidity in the El Tarf region promotes the proliferation of numerous plant pathogens, necessitating frequent fungicide treatments. Similarly, the work of Damalas and Koutroubas (2016) indicates that fungicides are among the most widely used pesticides in intensive agricultural systems where horticultural crops predominate. The high proportion of insecticides also reflects the need to control pests that may affect crop yields. Conversely, the low use of herbicides could be linked to the adoption of alternative weeding methods or lower weed pressure in certain crops. Similar trends have been reported in several studies conducted in Mediterranean regions, where fungicides and insecticides generally represent the main categories of plant protection products used (FAO & WHO, 2022).

Herbicides that penetrate through both the roots and foliage are the most widely used in the wilaya of El Tarf, followed by herbicides absorbed through the leaves and roots. In contrast, herbicides absorbed through the stem are rarely

used. This predominance can be explained by the effectiveness of foliar and root herbicides in weed control and their better distribution within the plant. These results are consistent with those of Hess and Foy (2000), who indicate that the majority of modern herbicides are absorbed mainly through the leaves and roots. Similarly, Délye et al. (2013) emphasize that the most widely used systemic herbicides rely on these routes of penetration to optimize their efficacy. The limited use of stem-absorbed herbicides confirms the observations of Duke (2012)a, who reports that these products play a minor role in current weed control strategies. Overall, the practices observed in El Tarf are similar to those described in other modern agricultural systems, where foliar and root-penetrating herbicides remain the most widely used.

The results show a clear predominance of selective herbicides in the wilaya of El Tarf, followed by systemic herbicides, whilst contact herbicides are rarely used. This hierarchy reflects a weed control strategy focused on efficacy and crop protection. The dominance of selective herbicides is consistent with observations reported in other Mediterranean agricultural regions, where this type of product is widely preferred for its ability to target weeds without affecting the main crops (Zimdahl, 2018). Studies conducted in similar cereal-growing areas have also shown that farmers favor selective herbicides due to their ease of use and a good balance between cost and efficacy. Systemic herbicides occupy an intermediate position, a finding also observed in several international studies. Their high efficacy against perennial weeds is well documented, but their use is often limited by cost and, above all, by the growing risks of resistance, particularly linked to the repeated use of glyphosate and enzyme inhibitors (Duke, 2012b; Heap, 2025). This trend is consistent with global observations showing an increase in cases of resistance in intensive agricultural systems (Powles & Yu, 2010). Conversely, the limited use of contact herbicides has also been reported in other studies, where these products are considered less effective in the long term due to their non-systemic action and the need for repeated applications (Zimdahl, 2018). Their role therefore remains secondary in modern production systems. Overall, the results from El Tarf are consistent with trends observed in several agricultural regions, where selective and systemic herbicides dominate chemical control strategies. However, this reliance highlights a potential risk of resistance developing, which reinforces the importance of adopting integrated weed management, already recommended in numerous recent studies (Powles & Yu, 2010).

Herbicides can have more pronounced effects on fish than on bees and birds because of their modes of action and their persistence in the aquatic environment (Khatib et al., 2022; Burch et al., 2024). Fish are often more exposed to chemicals in water and have a physiology that makes them more sensitive to these substances, as water may be contaminated by fungicides and herbicides leached from fields or by atmospheric deposition. They absorb these substances directly

through their gills or skin, and may also ingest them through their diet (Van der Oost et al., 2003; Khatib et al., 2022). Although bees and birds may be exposed to pesticides while foraging or consuming contaminated seeds, their direct exposure is often less frequent and intense than for fish. Pesticides can accumulate in aquatic organisms, including fish, and become more concentrated as they move up the food chain. This means that fish may be exposed to higher concentrations of pesticides than those found in the environment, thereby increasing the toxic effects on them [1]. Herbicides can persist longer in water, increasing the risk of prolonged exposure and accumulation in fish tissues (Van der Oost et al., 2003; Burch et al., 2024; Garrie, 2010; 2).

Conclusion:

For many decades, agriculture has relied on various plant protection products to combat pests, weeds, fungi, and other threats to crops. However, this study shows that agriculture in the wilaya of El Tarf is:

- ✓ Primarily market-oriented.
- ✓ Characterised by a predominance of vegetable and fruit crops.
- ✓ Dominated by the use of fungicides, followed by insecticides, with herbicides used less frequently and mainly of the selective and systemic types.
- ✓ The results also highlight potential environmental concerns, particularly regarding the effects of herbicides on non-target organisms, with fish perceived as the most sensitive.

Although plant protection products contribute significantly to agricultural productivity, their use needs better regulation. Strengthening farmer training, promoting integrated pest management, and environmental monitoring are essential to ensuring sustainable agriculture in the region.

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