DYNAMICS OF PLANT PROTECTION PRODUCT USE IN VÂLCEA COUNTY: ECOLOGICAL AND REGULATORY PERSPECTIVES

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Abstract

This study examines the long-term transformation of pesticide use in Romania between 1990 and 2024, integrating official statistical data with field evidence from Vâlcea County. The analysis reveals a structural paradox: although total pesticide quantities have decreased sharply since 2000, the ecological pressure remains significant, shifting from high-dose fungicidal applications to persistent herbicide use. Herbicides now account for approximately 88.6% of total PPP active substance mass nationally, and 44.3% in Vâlcea County. This "herbicidal risk paradox" illustrates that "less active substance" does not automatically mean "less ecological risk." A complementary field survey (n = 76) identifies a knowledge–practice gap among farmers, with only 48% regularly using protective equipment. The study concludes that quantitative reduction targets under the EU Farm to Fork Strategy are insufficient without Integrated Pest Management (IPM) adoption and enhanced farmer training.

Keywords: Plant Protection Products; Herbicides; Ecological Impact; Compliance; Sustainable Agriculture.

INTRODUCTION

Plant protection products (PPPs) play a central role in maintaining crop productivity and ensuring food security in modern agriculture. However, their intensive and prolonged use has raised growing concerns regarding environmental sustainability, biodiversity loss, and potential risks to human health (Carvalho, 2017; FAO, 2020). Within the European Union, the regulatory framework governing PPPs is being redefined through the Farm to Fork Strategy (F2F), which targets a 50% reduction in chemical pesticide use by 2030 (European Commission, 2020). Analyses of recent reforms of the Common Agricultural Policy (CAP) indicate that pesticide consumption remains misaligned with the sustainability objectives of the European Green Deal, despite increasing regulatory pressure (Alexoaei et al., 2022). In parallel, technological monitoring and strategic environmental management tools are becoming increasingly important for supporting the transition toward more sustainable agricultural systems (Iagăru et al., 2022; Iagăru et al., 2023).

Despite these policy ambitions, numerous studies show that reductions in the total volume of active substances do not necessarily correspond to decreases in ecological or toxicological pressure (Gaba et al., 2016; Kudsk & Jørgensen, 2018). This paradox is particularly evident in Central and Eastern Europe, where fragmented farm structures, heterogeneous production systems, and limited access to technical training hinder

the effective adoption of Integrated Pest Management (IPM) practices.

Romania exemplifies these contradictions. Although official statistics indicate a continuous decline in the total amount of active substances applied since the early 2000s, the composition of pesticide use has shifted markedly toward herbicides, which now dominate the national market. This shift suggests not a simple reduction in chemical dependency but a structural reallocation of risk, as modern formulations allow smaller doses to treat larger areas while herbicides remain persistent and ecologically disruptive.

Vâlcea County represents a particularly relevant case within this national context. Although the agricultural area is primarily dominated by cereals (approximately 74%), its landscape is characterized by orchards (accounting for over 20% of the cultivated area) and mixed farming systems. This structure, particularly the fruit sector, requires intensive plant protection, especially fungicidal treatments.

Starting from these observations, the present study addresses the existing research gap by quantifying the structural shift in pesticide-related risk and identifying the main compliance barriers at the local level. By combining long-term national statistics with a case study conducted in Vâlcea County (1990–2024), the research empirically tests the “herbicidal risk paradox” and evaluates the implications of the persistent knowledge–practice gap for implementing the EU Farm to Fork Strategy. This pattern aligns with evidence from other European farming systems, where limited awareness of pesticide-related risks influences farmer behaviour (Lamichhane & Laudinot, 2021) and where national-level mismanagement of pesticides has been documented (Popescu et al., 2021).

MATERIALS AND METHODS

The study adopted an exploratory mixed-methods design, combining national statistical datasets with primary field research in Vâlcea County. This integrative approach enabled the linkage of long-term quantitative trends with farmer-level behaviours and perceptions, following methodological frameworks applied in recent European pesticide studies (Schreinemachers & Tipraqsa, 2012).

Official statistical data were obtained from the TEMPO-Online database of the National Institute of Statistics (INSSE, 2024), which provides standardized information on pesticide use in Romanian agriculture. The analysis employed datasets AGR101A and AGR106A (quantities of active substances applied), AGR101B and AGR107A (treated agricultural areas), and AGR108A (crop and land-use structure). Data were exported in CSV format and processed using Microsoft Excel 365 for cleaning, aggregation, and cross-validation of consistency across years and pesticide categories.

Following the implementation of Eurostat Regulation No. 1185/2009 on pesticide statistics, certain INSSE datasets contain interpolated or constant values after 2015. This harmonization improved comparability but likely reduced variability in county-level time series. Consequently, the apparent stability of PPP intensity and composition after 2010 should be interpreted both as an outcome of data harmonization and as a reflection of technological modernization in pesticide application practices.

To assess both structural and ecological changes, two derived indicators were calculated, following the methodologies recommended by Eurostat (2023) and FAO (2020):

$$PPP\ Intensity = \frac{Total\ quantity\ of\ active\ substance\ (kg)}{Total\ treated\ area\ (ha)}$$

$$\text{Category Share} = \frac{\text{Quantity of PPP category (kg)}}{\text{Total PPP quantity (kg)}} \times 100$$

These indicators allowed the analysis to move beyond simple volume assessment, enabling the evaluation of pesticide use in terms of both application intensity and structural composition, and facilitating

comparisons between national and county-level ecological risk profiles.

At the county level, a semi-structured questionnaire was distributed to 76 farmers in Vâlcea County between March and May 2025, both in person (at a local PPP retail outlet) and online (via Google Forms). Respondents were recruited through convenience sampling (n = 76)—a necessary approach given the fragmented structure of small and medium-sized farms in the region, which renders formal random sampling costly and impractical. The findings are therefore presented not as statistically representative generalizations, but as diagnostic insights into local pesticide-use frequency, regulatory awareness, training participation, and handling practices.

To strengthen the qualitative dimension, a case study was conducted in the town of Băbeni, involving 15 semi-structured interviews with farmers engaged in fruit, cereal, and vegetable production systems. Interviews explored motivations for PPP use, perceived risks, and openness to sustainable alternatives such as biopesticides and crop diversification.

The qualitative material was analyzed thematically using inductive coding procedures (Braun & Clarke, 2019). Data collection continued until thematic saturation was achieved, ensuring that no new significant themes emerged and that the final coding structure captured a comprehensive understanding of local perspectives and compliance barriers.

Given the self-reported nature of both the questionnaire and the interviews, potential bias was acknowledged (Podsakoff et al., 2003). To enhance internal validity, key items were cross-checked for consistency, and qualitative findings were triangulated with statistical data. The relevance of farmer risk perception in shaping pesticide practices, documented in other European studies (Lamichhane & Laudinot, 2021), also informed the interpretation of behavioural responses in Vâlcea.

RESULTS AND DISCUSSIONS

The analysis of INSSE data for the period 1990–2024 reveals a structural shift in Romanian agriculture, presenting a clear paradox in pesticide use. While the total volume of active substances applied nationally decreased significantly after 2000 and stabilized at lower levels, the intensity of agricultural production and the ecological risk profile have changed — not necessarily declined. This contradiction reflects a move toward concentrated formulations and modern spraying technologies that enable large areas to be treated with smaller chemical inputs (FAO, 2020).

This structural change demonstrates that simple volume indicators (total kilograms) are no longer sufficient to assess environmental pressure. Therefore, the analysis was extended to include two derived indicators: PPP Application Intensity (kg a.s./ha) and Consumption Structure (Share %), which together capture the dynamics of ecological pressure and the redistribution of chemical risk.

PPP Application Intensity and Risk Convergence

The comparison of PPP application intensity between Vâlcea County and the national average (Figure 1) highlights important structural differences in pesticide use.

As illustrated in Figure 1, the national intensity trend demonstrates a primary concern centered on herbicides, which maintain a relatively stable and high intensity (≈ 0.7–1.0 kg/ha), dominating the overall chemical pressure. Conversely,

Vâlcea County exhibits a distinct agro-ecological profile:

- Historical Peak (1990s): Vâlcea recorded extremely high fungicide intensity values (≈ 13.76 kg/ha), corresponding to its fruit sector, which traditionally required heavy fungicidal protection.
- Convergence (Post-2000): After 2000, PPP intensity across all categories dropped sharply, approaching national averages as lower-dose products were introduced.

These findings strongly indicate a critical structural reallocation of risk across Romanian agriculture — a transition from the acute, localized risk of high-volume fungicidal practices (peak 13.76 kg/ha in Vâlcea) toward the persistent, systemic ecological pressure driven by modern herbicides.

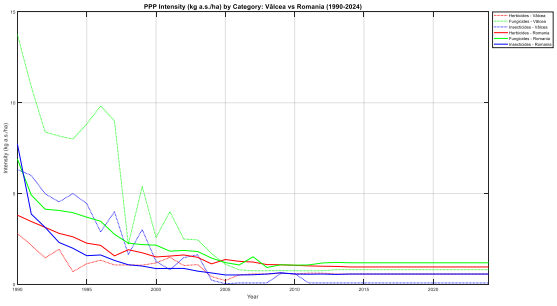

Figure 1. *PPP Intensity (kg a.s./ha) by Category in Vâlcea County and Romania (1990–2024). Source: INSSE (2024), AGR106A and AGR107A, own processing.*

PPP Consumption Structure (Share %)

To better capture this reallocation, Figure 2 presents the composition of PPP use by chemical category (Share %), comparing national and county-level dynamics.

Nationally, herbicides dominate the PPP structure, accounting for ≈ 88.6 % of total quantities by 2024, while fungicides and insecticides represent only ≈ 10.7 % and < 1 %, respectively. In contrast, Vâlcea shows a dual structure: although herbicides have increased sharply from < 10 % in 1990 to ≈ 44.3 % in 2024, fungicides still represent over 53 %, maintaining regional specificity linked to orchard and fruit systems.

This configuration substantiates the "herbicidal risk paradox" — overall chemical inputs declined, yet the ecological load remains concentrated in herbicides, which are persistent, systemic, and pose long-term risks to soil biodiversity and water quality (Gaba et al., 2016; Kudsk & Jørgensen, 2018; Silva et al., 2019).

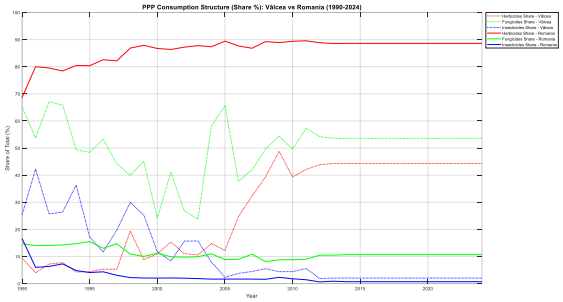

Figure 2. *PPP Consumption Structure (Share %) in Vâlcea County and Romania (1990–2024). Source: INSSE (2024), AGR106A–AGR107A, own processing.*

The apparent stabilization of PPP intensity and structure after 2010 reflects not a lack of recent data but a structural transformation in Romanian agriculture. Following 2000, the widespread adoption of lower-dose formulations and improved application technologies significantly reduced the quantities of active substances per hectare. In Vâlcea, the sharp decline of fungicide intensity — from a historical peak of ≈ 13.76 kg a.s./ha in the 1990s — illustrates this convergence. Nationally, the predominance of herbicides (currently > 88 % of PPP use) maintains a relatively stable intensity (~ 0.7–1.0 kg a.s./ha), giving the visual impression of plateaued trends. This stabilization may also reflect the effect of data harmonization introduced by Eurostat Regulation 1185/2009, which slightly reduced variability in county-level time series (European Parliament & Council, 2009c).

Local Compliance and the Knowledge–Practice Gap

The survey and interviews conducted in Băbeni further reinforce these patterns. Farmers emphasized the convenience of herbicides and their reduced labor requirements, while remaining cautious

about fungicides and insecticides due to cost and variable pest pressure.

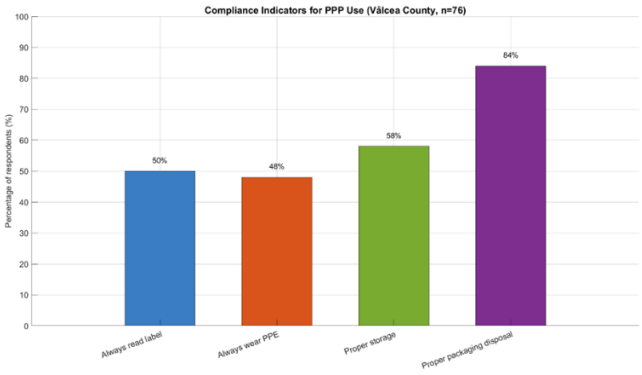

Figure 3. *Compliance indicators for PPP use in Vâlcea County (n = 76). Source: Authors' survey (Google Forms, 2025).*

As shown in Figure 3, compliance with safe-use requirements is uneven. About 50 % of farmers always read product labels, 48 % regularly use personal protective equipment (PPE), 58 % store PPPs in dedicated facilities, and 84 % properly manage packaging waste. Although packaging compliance is high, PPE use remains insufficient — a behavioral issue observed across EU agriculture (European Court of Auditors, 2020).

From the perspective of the EU Farm to Fork Strategy, these results expose a critical dual challenge. The reduction in the volume of active substances aligns with the strategy's quantitative goals. However, the increasing dominance of herbicides demonstrates that "less active substance does not automatically mean less ecological risk."

Table 1. Association between level of regulatory knowledge and frequency of PPP label reading (% of respondents, n = 76). Source: Authors' survey (Google Forms, 2025).

Level of regulatory knowledge	Always (%)	Sometimes (%)	Never (%)	Total (%)
Very good	19,35	6,45	0	25,81
To some extent	29,03	16,13	0	45,16
Not very familiar	8,06	19,35	1,61	29,03
Total	**56,45**	**41,94**	**1,61**	**100**

The prevalence of herbicide use is therefore driven by a combination of high crop area coverage (as reflected in the national data) and farmer preference for labor reduction, while the high proportion of fungicides in Vâlcea (Figure 2) is a structural necessity for local fruit systems — highlighting non-uniform policy challenges within Romania's agricultural landscape.

Finally, the knowledge–practice gap highlighted by the survey (e.g., 48 % PPE use) confirms that regulatory frameworks alone are insufficient. The primary policy imperative should therefore be to move beyond simple volume-reduction targets toward supporting robust, localized Integrated Pest Management (IPM) systems, combined with dedicated economic incentives and hands-on extension services to bridge the compliance gap.

Some limitations must also be acknowledged. The county-level survey relied on a convenience sample and self-reported answers, which are not statistically representative and may introduce social desirability bias. Nonetheless, the findings provide a valuable diagnostic of local practices and challenges, offering a foundation for targeted policy and educational interventions consistent with the EU Farm to Fork objectives. Despite these limitations, the integration of national statistics with field-level insights provides a robust empirical basis for understanding how pesticide-use patterns evolve under transitional agri-environmental policies.

CONCLUSIONS

This study provides an integrated, multi-scalar analysis of Plant Protection Product (PPP) use dynamics in Romania between 1990 and 2024, combining long-term

national statistics with diagnostic field evidence from Vâlcea County. The results confirm a fundamental transformation in Romanian agriculture, characterized by a shift from high-volume, localized chemical inputs toward more concentrated and persistent formulations.

The core outcome is the "herbicidal risk paradox," demonstrating that the substantial reduction in total active substance mass observed after 2000 does not correspond to a proportional decline in ecological pressure. Instead, risk has been structurally reallocated:

- National risk reallocation: Herbicides now represent approximately 88.6 % of the total PPP active substance mass nationally (INSSE, 2024). This dominance generates a persistent, systemic ecological load, particularly affecting soil health, biodiversity, and water quality — challenges that are not captured by simple quantitative reduction targets.
- Regional specificity: In contrast, Vâlcea County maintains a distinct agro-ecological profile, where fungicidal dependence (~53 %) persists due to the structural necessity of orchard protection (INSSE, 2024). This emphasizes the non-uniform policy challenges of implementing the Farm to Fork Strategy (F2F) across regions with heterogeneous production systems.

The second major finding concerns the knowledge–practice gap identified through the farmer survey. Although awareness of PPP safety and regulations exists, compliance remains limited: only 48 % of respondents reported consistent use of personal protective equipment (PPE). This discrepancy indicates that regulatory enforcement alone is insufficient and must be complemented by educational and economic support mechanisms (European Court of Auditors, 2020).

From a policy perspective, these findings point to two urgent imperatives:

- Move beyond volume-based reduction targets. The EU F2F Strategy should integrate risk-based indicators that account for the persistence, toxicity, and ecological behavior of dominant chemical classes — particularly herbicides — rather than focusing solely on aggregate reduction of active substance mass.
- Localize support for Integrated Pest Management (IPM). To close the compliance gap and reduce structural dependence on fungicides and herbicides, localized extension services and economic incentives must be established to assist small and medium-sized farms in adopting IPM systems and biopesticide-based alternatives.

In conclusion, the sustainability of Romanian agriculture depends on its capacity to confront a dual challenge: mitigating the structural ecological risk driven by herbicide dependence, while closing the behavioral compliance gap through targeted farmer education and incentive-based policy measures.

Future research should focus on long-term monitoring of soil and water contamination linked to herbicide residues, as well as the socio-economic drivers that influence farmers' adoption of IPM and sustainable pest management practices.

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