THE IMPACT OF LATE SPRING FROSTS IN 2025 ON THE FRUIT-GROWING SECTOR IN SOUTHEASTERN EUROPE: A COMPARATIVE STUDY BETWEEN THE REPUBLIC OF MOLDOVA, ROMANIA, UKRAINE, AND POLAND

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Abstract: *In the context of global climate change, the frequency and intensity of extreme weather events have increased, significantly affecting agricultural sectors in temperate regions. Late spring frosts represent one of the most damaging phenomena for perennial crops and fruit growing, as they coincide with critical phenological phases such as budding, flowering, and fruit set. The spring of 2025 was marked by severe frost episodes in April across Southeastern and Central-Eastern Europe, with the Republic of Moldova, Romania, Ukraine, and Poland being particularly affected. Minimum temperatures dropped below the critical thresholds for both pome (apple, pear) and stone fruit species (apricot, peach, cherry, plum), leading to substantial production losses and severe economic impacts on farmers. This paper presents a comparative analysis of the effects of the late frosts of April 2025 on the fruit-growing sector in the four countries, aiming to identify the extent of the phenomenon, regional differences in the intensity and distribution of damages, as well as institutional responses and adaptive strategies implemented. The analysis is based on official statistical data, climatic reports, production loss estimates, and relevant scientific literature. The results highlight the vulnerabilities of Eastern European fruit-growing systems to climatic risks and provide a foundation for developing sustainable measures to mitigate their impact.*

Keywords: *climate change, late frosts, fruit growing, crop losses, agricultural adaptation, Eastern Europe*

JEL Classification: Q10, Q12, Q54, Q51

INTRODUCTION

The increase in global average temperature represents one of the main effects of contemporary climate change, having a direct impact on the dynamics of annual meteorological and climatic processes. This phenomenon is primarily driven by the intensification of the greenhouse effect, caused by the accumulation of greenhouse gases in the atmosphere, such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) (Choudhary et. all, 2015). The rising concentration of these gases enhances the retention of thermal energy within the Earth's climatic system.

The consequences of this energy accumulation are reflected in significant alterations of the seasonal thermal regime, manifested through milder winters and earlier, warmer spring onsets (Makarova, D. H. (2025). In recent years, an increasing frequency of meteorological anomalies has been observed, with air temperatures exceeding the climatological norms toward the end of winter (late February–early March).

These thermal anomalies trigger the premature onset of vegetative processes, particularly in perennial species, and are often followed by sharp cooling episodes during April–May, coinciding with the flowering stage. Low temperatures during this phenological phase significantly affect the pollination process and, in severe cases, can lead to the freezing of blossoms. At the same time, the activity of bees — the main pollinating agents — is considerably reduced, further amplifying the negative effects on agricultural production.

A telling example is represented by the late frosts recorded between March and May 2025, when temperatures dropped to –8 °C, coinciding with critical stages of bud break and flowering in most fruit species. The most affected crops were stone fruits (cherry, sour cherry, apricot, plum, peach), although substantial losses were also recorded in apple and pear orchards in certain regions. The economic impact was significant across all four analyzed countries — the Republic of Moldova, Romania, Ukraine, and Poland — through a drastic reduction in production and disruptions in the horticultural value chains.

MATERIALS AND METHODS

The analysis of the effects of the late spring frosts of 2025 on the fruit-growing sector in the Republic of Moldova, Romania, Ukraine, and Poland was conducted using a comparative, descriptive, and evaluative methodology, focusing on agronomic and economic indicators. The study aims to identify production losses and financial impacts at both national and regional levels, as well as to highlight structural differences among the fruit-growing systems analyzed.

The data utilized were exclusively drawn from official statistical and economic sources, including: the National Bureau of Statistics of the Republic of Moldova; INSSE and MADR – Romania (official reports and releases on affected areas); GUS, Eurostat, and USDA FAS (GAIN Report, 2025) – Poland; FAO, Eurostat, and Freshplaza – Ukraine (data on losses and orchard structure). These sources were supplemented with ministerial communications, economic reports, and sectoral press articles, which provided additional information on the scale and distribution of losses.

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RESULTS AND DISCUSSION

The late spring frosts of 2025 generated significant economic consequences for the fruit-growing sector in the Republic of Moldova, highlighting the high vulnerability of this branch to sudden temperature fluctuations during the flowering phenological stage.

Although the total orchard area is relatively smaller compared to Romania, Ukraine, or Poland, the economic role of fruit growing within the national agricultural structure remains substantial, consistently contributing to the formation of the agricultural Gross Domestic Product and agro-food exports.

According to data from the National Bureau of Statistics, the total area of productive orchards in 2024 amounted to approximately 43.3 thousand hectares, with apple, walnut, plum, cherry, and sour cherry orchards predominating (Ministry of Agriculture and Food Industry – Moldavia, 2024). These species are particularly sensitive to temperature fluctuations, especially during bud break and flowering stages.

In this context, the frost episodes from March to May 2025 severely affected approximately 8,650 hectares of orchards, representing around 20% of the total productive area (Ministry of Agriculture and Food Industry – Moldavia, 2025). Losses were unevenly distributed across regions and species, directly impacting production volumes and farmers' incomes (IPN.md. (2025).

Preliminary estimates indicate a substantial reduction in fruit exports, projected at 150–160 million USD compared to approximately 290 million USD in 2024. This decline is driven both by the decreased volume available for export and by the deterioration in the quality of fruits intended for

international markets [3].

For apple orchards, which constitute the main component of horticultural exports, production losses are estimated at approximately 128 thousand tons compared to the previous year. In financial terms, lost gross revenues are estimated between 40 and 64 million USD, depending on average export prices and the level of domestic market absorption.

Table 1. Structure and Damage of Orchards in the Republic of Moldova in the Context of the Spring 2025 Frosts

Crop	Productive Area 2024 (ha)	Affected Share (%)	Affected Area 2025 (ha)
Apple	14 894	~13	1 940
Cherry	2 551	~30	779
Apricot	1 423	~16	228
Plum	8 577	~27.5	2 361
Sour Cherry	1 413	~10	141
Walnut	14 400	~22	3 201
Total	43 258	-	8 650

Source: Prepared by the author based on data provided by the Ministry of Agriculture and Food Industry (MAIA) and the State Hydrometeorological Service (SHS).

The total economic impact, including the reduction of export logistics and commercial capacity, is assessed at over 60 million USD, highlighting the high vulnerability of the Moldovan fruit-growing sector to recurrent climatic risks.

In Romania, the late spring frosts of 2025 had widespread effects on fruit crops in the southern and central regions, where negative temperatures occurred during the critical flowering and fruit-setting stages. The event particularly exposed the vulnerability of stone fruit orchards, resulting in significant losses in annual production.

According to data provided by the National Institute of Statistics (INSSE) and the Ministry of Agriculture and Rural Development (MADR), the total area of productive orchards amounted to approximately 138 thousand hectares, dominated by apple, plum, cherry, and apricot orchards. Among these, apples remain the main crop, accounting for about 45% of the total orchard area, followed by plum and cherry.

From an economic perspective, the late spring frosts of 2025 caused significant financial losses in the Romanian fruit-growing sector, directly affecting the agro-food trade balance and the incomes of producers in the main orchard regions.

The most affected crops were cherries, with financial damages estimated between 280 and 800 million euros, and a production deficit of approximately 140–160 thousand tons compared to the average of recent years. In many southern and central regions of the country, losses exceeded 60% of the potential harvest, severely impacting exports and international trade contracts (Fresh Plaza North America. (2025).

For other stone fruit crops — sour cherry, apricot, plum, and peach — losses are estimated between 180 and 600 million euros, depending on orchard density, microclimatic conditions, and the timing of the frosts.

Overall, the total economic impact on Romanian fruit growing is estimated between 1.5 and 2 billion euros, including crop losses, additional maintenance costs, and reduced export revenues. These results confirm the high vulnerability of the Romanian fruit-growing sector to climatic shocks and

underline the need to strengthen agricultural insurance systems and post-disaster financial support (MARD 2025).

Table 2. Structure and Damage of Orchards in Romania in the Context of the Spring 2025 Frosts

Crop	Productive Area 2024 (ha)	Affected Share (%)	Affected Area 2025 (ha)
Apple	47 600	3 587	7.5
Cherry	10 880	3 075	28.3
Apricot	6 800	2 434	35.8
Plum	34 000	5 445	16.0
Sour Cherry	6 800	1 922	28.3
Walnut	9 520	538	5.7
Total	115 600	17 000	-

Source: Prepared by the author based on data from INSSE and MADR.

In Ukraine, the late spring frosts of 2025 had particularly severe effects on the fruit-growing sector, impacting production in the central, southern, and western regions of the country Fresh Plaza North America. (2025). The phenomenon occurred during the critical flowering period of stone fruit species, causing massive yield losses and significant reductions in the quality of fruits intended for export. Data collected from national and international sources indicate production declines ranging from 40% to 80% for major apricot, peach, cherry, and sour cherry crops, particularly in the regions of Vinnytsia, Kherson, Odesa, Rivne, and Chernivtsi (NV English. (2025).

Table 3. Structure and Damage of Orchards in Ukraine in the Context of the Spring 2025 Frosts

Crop	Productive Area 2024 (ha)	Affected Share (%)	Affected Area 2025 (ha)
Apple	120 000	26	30 000
Cherry	18 400	33	9 000
Apricot	12 250	80	9600
Plum	25 650	34	8 125
Sour Cherry	15 430	39	6 300
Walnut	10 290	13	1 200
Total	202 020	-	72 875

Source: Prepared by the author based on data from Freshplaza and the State Statistics Service of Ukraine.

The total economic impact on Ukrainian fruit growing is estimated at 1.2–1.6 billion euros, with more than half attributed to stone fruit crops. For apples, losses were moderate (20–30%) but geographically widespread, affecting commercial orchards in the western regions (Mediacenter Ukraine, 2025).

The drastic reduction in domestic production created a supply deficit in the local market and a significant decline in fresh fruit exports, particularly to the European Union. In the short term, this

situation led to increased domestic prices, but it did not compensate for the economic losses incurred by producers.

In Poland, the late spring frosts of 2025 caused unprecedented economic losses in the past two decades, marking the most severe impact on the fruit-growing sector since the early 2000s.

The phenomenon occurred in multiple successive waves between March and May, with local temperatures dropping to –8 °C, particularly affecting the regions of Małopolska, Lublin, Lower Silesia, Podkarpackie, and Mazovia — the main orchard areas of the country, characterized by high-density plantings of cherry, plum, and apple.

As a result, production losses were estimated at over 40% of the multi-year average, and in some commercial orchards — especially in the south and center of the country — damages exceeded 80%, leading to the total compromise of the harvest. This event highlighted the vulnerability of Poland's intensive horticultural systems, which rely on specialized monocultures and remain exposed to recurring climatic risks despite advanced mechanization and technology.

Table 4. Structure and Damage of Orchards in Poland in the Context of the Spring 2025 Frosts

Crop	Productive Area 2024 (ha)	Affected Share (%)	Affected Area 2025 (ha)
Apple	150 000	8 500	5-7
Cherry, Sour Cherry	34 500	1 7000-19 000	50-55
Apricot, Plum	10 000	1 000	10
Total	194 500	25 000-30 000	-

Source: Prepared by the author based on data from Freshplaza and the Central Statistical Office of Poland (Główny Urząd Statystyczny).

According to USDA FAS reports (GAIN Report, 2025), supplemented by information from Freshplaza publications (2025) (FreshPlaza. (n.d.). and structural data from the Central Statistical Office of Poland (GUS) [9] and Eurostat, the financial losses at the national level are estimated between 1.5 and 2 billion euros, with the largest share attributed to cherries and other stone fruits (USDA-FAS). (2025).

The comparative analysis of the effects of the late spring frosts of 2025 on the fruit-growing sector in the Republic of Moldova, Romania, Ukraine, and Poland reveals a complex picture of the vulnerability of Eastern European horticulture to recurring climatic risks. Although the phenomenon was regional, the intensity and economic consequences varied depending on orchard structure, level of technology adoption, and institutional response capacity.

In the Republic of Moldova, where fruit growing plays an important role in agricultural income and exports, losses were severe, affecting approximately 20% of the total productive area and significantly reducing fruit export volumes. In Romania, the frosts caused the largest absolute losses in the region, estimated at 1.5–2 billion euros, with a pronounced impact on stone fruit crops and the agricultural trade balance. In Ukraine, the effects were territorial and uneven, but particularly severe in the southern and western regions, where losses exceeded 50% of the annual production for some species. In Poland, a country with a modern horticultural infrastructure, the event caused the largest production deficit in the past two decades, confirming that even intensive systems are not immune to extreme climatic shocks (USDA-FAS). (2025).

Comparatively, all four countries exhibit similar structural vulnerabilities: dependence on sensitive monocultures (apple, cherry, apricot), lack of effective agricultural insurance mechanisms, limited frost-protection infrastructure, and often delayed institutional responses. At the same time, differences between countries are determined by the level of capitalization and market integration — Poland has greater financial resources for replanting and compensation, whereas the Republic of Moldova and Ukraine remain reliant on external or ad hoc support.

To reduce future risks and increase the resilience of the fruit-growing sector, a regional adaptation strategy based on complementary interventions is required. In the short term, rapid financial compensation mechanisms for production losses and temporary support schemes for affected farmers, including preferential credit for orchard restoration, are necessary.

In the medium term, it is recommended to expand agricultural insurance systems specific to climatic risks, with subsidized policies and products indexed to agrometeorological data, as well as investments in frost-protection infrastructure — sprinklers, fans, thermal nets, and early warning technologies. Structural diversification of orchards through the introduction of cultivars and rootstocks with increased tolerance to thermal stress, adapted to new climatic conditions, is also essential.

In the long term, the analyzed countries should develop interstate partnerships and regional mechanisms to stabilize the fruit market, capable of mitigating price fluctuations and supply deficits caused by extreme events. Strengthening research, professional training, and agricultural extension systems will play a central role in enhancing farmers' and horticultural economies' adaptive capacity.

CONCLUSIONS

Overall, the 2025 frost experience confirms that adaptation of Eastern European fruit growing to climate change can no longer be addressed in isolation at the national level but must be treated as a regional priority, with coordinated policies, sustainable financing, and the exchange of best practices among affected countries.

The late spring frosts of 2025 serve as a reference point for understanding the climatic vulnerability of the Central-Eastern European fruit sector. The event clearly demonstrated that the intensification of extreme phenomena is no longer an isolated meteorological exception but a recurring manifestation of climate change with systemic impacts on the agricultural economy.

The results of the comparative analysis confirm that productivity losses, fruit quality deterioration, and reduced export capacity generate economic effects that extend beyond the primary sector, affecting processing and trade value chains. Consequently, climate risk management must be integrated into national rural development strategies and European agricultural transition policies.

The development of prevention, compensation, and adaptation mechanisms — agricultural insurance, frost-protection infrastructure, early warning systems, genetic diversification of cultivars, and professional training — constitutes the essential pillars of future resilience. At the same time, regional cooperation among the Republic of Moldova, Romania, Ukraine, and Poland should be strengthened through data sharing, technical expertise, and institutional coordination to create a common framework for managing climate risks in fruit growing.

Looking ahead, scientific research should focus on economic modeling of climate-related losses, assessment of adaptation costs, and optimization of resilience strategies at farm and regional levels. Only through an integrated approach, based on empirical data and transnational collaboration, can Eastern European fruit growing ensure continuity of production, economic competitiveness, and sustainability of agricultural ecosystems in an increasingly unstable climatic context.

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