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Growth Without Viability? Two Decades of Polish Fruit Growing and the Resilience of Family Farms

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Abstract

Resilience assessments of farming systems specify the unit of analysis and its disturbances but give less attention to how outcomes are distributed among the system's actors. This article examines whether system-level robustness and household-level economic viability diverged in fruit growing in Central–Eastern Poland. Statistics on area, yields, farm structure, and processing prices for 2004–2025, and farm accountancy data for permanent-crop farms in Farm Accountancy Data Network (FADN) region 795—Mazowsze i Podlasie for 2006–2024, are set against SURE-Farm project's participatory evidence collected in 2018–2020 (a survey of 70 farms, 46 interviews, a focus group of 9, and workshops with 20 and 12 stakeholders), mainly from soft-fruit growers. Tree fruit yields roughly doubled and output recovered after shocks, while farms with orchards fell by more than a third. Income per family work unit on fruit farms moved from above to below the regional all-farm average from 2013–2014, a shift supported by a break test and persisting when subsidies are excluded. Stakeholders rated economic viability the least well delivered of eight system functions. The two kinds of evidence converge without validating each other, and the descriptive design cannot identify the mechanism: the pattern is consistent with an agricultural treadmill but does not establish it.

Keywords: farming system; system function; resilience; resilience for whom; robustness; adaptability; transformability; family farms; horticulture; fruit growing; Poland

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Academic Editors: Liontakis Angelos, Alexandra Sintori and Tsiboukas Konstanitinos

Received: 18 October 2026
Revised: 10 November 2026
Accepted: 13 November 2026
Published: 16 November 2026

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1. Introduction

Agricultural sustainability seeks a balance between the economic, environmental, and social sides of farming, with farming systems that remain resilient over the long run, and the literature identifies a range of approaches through which it may be pursued [1,2].

Following Meuwissen and colleagues [3], the resilience of a farming system is understood here as its ability to keep delivering its functions despite accumulating economic, social, environmental, and institutional shocks and stresses, drawing on three capacities: robustness, adaptability, and transformability. Where a system has become overly rigid, the task may instead be to move it towards a different path [4], and resilience assessments aim less at an optimal solution than at understanding the system and fostering learning and adaptation [5].

Resilience is not, however, a fixed attribute that can be assessed without specifying its referents. Carpenter et al. established that any resilience claim must answer two questions: resilience of what, and to what [6]. The framework applied here answers both explicitly, the unit being the regional farming system and the disturbances the environmental, economic, social, and institutional pressures acting upon it [3]. A third question has since been added to these two, resilience for whom, on the grounds that a system may absorb a disturbance while particular groups within it bear the cost of that absorption [7,8]. This question is harder to answer at system level, because the aggregate indicators through which farming systems are conventionally described are silent about distribution. A system whose output is maintained will register as robust on output and trade indicators irrespective of how the returns are shared among the actors composing it. The framework of the SURE-Farm project (Towards SUstainable and REsilient EU FARMing systems) itself treats economic viability as one of the functions a farming system must deliver, so the divergence of interest here is between functions that are visible in output statistics, food production above all, and economic viability, which becomes visible only in farm accounts and in the assessments of those who farm.

Agricultural economics offers one well-established mechanism by which the two levels may come apart, although not the only one (Section 4). Cochrane's agricultural treadmill holds that producers adopting a productivity-raising innovation gain an advantage only until adoption becomes general; the additional supply then depresses prices, the advantage disappears, and those who did not adopt are obliged to leave, while the lasting gains are captured largely by landowners [9,10]. Testing the mechanism across twenty-five European countries for 1980–2015, Czyżewski et al. [11] concluded that it had lost much of its force since the mid-1990s and linked this to the evolution of the Common Agricultural Policy (CAP), while a parallel monograph [12] found that a treadmill of the income growth rate persisted, affecting mainly small and medium farms. Because these results rest on national aggregates, whether the mechanism operates in a particular sector remains an empirical question. Its observable implications, and those of competing explanations, are set out in Section 2.5 and examined in Section 4.

Many of the challenges facing agriculture arise less from the production process itself than from changes in the environment of the agricultural system. Agricultural regulation is variable at both national and community levels and accumulates over time, with a growing public-law and pro-environmental component [13]. The intertwining of production, market, and institutional risks, the long production cycle, and the dependence on factors beyond the farmer's control make decisions difficult [14], and producers adjust the volume of production and the organisation of their resources to climate risk and its fluctuations [14–16].

There is growing pressure on farmers to be economically viable and environmentally sustainable at the same time [17,18]. The key issues identified in the literature are access to farming resources and to markets: farmers face land use limitations, labour shortages, and constrained access to capital, and competition from other regions makes innovation, quality, and price decisive for their survival [17,18]. Small and medium farms have fragile bargaining power, cannot benefit from economies of scale, and typically lose out to larger operations offering higher and more stable supply [17], and a lack of collective action reduces their possibilities for profit and innovation.

Succession is a recurrent concern: in Polish horticulture the continuity of farms is uncertain even though most farm families have three or more children [19], while at the European level the consequences of succession for the resilience of farming systems are contested [20]. Succession is shaped by legal, fiscal, and cultural constraints on the transfer of farm assets and by the need to finance retirement [21], and its timing is critical: too early,

it places excessive pressure on an inexperienced successor [22]; too late, the successor may have moved into other work.

Horticulture in Poland faces price fluctuations alongside environmental risks, such as hail, frost, drought, and floods [23]. In the SURE-Farm farm survey, Polish horticultural farmers rated environmental challenges, jointly with economic ones, as the most relevant, singling out extreme weather events [24], which affect the volume of horticultural production far more than that of field crops [19]. Uncertainty about future irrigation needs [25] and environmental risks more generally [26] are recognised challenges for the sector.

Agricultural policies, the CAP in particular, shape the resilience and adaptability of food production systems and may also raise costs. The European Green Deal and the Polish Strategic Plan for the CAP for 2023 to 2027 present significant challenges for Polish agriculture [27]; insurance requirements, irrigation needs, and high temperatures are expected to increase fruit production costs [28], and the rapid growth of costs, especially of hired labour, can erode the cost competitiveness of Polish horticulture [29].

Horticultural production remains fragmented [30], and the number of the smallest producers is declining because of low capacity and high production costs [31]. The development of fruit production depends on proximity to absorptive markets, price-to-cost relations, a processing base, specialised equipment, and storage [32]. Fruit growers have limited control over the prices paid for processing fruit, and fragmentation weakens their position in the supply chain [33]; their reluctance to engage in horizontal cooperation, in particular to form producer groups, has long been identified as a weakness [34,35].

More recent accounts of the Polish orchard industry report rising production costs, competition from other European Union (EU) countries, and a shortage of seasonal workers [36], together with uncertainty about apple sales and rising energy costs [37]. The COVID-19 pandemic showed how much the system relies on seasonal workers from Ukraine and raised the prices of fertilisers and plant protection products [38], and the Russian full-scale invasion of Ukraine in 2022 added to these pressures, notably through higher energy and input prices [37].

What this literature does not resolve is a puzzle that becomes visible only when the aggregate performance of the sector is set beside the assessment of those who work within it. Measured by output, Polish fruit growing has been one of the clearer successes of accession; measured by the area under fruit trees since 2013 and by the number of farms with orchards between 2010 and 2020, it has been contracting. Stakeholders in the Polish case study of the SURE-Farm project scored economic viability lower than any of the other seven functions of the farming system, and the farmers among them placed its delivery below the level defined as poor [39].

The Polish horticultural farming system has been described previously, most fully within the SURE-Farm project by Zawalińska and Gradziuk [19], who analysed its resilience capacities and the alternative systems proposed by stakeholders, and by Martikainen [23,35], who examined how the CAP affects the resilience of the sector, in the later study by applying the SURE-Farm protocol for bottom-up policy analysis in the Lubelskie region. The perception of the importance and performance of the system's functions has been reported by Krupin and Bańkowska [39]. The contribution of the present article is to situate those findings against the long-run statistical trajectory of the sector, which none of them addresses.

The article addresses three questions. First, what has been the trajectory of Polish fruit growing since EU accession, measured not by output alone but by area, structure, and the income accruing to the families that farm it? Second, how do the actors within the system assess its condition, and does that assessment point in the same direction as the accounting evidence? Third, if system-level and household-level outcomes diverge, which explanations

are consistent with the evidence, and what does the divergence imply for assessing the resilience of farming systems composed of family farms? Section 2 describes the case study, the data, and the way the constructs are operationalised. Section 3 presents the trajectory, the participatory assessment, and the relation between them. Section 4 discusses candidate explanations and returns to the question of resilience for whom. Section 5 concludes.

2. Materials and Methods

2.1. Case Study Area

The case study focused on the border areas of two NUTS 2 (Nomenclature of Territorial Units for Statistics, level 2) regions in Central–Eastern Poland: PL92 (Mazowieckie) and PL81 (Lubelskie). Both lie within Farm Accountancy Data Network (FADN) region 795—Mazowsze i Podlasie, the smallest territorial unit for which Polish FADN results are published, which also comprises Łódzkie and Podlaskie. The region is known for diverse agriculture and in particular for horticulture: apples, pears, plums, and cherries dominate tree fruit production, the main soft fruits are strawberries, raspberries, currants, and gooseberries, and onions, carrots, cabbages, cucumbers, and tomatoes are the main vegetables. It is characterised by weak horizontal and vertical cooperation among producers and a shortage of labour.

Four typical farm types were defined for the case study area: small farms of less than 10 hectares engaged mainly in crop farming, medium-sized farms of 10 to 30 hectares engaged in either crop farming or milk production, small farms of less than 10 hectares specialising in horticulture, and small farms of less than 5 hectares focused on poultry. The family households connected to these farms formed a further unit of analysis. The third of these, small family horticultural farms, is the focal type of the present analysis.

The article is framed nationally, with the case region treated as a case within that frame—claims derived from the participatory data concern this region and are not presented as nationally representative. Within the SURE-Farm fruit and vegetable case, the article concentrates on fruit growing: field vegetables are reported for context, but the income evidence concerns farms specialising in fruit trees and bushes and the workshop participants came predominantly from soft-fruit farms (Section 2.4), so the conclusions are confined to fruit and bear most directly on soft fruit. The accountancy data exclude farms below the FADN economic size threshold, so neither strand is representative of all Polish fruit farms. The case study area denotes the border areas from which the participatory evidence derives, and the case study region of the Mazowieckie and Lubelskie voivodeships in full, for which the statistics are reported.

2.2. Participatory and Qualitative Methods

To assess the challenges to the resilience of the Polish horticulture farming system, several methods were employed as part of the SURE-Farm project:

- **Farm survey:** a survey of 70 participants, including 26 horticultural farms and 44 permanent crop farms in the case study region, addressing the challenges they face, fielded in 2018 and completed in early 2019 [40].
- **Demographic interviews:** 17 interviews with private family fruit and vegetable farms, organised into nine minicases [41].
- **Learning capacity interviews:** nine interviews in the case study region between May and November 2018 exploring farmers' learning capacity [42].
- **FoPIA-SURE-Farm 1** (Framework of Participatory Impact Assessment for Sustainable and Resilient FARMing systems): a workshop held in Widniówka in March 2019, attended by 20 stakeholders, including farmers and government representatives, to assess the resilience and sustainability of the farming system [43].

- **Risk management focus group:** in June 2019, a focus group with nine participants from various farming-related organisations [44].
- **Policy interviews:** interviews with 20 stakeholders, including farmers and officials, together with a desk study [45].
- **Ecosystem service assessment:** analysis of ecosystem service indicators using publicly available datasets [24].
- **ResAT** (Resilience Assessment Tool) assessment: evaluation of the goals and instruments of the CAP and national agricultural policy relevant to the case study area on the basis of policy documents [46,47].
- **FoPIA-SURE-Farm 2**: a second workshop with 12 participants, 7 of them farmers, addressing 4 indicators relating to utilised agricultural area, purchase prices, income dynamics, and labour costs [48,49].

The FoPIA-SURE-Farm framework was applied following common workshop guidelines in all eleven SURE-Farm case studies, with some case-specific adaptations [50,51], which allows the Polish results to be read against those from other European farming systems. In the first workshop, participants ranked the importance of 8 system functions, 4 private (food production, bio-based resources, economic viability, and quality of life) and 4 public (natural resources, biodiversity and habitat, animal health and welfare, and attractiveness of the area), by distributing 100 points among them, weighted 3 pre-selected representative indicators per function, with the option of adding 1, scored indicator performance on a five-point scale, and assessed the presence of 13 resilience attributes together with their contribution to robustness, adaptability, and transformability [43]. The function scores reported in Section 3.3 derive from this workshop, the classification of challenges in Section 3.2 draws on the synthesis of all methods in the SURE-Farm resilience assessment [24], and the thresholds in Section 3.3 derive from the second workshop [49]. The ecosystem service and ResAT assessments inform the description of the case and are not reported separately.

Twenty stakeholders took part in the first workshop and were classified into three groups: Farmer (n = 10), Government (n = 4), and Other (n = 6). In some exercises fewer participants provided responses, so most analyses report n = 19 [39]. Several participants held more than one role. Three of the four participants classified as Government were themselves farmers holding positions in local self-government, and two of the six classified as Other also farmed. This overlap is discussed in Section 3.3, since it bears directly on how differences between the groups should be read.

2.3. Statistical Sources

The trajectory of the sector is described using published national and European statistics. Production volumes and cultivated areas are taken from Statistics Poland (GUS), principally the annual series on the production of agricultural and horticultural crops [52] and, until its last edition for 2019, on land use and sown area [53]. Structural data are taken from the Agricultural Censuses of 2010 and 2020 [54–56]. Purchase prices and market volumes are drawn from the fruit and vegetable market series published by the Institute of Agricultural and Food Economics, National Research Institute (IERiGŻ-PIB) [57–59]. Farm income for farms specialising in permanent crops, the FADN type of farming that covers fruit trees and bushes, is taken from the Polish standard results for FADN region 795—Mazowsze i Podlasie, for every accounting year from 2006 to 2024 [60,61]. Income is measured as family farm income per family work unit (FWU, FADN variable SE430), a family work unit being the full-time equivalent of unpaid family labour—it is referred to below as income per FWU. Because family farm income remunerates the family's own labour, land, and capital and includes the balance of current subsidies and taxes, it is not

a return to labour alone. It is used here as the accountancy indicator of household-level economic viability and is also reported net of that balance. Real values are obtained with the consumer price index and with the index of prices of goods and services purchased for current agricultural production, and fruit farms are compared with the average across all farm types in the same region, exposed to the same regional conditions and sample design. The Polish FADN sample consists almost entirely of farms operated by natural persons: in 2019, for example, results for FADN region 795—Mazowsze i Podlasie, were computed for 4448 holdings, of which 14 had legal personality [61]. Producer prices are reported in nominal and real terms. Cross-European positioning uses Eurostat statistics [62–64]. Data on producer organisations are taken from European Commission sources [65–67] and from national studies of producer organisations [68,69].

2.4. Scope and Limitations of the Evidence

Three footprints are involved and they are not coextensive. The participatory evidence derives from stakeholders in the border areas of the Mazowieckie and Lubelskie voivodeships, the physical statistics cover those two voivodeships in full, and the accountancy data are published only for FADN region 795—Mazowsze i Podlasie, which also includes Łódzkie and Podlaskie. Section 3.1 reports the overlap and the correspondence of physical trends; because similar trends do not make the farm populations identical, the income series is read as describing the regional context in which the case study farms operate, not those farms themselves.

The strands also differ in crop composition. The FADN category covers farms specialising in fruit trees and bushes and so includes both apple production and soft fruit other than strawberries, and it cannot be divided between them. The participants in the first workshop came predominantly from farms specialising in soft fruit and other crops: while noting that apples and onions are more representative of Polish horticulture, they reported that farms in their own area specialise in black currant, raspberry, rhubarb, and sugar beet [43]; apple growers are not identified among them. Soft fruit is not marginal in the case study region, where, excluding strawberries, it occupied 62.6 thousand hectares in 2025 against 81.2 thousand under apples [70]. The participatory assessment is, therefore, not read as speaking for apple growers, and the correspondence between the strands is examined with this heterogeneity in view (Sections 3.3 and 4).

The participatory strand has further limitations. The sample is small and unevenly distributed across groups, so differences between groups are not tested statistically; participation was self-selected, a limitation also noted for other FoPIA-SURE-Farm workshops [51], and farmers formed the largest group. Some scoring sheets contain missing responses, so the number of observations is 19 or 20 for most exercises [39]. The first workshop was also held in March 2019, immediately after the season in which fruit farms stood furthest behind all farms in the accountancy series, so its assessment may carry a recency effect (Section 4).

The statistical and accountancy strands have limitations of their own. The FADN results are means for an annual sample whose composition changes; the field of observation and the sampling plan were revised in 2013 and 2020, and the 2006–2009 editions apply an earlier typology. Exit, entry, and sample replacement may, therefore, affect the means independently of change within farms, which the published results do not allow to be followed. The price series is joined from three editions of one source, and the crop statistics changed methodology in 2015 and 2021. These limitations are addressed, as far as the published data allow, by comparing fruit farms with all farms in the same region and sample design, by concentrating on the years since 2010, and by testing the timing of change and its sensitivity (Section 2.5, Appendix A).

2.5. Analytical Approach

The analysis compares two levels of the same farming system. Following the SURE-Farm framework [3], resilience is understood as the ability of the system to keep delivering its functions. The analysis does not measure resilience as such but compares observable traces of two functions. The first is food production, whose robustness is indicated by whether output and trade were maintained or recovered after the main disturbances of the period: the frosts of 2007 and 2024 and the Russian embargo of 2014. The second is economic viability, observed through the accountancy indicator of income per FWU and through the assessment of stakeholders. Structural change is recorded as evidence of adjustment, not as a measure of adaptability, and transformability is not operationalised because the data contain no observable indicator of it. Table 1 lists the constructs and indicators.

Table 1. Constructs, indicators, and data used to compare system-level and household-level outcomes.

Construct	Indicators	Data and Coverage	Pattern Expected Under Divergence
Robustness of the food production function (system level)	Area, harvest, and yield of tree fruit; export value of fruit and vegetables; recovery after the frosts of 2007 and 2024 and the embargo of 2014	Statistics Poland, 2004–2025; Eurostat Comext, 2004–2025	Output and exports maintained or recovered
Structural adjustment (system level)	Number of farms with orchards and orchard area per farm; hired and family labour input	Agricultural Censuses 2010 and 2020; FADN, 2006–2024	Fewer and larger farms; work shifting to the family
Economic viability: accountancy indicator (household level)	Income per FWU (SE430) relative to the regional all-farm average; real income per FWU (two deflators); income per FWU net of current subsidies and taxes	FADN region 795—Mazowsze i Podlasie, permanent crops, 2006–2024	Relative decline robust to deflator, subsidies, and sample design
Economic viability: stakeholder assessment (system function)	Importance weight and performance score (1–5) of the economic viability function; thresholds	FoPIA-SURE-Farm 1, March 2019 (n = 19–20); FoPIA-SURE-Farm 2 (n = 12)	Lowest performance score of the eight functions
Market conditions (context)	Processing prices, nominal and real; price relation index; input price index	IERiGŻ-PIB, 2007–2025; Statistics Poland	Used to interpret, not to test, the divergence

Abbreviations: FADN, Farm Accountancy Data Network; FoPIA-SURE-Farm, Framework of Participatory Impact Assessment for Sustainable and Resilient FARMing systems; FWU, family work unit; IERiGŻ-PIB, Institute of Agricultural and Food Economics, National Research Institute; SE430, FADN variable code for family farm income per FWU. Source: own elaboration. The data sources are described in Sections 2.2 and 2.3.

The question of resilience for whom is operationalised as three expectations. If the system was robust in delivering food production, output and exports should have been maintained or recovered after each disturbance. If household-level viability nevertheless deteriorated, income per FWU on fruit farms should have declined relative to the all-farm average in the same region, and the decline should not be an artefact of the deflator, of subsidies, or of changes in the FADN sample. If the participatory assessment reflects the same condition, stakeholders should rate economic viability below the other functions. The two levels can move in opposite directions where productivity gains are not retained by the farms that generate them: because prices fall as supply grows, because many small sellers face few buyers, because gains are capitalised in land, or because support sustains farms

without changing their market position. Section 4 sets out the observable implications of these and alternative explanations and states which of them the evidence can discriminate.

The design is descriptive and does not identify causal effects. Because the strands differ in footprint and population, their agreement is treated as convergence between sources at different levels of aggregation, not as validation of one by another. To check that the central accountancy result does not depend on period boundaries chosen after inspecting the data, the timing of the change in the relative position of fruit farms was tested with a search for a single break in the mean over all candidate years, with permutation *p*-values, together with tests of the difference between periods and sensitivity analyses with alternative boundaries, deflators, and an income measure excluding subsidies (Appendix A).

3. Results

3.1. The Trajectory of Polish Fruit Growing Since 2004

Three territorial scales are used in this section. Area, harvest, and yield are reported for Poland and for the case study region, the Mazowieckie and Lubelskie voivodeships taken together. Farm accounts are published only for FADN region 795—Mazowsze i Podlasie, which contains the case study region together with the Łódzkie and Podlaskie voivodeships, so the income analysis that follows the price series moves to this larger footprint. The participatory evidence (Sections 3.2 and 3.3) comes from the border areas of the case study region.

Polish horticulture occupies a small share of the agricultural area and a relatively disproportionately large share of the plant production value. According to the estimate presented by Zawalińska and Gradziuk [19], horticulture occupies roughly 635,000 hectares, some 4.4% of agricultural land in good condition, while accounting for more than 40% of the value of total plant production in 2019.

The area under cultivation, however, has contracted since 2013 (Figure 1; Table 2). After a slight rise to 2013, the area under fruit trees in Poland fell to 209,006 hectares in 2025, against 273,428 hectares in 2004, a decline of some 24% over the whole period; in the case study region, comprising the Mazowieckie and Lubelskie voivodeships, the corresponding fall was from 126,970 to 106,126 hectares, or 16%. The area under field vegetables declined by a comparable proportion nationally, from 207,752 to 165,004 hectares [70]. The contraction has continued in the most recent years: the area under apples in the case study region fell from 90,613 hectares in 2021 to 81,174 hectares in 2025, a decline of 10% in four years.

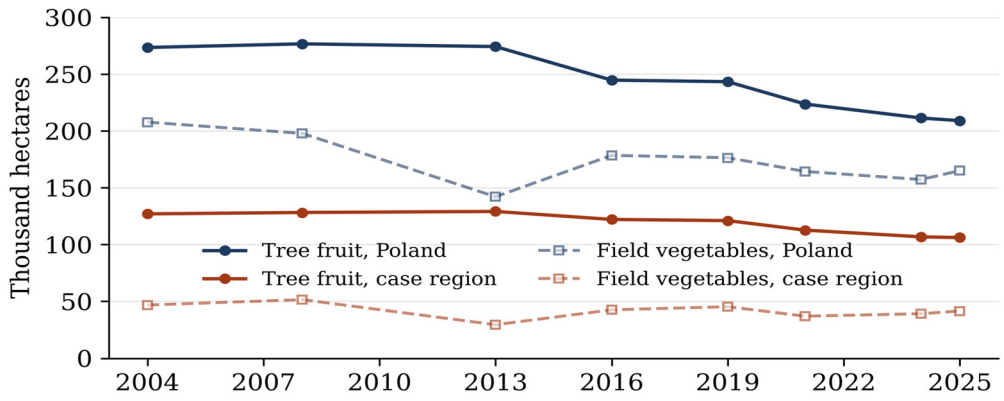


Figure 1. Area under fruit trees and field vegetables in Poland and the case study region (Mazowieckie and Lubelskie voivodeships combined, shown as "case region"), selected years: 2004–2025. Source: own calculations and elaboration based on Statistics Poland, Local Data Bank [70].

Table 2. Area under fruit trees and field vegetables in Poland and the case study region (Mazowieckie and Lubelskie voivodeships): selected years and hectares.

Year	Tree Fruit, Poland	Tree Fruit, Case Region	Field Vegetables, Poland	Field Vegetables, Case Region
2004	273,428	126,970	207,752	46,726
2008	276,627	128,195	197,811	51,478
2013	274,230	129,115	142,056	29,410
2016	244,695	122,075	178,455	42,511
2019	243,315	121,045	176,379	45,276
2021	223,651	112,669	164,305	36,943
2024	211,341	106,751	157,223	39,085
2025	209,006	106,126	165,004	41,527

Notes: The case study region (Mazowieckie and Lubelskie) is a subset of Farm Accountancy Data Network (FADN) region 795—Mazowsze i Podlasie (which also includes Łódzkie and Podlaskie), to which the income data in Section 3.1 refer. The participatory evidence comes from the border areas of the case study region. Field vegetables are shown for comparison. Source: own calculations based on Statistics Poland, Local Data Bank [70]. The methodology of the agricultural surveys changed in 2015 and again in 2021, so the series is not fully continuous; the low 2013 values for field vegetables, which are not matched in the adjacent years, should be read with caution.

Relating the harvest to the cultivated area shows whether increased output reflects a larger area or higher yields (Figure 2). In the case study region, the area under fruit trees fell by 16% between 2004 and 2025 while the harvest rose by 47%, so that the yield per hectare increased by 76%. The growth in output was attributable to higher yields, although the statistics do not show whether these came from more intensive use of inputs, from new plantings and varieties, or from both. Because harvests vary with weather, period averages are more informative: the mean yield was 11.0 tonnes per hectare over 2004 to 2008 and 22.4 over 2021 to 2025, with a linear trend of 0.65 tonnes per hectare per year [70]. The series also records the exposure of the sector to weather: in 2007 the yield fell to 4.63 tonnes per hectare from 13.06 the previous year, a loss of some 65% after spring frosts, and less severe reversals recur across the period. Nationally the area fell by 24%, while the yield rose from 11.0 tonnes per hectare in 2004 to 20.3 in 2025 (single-year values).

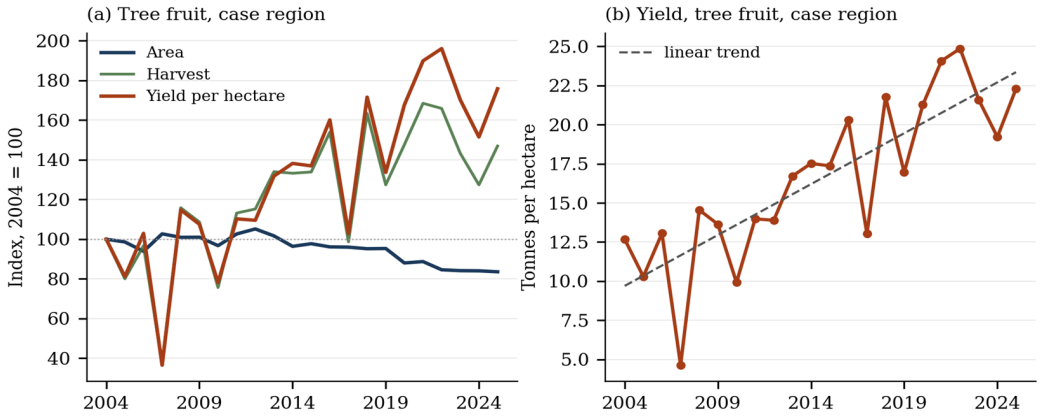


Figure 2. Tree fruit in the case study region (Mazowieckie and Lubelskie voivodeships combined, shown as "case region"), 2004–2025: (**a**) area, harvest, and yield per hectare, indexed to 2004, and (**b**) yield in tonnes per hectare with linear trend. Source: own calculations and elaboration based on Statistics Poland, Local Data Bank [70].

Field vegetables followed a different course. Their area in the case study region declined by 11% and the harvest by 2%, so that yields rose by only 10%. Yield growth on this scale is

thus specific to fruit rather than general to horticulture, which is consistent with the focus of the present analysis on farms specialising in permanent crops.

Two features of the sector, therefore, coincide. Fruit output grew substantially while the area under fruit trees, after 2013, contracted by about a sixth in the case study region and a quarter nationally, and the number of farms with orchards fell by more than a third between the censuses of 2010 and 2020 (see below). The growth was achieved by obtaining roughly twice as much fruit from each hectare, and it accompanied a reduction in the number of households engaged in it.

One qualification concerns the measurement of area. The crop statistics used here record the area of fruit trees, and the land use statistics record the area of orchards, which also includes fruit bushes and nurseries and is accordingly larger, at 310.2 against 209.0 thousand hectares in 2025 [70,71]. The difference reflects mainly berry bushes, whose area in orchards rose by 11.3% between the censuses of 2010 and 2020 while that of fruit trees fell by 11.1% [54–56]. The fruit tree series is used because it is the appropriate denominator for yield.

Within the European Union, Poland is the leading producer of apples, which dominate its fruit sector. In 2022 the EU harvested 12.6 million tonnes of apples, of which Poland supplied 34.0%, ahead of Italy at 18.0% and France at 14.2% [62]. Structurally the position is similar: of roughly 444 thousand hectares of apple orchards in the EU in 2023, close to one-third were located in Poland, with Italy and France accounting for 13 and 12%, respectively [63]. Apples occupy almost half (47%) of the total Polish fruit area [62].

The most recent years complicate the growth narrative rather than extending it. EU apple production in 2024 was 11.6 million tonnes, 4% below 2023, and although Poland remained the largest producer its share had fallen to 29%, with Italy at 21% and France at 17% [64]. Polish output from fruit trees declined in two successive seasons, 2023 and 2024 [70]. In Poland the 2024 decline followed the spring frosts and rainfall deficit recorded in the preliminary official crop estimate [72]. The aggregate expansion is, therefore, not a monotonic trend, and its recent reversal was driven by the environmental challenge that stakeholders had ranked, jointly with economic challenges, as most relevant. The national series indicate a yield effect rather than a change of trajectory: output from fruit trees reached 4.76 million tonnes in 2022 and 4.36 million in 2023 before falling to 3.73 million in the frost year of 2024 [73] and recovering to 4.23 million in 2025, with yields moving from 22.1 to 17.7 and back to 20.3 tonnes per hectare while the area declined steadily throughout [70].

The structural picture at the national level is one of slow consolidation from a highly fragmented base, within which horticulture changed considerably faster. Between the Agricultural Censuses of 2010 and 2020 the total number of farms in Poland fell by about 192 thousand, or 12.7%, to 1317.4 thousand, while the average agricultural area per farm rose by about 13%, from 9.8 to 11.1 hectares [54–56].

Within horticulture the change was far sharper than that national figure suggests. On the like-for-like basis published by Statistics Poland, the number of farms with orchards fell by 36.3% between 2010 and 2020, to 155.9 thousand, while the orchard area contracted by only about 3.0%, to 355.7 thousand hectares; the mean orchard area per farm rose correspondingly, from 1.50 to 2.28 hectares [54–56]. In the orchard sector, therefore, the number of farms fell by more than a third within a decade while the land remained in cultivation.

The census records the same process in the average size of the farms that remained: the mean area of fruit trees per farm rose from 1.54 hectares in 2010 to 2.39 in 2020, and that of fruit bushes from 1.00 to 1.64 hectares, while the number of farms growing fruit bushes fell by 33% [54–56]. Fewer and larger farms thus produced more from less land. The case study region accounts for a substantial share of what remains, with 23.5% of all Polish farms cultivating fruit trees located in Mazowieckie and 16.5% in Lubelskie [54–56].

Export performance across the period is marked by one sharp discontinuity. In 2013 Poland exported fresh apples worth EUR 444.1 million, of which 254.3 million, or 57.3%, went to the Russian Federation; by volume, the Russian share was 676.3 thousand tonnes out of 1230.4 thousand, or 55.0% [74]. Across fruit and vegetables as a whole Russia absorbed 24.3% of Polish export value in that year. The embargo introduced in August 2014, immediately before the harvest, removed that outlet at the moment of greatest supply. The immediate effect on growers was severe: exports of apples to Russia fell by 41% during 2014, and in the autumn of that year processing plants were paying around PLN 0.10 per kilogram [75].

The loss was sudden and permanent. The Russian share of Polish fruit and vegetable export value fell from 24.3% in 2013 to 14.5% in 2014 and 0.1% in 2015, and it has not exceeded 1% in any year since [74]. Belarus, believed to be an unofficial route to Russia, took over part of the vacated role, its share rising from 5.2% in 2013 to 11.4% in 2016, until it introduced its own ban on a range of EU agri-food imports from January 2022. The Polish assessment submitted to the Council of the European Union expected the effects to fall principally on horticultural production [76]. By 2025 the Belarusian share stood at 3.1%.

What did not happen is equally instructive. Aggregate export value fell by only about 4% in nominal terms between 2013 and 2015 and then resumed its growth: Polish horticulture exports rose from EUR 871 million in 2004 to 2104 million in 2013, held at 2013 million in 2015 despite the loss of the Russian market, and reached 3677 million by 2025, or EUR 5134 million including processed products and juices [74]. At the level of the system the shock was absorbed through redirection to other markets, domestic demand, subsidised withdrawal, and processing. At the level of the farms, it was not: in 2014 the processing price fell to PLN 0.25 per kilogram for apples, against the autumn low of about PLN 0.10 noted above, and to PLN 0.60 for black currant [57–59], and income per family work unit on fruit farms fell to 59% of the regional all-farm average (see below). The same event thus reads as robustness in the trade statistics and as a severe reverse in the prices received by producers.

The mechanism most often identified by producers, price volatility, can be quantified directly. Table 3 presents the prices paid to producers for fruit destined for processing between 2007 and 2025, in nominal and real terms, and Figure 3 the nominal series, compiled from three editions of the market analysis published by IERiGŻ-PIB [57–59]. Wherever two editions report outturn data for the same year the processing prices agree exactly, which permits the three to be joined into a single run; the 2014 edition reports a forecast for 2014 itself, and that value is replaced here by the outturn reported in the 2020 edition.

The amplitude is considerable even after deflation. In real terms the coefficient of variation ranges from 0.49 for apples and sour cherries to 0.72 for black currant, and the ratio of the 90th to the 10th percentile, which is less sensitive to single extreme years than the max./min. ratio, from 2.9 for apples and sour cherries to 8.9 for black currant (Table 3). The movements are also abrupt rather than gradual. The price of black currant fell by three-quarters between 2022 and 2023 and rose more than fourfold between 2023 and 2024, that of raspberries rose by 161% between 2020 and 2021 and fell by 64% between 2022 and 2023, and apples destined for processing fetched PLN 0.15 per kilogram in 2008 against 0.95 the preceding year. None of the four real price series shows a significant trend over 2007–2025 at the 5% level.

A complementary measure is the price relation index, or price gap, published by Statistics Poland as the ratio of the index of prices of agricultural products sold to that of goods and services purchased by individual farms [77]. Measured against 2010, it stood at 100.0 in 2014, 107.6 in 2017, 110.4 in 2020, and 112.2 in 2021, before falling to 94.4 in 2024 [77]. The terms of trade of Polish agriculture, therefore, moved favourably for most of the period

and deteriorated sharply only after 2021. The index covers agriculture as a whole rather than horticulture, and the values are taken from the most recent edition of the statistical yearbook, which revises some earlier figures.

Table 3. Prices paid to producers for fruit destined for processing, Poland, 2007–2025, in PLN per kilogram, net of value added tax: nominal values, with real values at constant 2013 prices in parentheses.

Year	Apples for Processing	Black Currant	Raspberries	Sour Cherries for Freezing
2007	0.95 (1.15)	3.75 (4.53)	4.30 (5.20)	1.80 (2.18)
2008	0.15 (0.17)	1.80 (2.09)	4.10 (4.76)	0.85 (0.99)
2009	0.17 (0.19)	2.15 (2.40)	3.25 (3.63)	0.80 (0.89)
2010	0.65 (0.71)	1.90 (2.07)	3.60 (3.92)	2.80 (3.05)
2011	0.65 (0.68)	4.10 (4.29)	2.30 (2.41)	2.65 (2.77)
2012	0.40 (0.40)	1.75 (1.77)	2.70 (2.73)	3.30 (3.33)
2013	0.45 (0.45)	1.45 (1.45)	4.30 (4.30)	2.35 (2.35)
2014	0.25 (0.25)	0.60 (0.60)	4.75 (4.75)	1.35 (1.35)
2015	0.37 (0.37)	0.55 (0.55)	7.70 (7.76)	1.70 (1.71)
2016	0.25 (0.25)	0.60 (0.61)	5.20 (5.28)	1.45 (1.47)
2017	0.70 (0.70)	1.10 (1.09)	4.40 (4.38)	5.10 (5.07)
2018	0.27 (0.26)	0.67 (0.65)	2.40 (2.34)	1.49 (1.46)
2019	0.50 (0.48)	1.45 (1.39)	4.25 (4.06)	3.30 (3.15)
2020	0.60 (0.55)	3.20 (2.96)	6.10 (5.64)	2.20 (2.03)
2021	0.48 (0.42)	4.70 (4.13)	15.90 (13.99)	1.81 (1.59)
2022	0.50 (0.38)	8.10 (6.23)	14.00 (10.76)	2.70 (2.08)
2023	0.80 (0.55)	2.00 (1.38)	5.00 (3.45)	2.75 (1.90)
2024	1.00 (0.66)	8.70 (5.78)	10.42 (6.92)	4.77 (3.17)
2025	0.70 (0.45)	8.30 (5.31)	11.40 (7.29)	7.80 (4.99)
Min.	0.15 (0.17)	0.55 (0.55)	2.30 (2.34)	0.80 (0.89)
Max.	1.00 (1.15)	8.70 (6.23)	15.90 (13.99)	7.80 (5.07)
Max./min.	6.7 (6.6)	15.8 (11.2)	6.9 (6.0)	9.8 (5.7)
Coeff. of variation	0.48 (0.49)	0.89 (0.72)	0.65 (0.54)	0.63 (0.49)
P90/P10, real	2.9	8.9	3.1	2.9

Source: own compilation from the Institute of Agricultural and Food Economics, National Research Institute (IERiGŻ-PIB) fruit and vegetable market analyses Nos. 44 (2014), 56 (2020), and 68 (2026), Table 7 in each edition [57–59]—quotations at processing plants. Prices for fruit sold on the fresh market are reported in the same source but the basis of those quotations changed between the 2014 and 2020 editions, so they are not used here. Real values are nominal values deflated by the consumer price index (2013 = 100). The coefficient of variation is computed from the sample standard deviation. P90/P10 is the ratio of the 90th to the 10th percentile of the real series, a measure less sensitive than the max./min. ratio to single extreme years. For comparison, over 2010–2024 the index of prices of goods and services purchased for current agricultural production rose by 98% [77], against 64% for the consumer price index [78].

Two implications follow. A grower deciding in one year what to plant, how much labour to engage, or whether to invest faces a price in the following year that may credibly be a quarter or four times the current one. Area statistics need careful reading: the area under black currant in the case study region rose by some 12% between 2021 and 2025, following the price rise from PLN 1.45 per kilogram in 2019 to 8.10 in 2022, but the bushes come into bearing some three years after planting and have since met prices ranging from PLN 2.00 in 2023 to 8.70 in 2024, so the expansion reflects a response to a strong but unstable price signal rather than stable profitability.

The household side of the sector's performance can be traced through the farm accountancy results for FADN region 795—Mazowsze i Podlasie, which are not published for smaller areas. The case study voivodeships accounted for 80.3% of its tree fruit area in 2004 and 78.5% in 2025, Podlaskie contributing under 2000 hectares in 2025, and the

physical trends are almost identical: the yield rose from 12.7 to 22.0 tonnes per hectare across the FADN region against 12.7 to 22.3 in the case study region, on areas contracting by 14.5 and 16.4%, respectively [70]. The trends are, therefore, comparable, although the farm populations are not identical. The relevant FADN category, farms specialising in permanent crops, covers fruit trees and bushes, and so both the apple production that dominates by volume and the soft fruit that predominated among the workshop participants; between 258 and 318 such farms were in the sample in each year from 2006 to 2024 [60,61]. Because the sample design changed in 2013 and 2020, the position of fruit farms is assessed mainly relative to all farms in the same region and year.

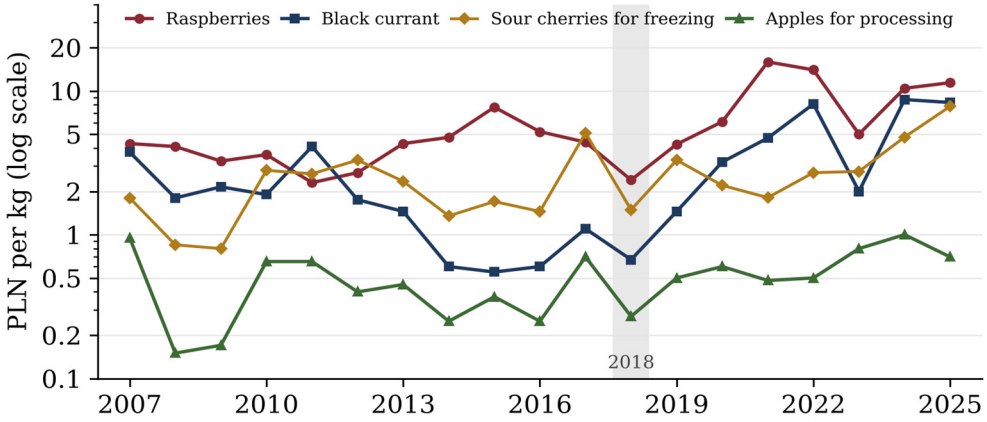


Figure 3. Prices paid to producers for fruit destined for processing, Poland, 2007–2025, in nominal PLN per kilogram, logarithmic scale. The shaded band marks the 2018 season, which preceded the first workshop in March 2019. Source: own elaboration based on the Institute of Agricultural and Food Economics, National Research Institute (IERiGŻ-PIB) [57–59].

Income per FWU on these farms did not follow the trajectory of sector output (Table 4; Figure 4). Until 2013, farms specialising in fruit earned more per FWU than the average farm in the region in six of the eight years, and over 2010 to 2013 their income averaged 136% of the regional average. From 2014 the position reversed: in nine of the eleven years to 2024 income on fruit farms fell below the regional average, averaging 79% of it over 2014 to 2019 and 89% over 2020 to 2024, with the lowest values in 2018 (56%) and 2014 (59%) [60,61]. A search for a single break over all candidate years places the change in this ratio between 2013 and 2014 in the 2006–2024 series (permutation $p = 0.02$) and between 2012 and 2013 in the 2010–2024 series ($p = 0.008$), with 2013/2014 almost equally supported—the mean ratio was 1.36 in 2010–2013 and 0.84 in 2014–2024 (Welch test $p = 0.008$). The ratio shows no recovering trend after 2014 and remains below 1 on average when 2014 and 2018 are excluded (Appendix A). The timing needs one qualification: 2013 was the first year of a revised FADN field of observation and sampling plan, under which the number of fruit farms represented rose from about 14.8 to 23.8 thousand, so part of the fall from an average of 1.45 in 2010–2012 to 1.11 in 2013 may reflect the redesign; the further fall to an average of 0.79 in 2014–2019 occurred within a single plan.

In real terms the picture depends on the comparison. Deflated by the consumer price index [78], income per FWU on fruit farms averaged 32.7 thousand PLN at 2013 prices over 2010 to 2013, 18.3 thousand over 2014 to 2019, and 27.8 thousand over 2020 to 2024, against 24.0, 23.1, and 31.8 thousand PLN for all farms. Deflation by the index of prices of goods and services purchased for current agricultural production [77] gives the same pattern (Appendix A). Real income on fruit farms in 2014–2024 was significantly lower than in 2010–2013, but not lower than in 2006–2009, so 2010–2013 was itself a high point. What is robust across deflators and periods is the decline relative to other farming in the

region. Real income on fruit farms was also more volatile, with a coefficient of variation over 2010–2024 of 0.32 against 0.26 for all farms.

Table 4. Income per family work unit in farms specialising in permanent crops (fruit trees and bushes), Farm Accountancy Data Network (FADN) region 795—Mazowsze i Podlasie, 2006–2024, in nominal and constant 2013 PLN.

Year	Income per FWU, Nominal (PLN)	Income per FWU, Constant 2013 PLN	Real Index, 2013 = 100	Regional Average per FWU (PLN)	Ratio to Regional Average	Farms in Sample
2006	20,039	24,826	92	15,518	1.29	286
2007	23,045	27,865	103	17,065	1.35	293
2008	12,509	14,520	54	14,476	0.86	300
2009	10,499	11,742	44	12,062	0.87	309
2010	28,082	30,615	114	22,046	1.27	261
2011	37,720	39,450	146	23,789	1.59	258
2012	33,497	33,829	125	22,615	1.48	272
2013	26,970	26,970	100	24,386	1.11	287
2014	12,036	12,030	45	20,298	0.59	285
2015	25,265	25,474	94	21,125	1.20	300
2016	18,752	19,034	71	22,164	0.85	309
2017	21,986	21,862	81	25,845	0.85	318
2018	12,780	12,482	46	22,711	0.56	306
2019	19,507	18,637	69	27,619	0.71	287
2020	31,727	29,322	109	30,318	1.05	286
2021	33,671	29,622	110	39,894	0.84	274
2022	46,254	35,560	132	61,202	0.76	267
2023	31,087	21,429	79	35,837	0.87	278
2024	34,924	23,195	86	36,527	0.96	280

Source: own calculations based on Polish standard results for FADN region 795—Mazowsze i Podlasie, variable SE430, family farm income per family work unit (FWU) [60,61], deflated using the World Bank consumer price index for Poland [78]. The editions for 2006 to 2009 apply the earlier typology of farm types, based on economic size in European size units (ESUs) with a threshold of 2 ESU, and are not strictly comparable with those from 2010, which classify farms by standard output. The field of observation and sampling plan were revised in 2013 and 2020, so year-to-year comparisons of levels are indicative, and ratios compare farms within the same year and design. FADN covers farms above an economic size threshold, so the smallest farms are not represented.

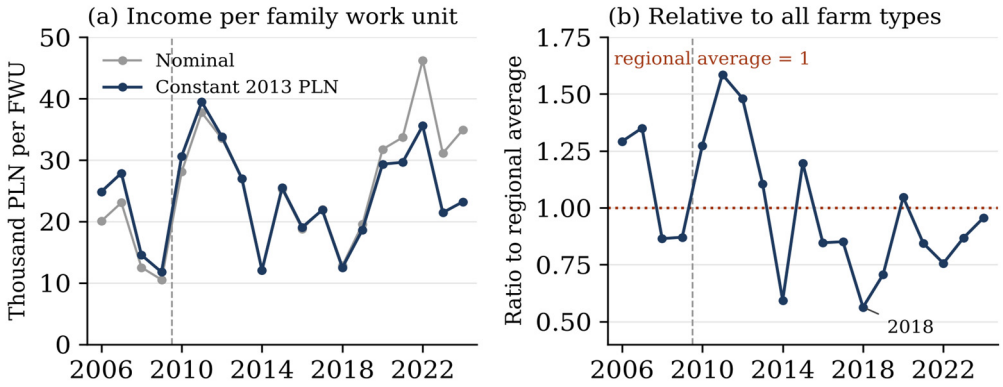


Figure 4. Income per family work unit in farms specialising in permanent crops, Farm Accountancy Data Network (FADN) region 795—Mazowsze i Podlasie, 2006–2024: (**a**) nominal and real values and (**b**) ratio to the average across all farm types in the region. The dashed line marks the change of farm typology between 2009 and 2010. Source: own calculations and elaboration based on Polish standard results for FADN region 795—Mazowsze i Podlasie [60,61]. Real values at constant 2013 prices, deflated using the World Bank consumer price index for Poland (2013 = 100) [78].

The FADN accounts show where the change came from (per farm, at 2013 prices, period means). Between 2010 to 2013 and 2014 to 2019, real output per fruit farm fell by a quarter, from PLN 121.4 to 91.5 thousand, while total costs changed little, so that costs rose from 70% to 87% of output and family farm income almost halved, from PLN 46.8 to 25.2 thousand. The balance of current subsidies and taxes, at PLN 13.2 thousand, then accounted for about half of it, a share driven largely by 2014 and in other years below that recorded for all farms. Excluding that balance, income per FWU on fruit farms fell from more than twice the all-farm level in 2010–2013 (2.17) to parity in 2014–2019 (1.00) and 1.19 in 2020–2024, so the relative decline is sharper without subsidies. The partial recovery after 2020 came from lower costs rather than higher output: intermediate consumption, depreciation, and hired labour fell, hired labour input from 0.57 to 0.33 annual work units, while family labour remained at about 1.4 FWU per farm, so the family share of labour input rose from 67% in 2010 to 2013 to 81% in 2020 to 2024, approaching the 93% recorded for all farms in 2020–2024. These are sample means whose composition changes, so they indicate direction rather than precise magnitudes, but the relative economic size of fruit farms (0.81 of the all-farm average) and their area (8.9 hectares) were the same in 2010–2013 and 2014–2019 [60,61].

Whether the fall in output value after 2013 reflected prices or volumes cannot be decomposed with the published accounts, which do not report quantities, but the available series point to prices. In real terms, mean processing prices in 2014–2019 were 31% lower than in 2010–2013 for apples, 66% lower for black currant, and 18% lower for sour cherries, while those for raspberries were 43% higher; excluding the embargo year 2014, the declines for 2015–2019 were 26%, 64%, and 11%, so the fall persisted beyond the immediate shock. Over the same periods the tree fruit yield in FADN region 795—Mazowsze i Podlasie, rose from 13.5 to 17.5 tonnes per hectare, whereas real total output per hectare of permanent crops on FADN fruit farms fell from PLN 17.9 to 13.6 thousand [57–61,70]. Lower prices for the main processing fruits, rather than lower volumes, are, therefore, the more likely source of the fall, although the composition of output on FADN farms and the prices of fruit sold on the fresh market are not observed.

3.2. The Farming System as Its Participants Describe It

Across the farm survey, the interviews, the focus group, and the two workshops, participants classified the difficulties they face by type, as environmental, economic, social, or institutional, and by mode of occurrence, as shocks or long-term stresses. Across all the methods applied, environmental and economic difficulties were identified as the most relevant and social ones as the least [24].

Environmental. Climate change is a major source of environmental challenges for farming systems, as it is expected to alter rainfall patterns and to make extreme weather, notably droughts and floods, both more frequent and more severe [79]. Participants placed extreme events first: drought, floods, spring and autumn frosts, hail, and severe winters. They observed that spring frosts can be anticipated and their effects mitigated, whereas autumn frosts have shifted in their month of occurrence and are, therefore, the riskier of the two, and that extreme winters threaten orchards if they recur more than twice in a decade. Among long-term stresses they identified intensifying pest and disease pressure, declining soil organic matter, water supply, and erosion. One observation bears on farm structure: dispersed plots, usually treated as a weakness, were seen as protective, since the distance between fields means a single hail or frost event does not reach the whole farm.

Economic. Economic difficulties, which the farm survey ranked jointly first with environmental ones, were framed almost entirely as long-term stresses: price volatility, declining profitability, unfavourable relations between output and input prices, weak bargaining

power against processors and retailers, and, at household level, the absence of any economic incentive to continue. For black currant and raspberries, the soft fruit most common among participants, the ratio of the 90th to the 10th percentile of real prices was 8.9 and 3.1, respectively, with year-on-year rises of up to 335% and falls of up to 75% (Table 3). Rising costs of plant protection products, fertiliser, fuel, and seasonal labour compound the difficulty, and high costs discourage farmers from raising wages, which deters workers and constrains the area that can be harvested.

Two structural conditions underlie these difficulties. The first is access to land: restrictions on land turnover introduced in April 2016 limited entry, prevailing prices place additional land beyond the reach of many farmers, and some landowners retain land to receive direct payments without cultivating it. The second is weak integration. Participants did not reject cooperation in principle and described concrete reasons to act collectively, above all cold storage, which determines whether a grower can hold produce back from a saturated market; what is missing is the organisational form and the trust between growers on which it would rest. Buyers are far more concentrated than the growers who supply them. Apple growers have some collective presence, whereas currant and raspberry growers have almost none, and it is there that purchase prices fall furthest and fastest, in some seasons below the cost of production.

Institutional. Institutional difficulties were ranked third. The complaint most often raised was the volume and instability of regulation: requirements governing emissions, animal welfare, and plant protection change frequently, and restrictions on the purchase of agricultural land bear directly on the area that can be brought into production. Farmers were particularly affected by rules narrowing the list of permitted plant protection products without offering guidance on alternatives. Others cited the Russian embargo, the auction arrangements for supplying fruit to public institutions, the certification process, and the bureaucracy surrounding the employment of seasonal workers from Ukraine. Several described the frequency of inspections by different state agencies as the maximum they could withstand. At the system level, participants pointed to the absence of any long-term vision beyond maintaining the status quo, and to low uptake of insurance.

Social. Social difficulties were ranked last, though the issues raised were not minor ones. The most frequently identified were the absence of successors and the unattractiveness of farming as an occupation, driven by an ageing farmer population and by the higher incomes that potential successors can expect outside agriculture [20]. Others were low trust between farmers, which obstructs the cooperation discussed above, and the historical fragmentation of farms in southern and eastern Poland. The labour shortage was described as acute: wage differentials draw workers to Western Europe, and the strategy of recruiting from Ukraine met the same difficulty, with workers moving onward westward. For dessert fruit a shortage of two to four days at harvest causes serious losses; for hard fruit, the margin is about seven days. The outflow appears to reflect the disproportion between the intensity of work required and the income obtained from it.

3.3. Thresholds and the Divergence Between Aggregate and Participant Assessment

In the second workshop, participants set thresholds for the four indicators it addressed [49]. For land, whose availability is limited by fragmentation, high prices, and state restrictions on turnover, they regarded prices of PLN 60 to 100 thousand per hectare, depending on land class, as the maximum beyond which adaptation through larger scale and transformation through new crops would be endangered. Profitability was described as already endangered by constant price fluctuation: because purchase prices are the basic determinant of income, frequent operation near the zero-profit point, which applies, for example, to raspberries and currants, drains the savings that could finance change or a

farmer's own contribution to a loan. A further increase in labour costs, beyond about PLN 10 per hour, could render farming permanently unprofitable [49]. Exceeding these thresholds was expected to bring failure of the farming system, permanent emigration of rural inhabitants, and a decline in the domestic supply of horticultural products.

Participants described three thresholds as close rather than distant, judging the system as a whole to be close to its tipping points [49]; two of them, concerning weather and administrative burden, go beyond the four indicators above. Profitability was the first, and the mechanism they identified was the volatility of purchase prices rather than their average level, a reading consistent with analyses of food price formation in Poland [80] and of food price volatility on world markets [81], and with Table 3: within the five seasons to 2019 alone, the price of raspberries ranged from PLN 2.40 to 7.70 per kilogram and that of black currant from PLN 0.55 to 1.45. Weather was the second: in participants' perception, damaging events had become frequent enough that a single further bad season would exhaust reserves rather than merely reduce them. Administrative burden was the third, expressed as the cumulative weight of inspections and application procedures rather than as objection to any single requirement. In each case participants described not a failure but a narrowing margin before failure.

Their account of their own capacities was correspondingly specific rather than despairing. Adaptation was the capacity they claimed with most confidence, and they tied it to information: given sufficient warning of an approaching frost or hailstorm, they described concrete measures they could take to limit damage, which locates the binding constraint in forecasting and its transmission rather than in the farm itself. Beyond adaptation, participants identified diversification, small-scale on-farm processing, and direct sales as routes that were open to them, the last of these having become available under legislation in force from 2019 [49] permitting farmers to sell directly to consumers and to restaurants. The pessimism recorded in the function scores is, therefore, not a generalised fatalism: participants distinguished between what they could influence and what they could not and located their economic position in the second category.

Setting this assessment beside the aggregate trajectory shows the divergence examined in this article. Over the period in which the sector expanded its output, consolidated its structure, and established a leading position in European markets, the stakeholders of the system, half of them farmers, assessed its economic viability as the weakest of its functions. Asked to rate how well each function of the farming system is delivered, on a scale from 1 for very poorly performing to 5 for performing perfectly, participants ($n = 19$) rated no function above the range between 2 and 3; the delivery of private goods was scored at an average of 2.10, and that of public functions at 2.46 [39]. Economic viability, the function to which participants attached the greatest importance, received the lowest performance score of all eight.

The accounting evidence presented in Section 3.1 points in the same direction. The workshop followed the 2018 season, in which the processing prices of all four fruits in Table 3 fell sharply, that of raspberries to PLN 2.40 per kilogram, and income per FWU in farms specialising in fruit trees and bushes in FADN region 795—Mazowsze i Podlasie, fell to 56% of the average across all farm types, the lowest value in the 2006–2024 series; it remained at 71% in 2019 (Table 4). The two strands describe different populations and cannot validate each other, and the timing raises the possibility that the assessment was coloured by the season just ended. They are nonetheless convergent: the participants' judgement was recorded at the trough of a relative position that the accounts show to have weakened from 2014 and not to have recovered by 2024.

The pattern of assessment across stakeholder groups is reported elsewhere [39]: farmers rated economic viability and quality of life markedly lower than representatives of

government did. Since most participants classified as government were themselves farmers holding positions in local self-government, and the group is too small for any test, the comparison is not developed further here. The relevant point is the aggregate one: the farmers whose households depend on the system rated its economic viability lowest of all functions, and the accountancy data point in the same direction.

4. Discussion

Several explanations for the divergence deserve consideration. They are not mutually exclusive, and because the design is descriptive, none of them is identified by the evidence. The aim is to state what each would imply and how far the evidence is consistent with it. Table 5 summarises the comparison.

Table 5. Candidate explanations for the divergence, their observable implications, and the evidence assembled in this study.

Explanation	Observable Implication	Evidence in This Study	Assessment
Agricultural treadmill	Rising yields; falling number of producers; falling real output prices or terms of trade; stagnating returns of remaining producers	Yields doubled; farms with orchards fell by 36%; no long-run fall in real processing prices; lower real prices for apples and black currant in 2014–2019; relative income fell after 2013	Partly consistent; price implication present only in some periods and crops
Value-chain position	Falling farm share of value; concentrated buyers	Not measured; participants report weak bargaining power	Not tested
Cooperation deficit	Low share of output marketed collectively; weaker outcomes where marketing is individual	Organisational rate 12% against 46.3% in the EU-27; participants, mainly soft-fruit growers, report weak viability	Consistent; causal link not tested
Orientation of policy support	Instruments sustaining robustness rather than adaptation; subsidies sustaining income without changing market position	Assessments of the CAP; subsidies a large share of family farm income on fruit farms and on all farms alike	Consistent; not tested; not specific to fruit farms
Market shocks	Temporary falls followed by recovery	Relative income below average in 9 of 11 years after 2013, with no recovering trend	Does not account for the persistence alone
Sample composition and selection	Changes in means without change within farms	Relative economic size and area unchanged across the break; 2010–2024 break in 2013, the first year of a revised sampling plan; no panel data	Cannot be excluded; direction of bias unknown
Wider structural change, labour substitution, and opportunity cost of labour	Exit and labour outflow across all farm types	Orchard farms fell by 36% against 12.7% for all farms; hired labour replaced by family labour; labour shortage reported	Consistent; not separable from the above

Abbreviations: CAP, Common Agricultural Policy; EU-27, the 27 member states of the European Union. Source: own elaboration based on Sections 3 and 4.

The first candidate is the agricultural treadmill (Section 1). Output growth achieved through innovation and investment raises volumes but not margins: falling output prices erode the gains, rising input and land costs absorb what remains, and the least efficient producers leave the sector [9–12]. Several observable implications of that mechanism are

present here. Yields per hectare approximately doubled between 2004 and 2025, the number of farms with orchards fell by more than a third between 2010 and 2020 while the land remained in production, and income per FWU on fruit farms fell from above to below the regional all-farm average after 2013, while real output per fruit farm was lower in 2014–2024 than in 2010–2013 despite higher yields. In the farms examined here the adjustment ran through the farm family: as hired labour was shed, family labour input was maintained, which is the form adjustment pressure would be expected to take on family farms that can absorb falling returns by accepting a lower reward for their own labour rather than leaving production at once.

The price implication of the treadmill is only partly present. The producer prices in Table 3 show extreme volatility but no significant trend in real terms over 2007–2025, and the price relation index for Polish agriculture improved by some 12% between 2010 and 2021 before its reversal; deflated by the consumer price index, the mean processing prices for 2021 to 2025 were higher than those for 2007 to 2011 for black currant (by 48%), raspberries (by 113%), and sour cherries (by 39%), and lower only for apples (by 15%), the crop whose yields drive the aggregate growth. Within 2014–2019, however, real prices for apples and black currant were well below their 2010–2013 level while regional yields rose, which is the configuration in which a price-driven squeeze would appear at farm level.

The evidence is, therefore, consistent with a treadmill operating in particular periods and crops, but not with a sustained deterioration of the terms of trade, and other processes fit the same observations: the general structural change of Polish agriculture, the rising opportunity cost of family labour outside agriculture, the rapid growth of seasonal labour costs, and the market shocks of 2014 and later. Two further explanations concern measurement rather than mechanism. Changes in the FADN sample could alter the means without any change within farms. This cannot be excluded without panel data: the search for a break in 2010–2024 points to 2013, the first year of a revised sampling plan, although the relative economic size and area of fruit farms were unchanged across the break and the further fall from 2013 to 2014–2019 occurred within one plan. Because exit is itself part of the pattern described, the farms observed in later years are a selected group, shaped also by entry and by the redesign of the field of observation—the direction of the resulting bias cannot be determined. The treadmill is, therefore, treated here as one hypothesis among several, which the price and accountancy evidence narrows but does not settle.

The second is position in the value chain. Sector-level growth may accrue disproportionately to concentrated actors downstream of the farm. Margins along the chain are not observed here, so the point rests on the literature, according to which Polish fruit growers have limited control over processing prices and fragmentation weakens their position [33], and on participants' reports of low bargaining power, which are consistent with it but do not measure it.

The composition of the sector gives these mechanisms a specific shape (Section 2.4). Apples account for about three-quarters (76%) of the tree fruit area of the case study region and drive the aggregate growth; they have genuine export scale, an established processing outlet, and some collective marketing capacity. The participants came predominantly from farms specialising in currants and raspberries [43], which the case study evidence identifies as the part of the sector with the weakest market organisation and the most frequent instances of purchase prices falling below production costs. Both belong to the same FADN category and to the same farming system as SURE-Farm defines it. The divergence between sector performance and stakeholder assessment may, therefore, partly reflect a distinction within the sector between crops with an organised route to market and crops without one, which the available data cannot test directly.

The third is the cooperation deficit, which may be one channel through which the second operates: where producer organisations market a substantial share of output, growers are expected to capture more of the value. The Commission measures this through the organisational rate, the value of production marketed by producer organisations as a proportion of the value of national production [66], and reports that, in general, marketing through such organisations accounts for about half of the value of a country's total fruit and vegetable production [67].

Poland is far from that level. By number of organisations it appears well placed, with 196 of the 1603 recognised fruit and vegetable producer organisations in the EU-27 in 2020, fourth behind Spain, Italy, and France [65,67]; but in 2022, its organisational rate stood at 12% against an EU-27 figure of 46.3%, nineteenth of the twenty-four member states reported [66]. Earlier national assessments are consistent with this: producer groups and organisations covered about 5% of commercial horticultural farms in 2012, and their share in the market supply of fruit, predominantly apples, did not exceed 20% [68]. Analyses since accession reach comparable conclusions [69], and comparative work places Poland among the countries in which numerous members with relatively small areas direct only a limited share of output to retail chains [82].

Weak collective marketing in Poland is often attributed to the legacy of the period before 1989, yet Czechia and Slovakia, also post-socialist, recorded organisational rates of 71 and 68% in 2022 [66]. Agriculture there was collectivised and is now dominated by large successor enterprises, so the comparison suggests only that the post-socialist inheritance as such is unlikely to explain the Polish position, not that stronger organisation would by itself improve the viability of Polish fruit farms.

Two mechanisms sustain this position. The first, recorded both here and in the literature, is the reluctance of Polish farmers to engage in horizontal cooperation [34,35], which stakeholders described as a deficit of trust. The second is a matter of cost: for small producers, membership requires entrance fees and the purchase of shares, so the farms with the weakest individual bargaining position are also those least able to acquire a collective one, and the value added that collective marketing would retain accrues instead to intermediaries, distributors, and retail chains [68].

The fourth is the orientation of policy support. Assessments of the Common Agricultural Policy in the Polish fruit and vegetable system [35], and across the SURE-Farm case studies more generally [83], have found that its instruments predominantly support robustness, sustaining the capacity to endure while often neglecting the capacity to adapt or transform. Support of that character is consistent with a sector that persists and grows in aggregate while the position of individual farms does not improve, although the large share of subsidies in family farm income is common to all farm types in the region and is not specific to fruit farms.

Table 5 summarises the observable implications of each explanation and the extent to which the evidence assembled here is consistent with them. No explanation is excluded, and none is established; the evidence is strongest for the pattern itself and weakest for the distribution of value along the chain, which is not observed.

The cross-case results of the SURE-Farm project allow the Polish profile to be read against ten other European farming systems [51,84]. Across the eleven cases, stakeholders identified food production, economic viability, and the maintenance of natural resources as the principal functions, rated their performance as moderate, and judged overall resilience to be low to moderate, with robustness and adaptability more evident than transformability [84]. The Polish case departs from this pattern: stakeholders substituted quality of life for natural resources among the most important functions, and perceived the performance of their system as low, which the cross-case analysis relates to lower product prices following

accession [84]. The farmers among them rated economic viability below the level defined as poor [39].

The ranking of challenge types distinguishes the Polish case more clearly. In the SURE-Farm farm survey, institutional challenges were ranked first or joint first in six of the ten case studies for which the SURE-Farm resilience assessment reports a ranking (counting the arable row for the German case), whereas in Poland environmental and economic challenges received the highest scores, both 5.2 on a seven-point scale, ahead of institutional (4.3) and social challenges (3.8) [24]. Among the other case studies only the Italian hazelnut and the Bulgarian grain systems show the same ordering, with environmental and economic challenges ranked above institutional ones [24].

These explanations share a structural feature specific to family farming: a large number of small units, marketing individually, facing a small number of large buyers. The treadmill, if present, bears hardest on farms whose capital is their own and whose labour is largely unpaid family labour, weak value-chain position and the cooperation deficit are the same problem seen from two sides, and policy oriented towards robustness sustains farms in place without altering the position they occupy. This is offered as an interpretation that the evidence makes plausible, not as a finding the design can establish.

These findings bear on the question with which the article opened. Of the three expectations set out in Section 2.5, the first and third are met, and the second is met for the relative position of fruit farms, with the qualification that effects of sample composition cannot be fully excluded. Assessed as a system, Polish fruit growing over the past two decades appears robust on output and trade indicators: it absorbed the loss of its principal export market in 2014 and of the Belarusian outlet in 2022, sustained its output through repeated weather shocks, and remained the largest apple producer in the European Union. Assessed at the level of the families who deliver its functions, the same decades produced income per FWU that fell from above to below the regional all-farm average in most years after 2013, and a fall of more than a third in the number of farms with orchards. Both descriptions are accurate; they answer different questions, and the one they answer differently is the question added to those of Carpenter et al.—resilience for whom [6–8].

The implication for the assessment of farming systems is methodological. Where a system consists of many small units facing few large buyers, and where the gains of productivity growth are not retained by the farm, system-level robustness and household-level viability may move in opposite directions. Output, area, and trade indicators register the first and are silent on the second, which becomes visible in farm accounts and in participatory assessment. Neither source is sufficient alone, and for farming systems composed of family farms the two are best treated as answering complementary questions rather than as alternative measurements of the same thing.

A note on periodisation is required. The participatory data were collected between 2018 and 2020, whereas the statistical series extend to 2025. The environmental challenges participants identified have continued to materialise: in the second half of April 2024 frosts locally below minus nine degrees damaged blossoming fruit trees, bushes, and berry plantations, followed by a rainfall deficit and localised hailstorms [72], and Commission Implementing Regulation (EU) 2024/2146 introduced temporary emergency measures for the fruit and vegetable sector to address the consequences [85]. The economic situation has also been affected by the war in Ukraine. How these developments would change stakeholders' assessment cannot be established from the present data.

The participatory evidence also has to be weighed for what it is. It comes from a small, self-selected group, half of them farmers and predominantly soft-fruit growers, assembled once in March 2019. In the threshold workshops held across the eleven SURE-Farm case studies, every farming system was perceived to be close to, at, or beyond at least one critical

threshold, with economic viability among the main concerns [86], which suggests both that the Polish concern is not idiosyncratic and that workshop assessments may share a tendency to emphasise proximity to thresholds. Farmers' perceptions of the resilience of their farms are associated with their own characteristics, such as risk aversion, involvement in networks, and openness to innovation [87], so the composition of a self-selected group can shape the result. The workshop also followed the season in which fruit farms stood furthest behind all farms in the accountancy series, so the severity of the rating may reflect a recency effect. These concerns are limited but not removed. The farm survey [24,40], whose 70 respondents were selected to reflect the FADN structure of horticultural and permanent-crop farms in the region, also ranked economic challenges jointly first, which speaks against an artefact of the workshop group, but the survey was fielded in the same season, with questionnaires still being completed after mid-January 2019 [40], so it shares the recency concern. That concern is limited only by the accountancy data, which show that the weak relative position was not confined to 2018. The participatory assessment is, therefore, best read as a snapshot taken at the low point of a persistently weaker relative position, which it corroborates but cannot by itself establish.

5. Conclusions

Between 2004 and 2025, fruit growing in the case study region roughly doubled the yield of its tree fruit plantations, from about 11 to about 22 tonnes per hectare (five-year means), while the area under fruit trees contracted after 2013 and the number of farms with orchards fell by more than a third between 2010 and 2020. Income per FWU on fruit farms in FADN region 795—Mazowsze i Podlasie, which had exceeded the regional all-farm average in most years to 2013, fell below it in nine of the eleven years from 2014 to 2024, a change whose timing is supported by a formal break test, which persists when subsidies are excluded and which is partly concurrent with a revision of the FADN sample in 2013. The work of these farms came to rest increasingly on family labour. The sector became more productive, while the families within it lost ground relative to other farm households in their region.

The assessment offered by the actors of the farming system points in the same direction. Participants identified environmental and economic pressures as the most consequential, described profitability as close to a threshold beyond which continuation would not be possible, and rated economic viability, the function to which they attached the greatest importance, lowest of all functions. Their assessment was made immediately after the season in which fruit farms stood furthest behind other farming in the region, so it may carry a recency effect; the two kinds of evidence are convergent but describe different populations and do not validate each other.

Three implications follow. For the assessment of resilience, the case indicates that a farming system may be robust at the level of food production while the economic viability of its constituent family farms declines relative to other farming, and that output, area, and trade indicators will not disclose the difference. The question of resilience for whom accordingly appears to be a condition of assessing family farming systems rather than a refinement of it. For policy, the evidence is consistent with, but does not demonstrate, the view that the market position of small fruit farms, rather than their productivity, constrains their income. Measures affecting the distribution of value, such as support for collective marketing and lower barriers to membership of producer organisations, where Poland's organisational rate of 12% is far below the EU-27 level of 46.3%, and instruments oriented towards adaptability and transformability rather than robustness alone, deserve evaluation alongside measures raising output. For method, participatory and accountancy evidence

answer different questions and neither substitutes for the other; combining them makes visible a distributional question that output statistics conceal.

These conclusions are bounded by the evidence. The participatory evidence derives from a small number of stakeholders, mainly soft-fruit growers in one region, collected between 2018 and 2020, the accountancy data exclude farms below the FADN economic size threshold, which may include those under the greatest pressure, so the decline could be understated for the smallest farms, and they cannot follow individual farms over time, and the design is descriptive, so the mechanisms discussed remain hypotheses. Panel accountancy data for fruit farms, crop-specific income series, and measures of margins along the chain would allow these hypotheses to be tested, and a comparison with permanent-crop farms in other FADN regions and with horticultural systems elsewhere in Central and Eastern Europe would show how far the pattern is particular to this case.

Author Contributions: Conceptualisation, V.K. and A.W.; methodology, V.K.; investigation, V.K., A.W., A.P., Y.Z., N.P., R.K., K.Z. and P.G.; formal analysis, V.K., A.W., A.P., Y.Z., N.P., R.K., K.Z. and P.G.; writing—original draft preparation, V.K., A.W., A.P., Y.Z., N.P., R.K., K.Z. and P.G.; writing—review and editing, V.K., A.W., A.P., Y.Z., N.P., R.K., K.Z. and P.G.; visualisation, V.K. and A.W.; supervision, V.K.; funding acquisition, V.K., A.W., K.Z. and P.G. All authors have read and agreed to the published version of the manuscript.

Funding: This work draws on research conducted within the SURE-Farm project, which received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520.

Institutional Review Board Statement: The stakeholder data analysed in this article were collected within the SURE-Farm project (Horizon 2020, Grant Agreement No. 727520). The project was reviewed by the Social Sciences Ethics Committee of Wageningen University and Research, the project coordinator, which issued its approval on 18 December 2017; no approval code was issued. Ethical clearance for the fieldwork in Poland was confirmed on 27 February 2018 by the Director of the Institute of Rural and Agricultural Development, Polish Academy of Sciences, in accordance with the Code of Ethics for Research Workers of the Polish Academy of Sciences. The present analysis reuses these data in anonymised and aggregated form and involved no further data collection from human participants.

Informed Consent Statement: Participation in all data collection activities of the Polish case study (farm survey, interviews, focus group, and stakeholder workshops) was voluntary. Before each activity, participants received a written information clause stating that the activity was conducted for research purposes within the SURE-Farm project and describing how their data would be processed, reported, and published, and they gave written consent by signature. Results are reported only in anonymised and aggregated form.

Data Availability Statement: The statistical series analysed in this article are publicly available from the sources cited: Statistics Poland, Eurostat, the Polish standard results for FADN region 795—Mazowsze i Podlasie, and the market analyses of IERiGŻ-PIB. The participatory data derive from the SURE-Farm project. The case study reports are available openly from the project website (https://surefarmproject.eu), and the underlying Polish workshop records are held by the Institute of Rural and Agricultural Development, Polish Academy of Sciences, and are available from the corresponding author upon reasonable request. The derived series and the calculations underlying Tables 3 and 4 and Appendix A are available from the corresponding author.

Acknowledgments: The authors thank the stakeholders who participated in the SURE-Farm workshops, interviews, and focus groups in Poland. During the preparation of this manuscript, the authors used an AI assistant (Claude Opus 5 from Anthropic) to support language translation (the original version was partly written in Polish), supporting literature and data search, bibliographic formatting according to the journal's style, and final document formatting. The AI tool was not used for any research processes, including literature analysis and synthesis, data analysis, or interpretation of results.

The research design, analysis, findings, and conclusions are the authors' own. The authors reviewed and verified all AI-assisted output and take full responsibility for the content of the manuscript.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

This appendix reports the tests of the timing of change in the income of fruit farms and the sensitivity of the main comparisons to the choice of deflator, the treatment of subsidies, and the period boundaries. The search for a single break in the mean follows the sup-F approach of Andrews [88]: for every candidate break year, excluding the first and last 15% of observations, the F statistic for a difference in means before and after the break is computed and the largest value is retained. Because asymptotic critical values are unreliable with 15 to 19 annual observations, *p*-values are obtained by recomputing the largest F statistic for 10,000 random permutations of the series. This treats the annual observations as exchangeable, and since the first-order autocorrelation of the residuals around the estimated break ranges from −0.57 to 0.32, the *p*-values are approximate. All figures are computed from the Polish standard results for FADN region 795—Mazowsze i Podlasie [60,61], the consumer price index [78], and the index of prices of goods and services purchased for current agricultural production [77]. Tables A1–A3 report the tests and Table A4 the period means of alternative income, cost, and structural indicators.

Table A1. Tests of the timing of the change in the income of fruit farms: search for a single break in the mean, Farm Accountancy Data Network (FADN) region 795—Mazowsze i Podlasie.

Indicator	Period	Most Likely Break	sup-F	Permutation *p*
Ratio of income per FWU to the all-farm average	2006–2024	2013/2014	14.3	0.020
	2010–2024	2012/2013	23.2	0.008
Ratio of income per FWU net of subsidies and taxes	2006–2024	2013/2014	13.1	0.012
	2010–2024	2012/2013	11.1	0.029
Real income per FWU, fruit farms (CPI)	2006–2024	2009/2010	1.5	0.79
	2010–2024	2012/2013	7.4	0.11
Real income per FWU, fruit farms (input price index)	2006–2024	2013/2014	2.8	0.52
	2010–2024	2012/2013	12.3	0.027

Notes: Break years are written as the last year of the earlier and the first year of the later regime. Real values at 2013 prices. Excluding 2014 and 2018, the mean ratio for 2014–2024 is 0.90; the linear trend of the ratio over 2014–2024 is not significant ($p = 0.74$). Abbreviations: CPI, consumer price index; FWU, family work unit; sup-F, largest F statistic over the candidate break years. Source: own calculations based on [60,61,77,78].

Table A2. Tests of the size of the change in the income of fruit farms: comparison of means for 2010–2013 and 2014–2024, Farm Accountancy Data Network (FADN) region 795—Mazowsze i Podlasie.

Indicator	Mean 2010–2013	Mean 2014–2024	Welch *p*	Mann–Whitney *p*
Ratio of income per FWU to the all-farm average	1.36	0.84	0.008	0.003
Ratio of income per FWU net of subsidies and taxes	2.17	1.09	0.005	0.010
Real income per FWU, fruit farms, thousand PLN (CPI)	32.7	22.6	0.020	0.026
Real income per FWU, fruit farms, thousand PLN (input price index)	33.9	22.2	0.014	0.010
Real income per FWU, all farms, thousand PLN (CPI)	24.0	27.0	0.23	0.75

Notes: Real values at 2013 prices. Abbreviations: CPI, consumer price index; FWU, family work unit. Source: own calculations based on [60,61,77,78].

Table A3. Ratio of income per family work unit on fruit farms to the all-farm average: comparison of means with alternative first years of the later period, Farm Accountancy Data Network (FADN) region 795—Mazowsze i Podlasie.

First Year of the Later Period	Mean Before	Mean After	Welch *p*
2012 (2010–2011 against 2012–2024)	1.43	0.91	0.14
2013	1.45	0.86	0.007
2014	1.36	0.84	0.008
2015	1.21	0.86	0.12
2016	1.21	0.83	0.044

Notes: The earlier period starts in 2010, and the later period ends in 2024. Source: own calculations based on [60,61].

Table A4. Income, costs, and structure of farms specialising in permanent crops, Farm Accountancy Data Network (FADN) region 795—Mazowsze i Podlasie, period means.

Indicator	2006–2009	2010–2013	2014–2019	2020–2024
Income per FWU, ratio to the all-farm average	1.09	1.36	0.79	0.89
Real income per FWU, fruit farms/all farms, thousand PLN (CPI)	19.7/17.5	32.7/24.0	18.3/23.1	27.8/31.8
Real income per FWU, fruit farms/all farms, thousand PLN (input price index)	22.7/20.0	33.9/24.9	18.9/23.9	26.2/29.7
Income per FWU net of current subsidies and taxes, ratio to the all-farm average	1.76	2.17	1.00	1.19
Balance of current subsidies and taxes, % of family farm income, fruit farms/all farms	30/55	24/52	58 (47 b)/63	25/45
Real output per farm, thousand PLN (CPI)	93.7	121.4	91.5	87.3
Total costs, % of output	78	70	87	68
Economic size, ratio to the all-farm average	n.c.	0.81	0.81	0.74 (a)
Utilised agricultural area/permanent crops per farm, hectares	7.9/5.8	8.9/6.8	8.9/6.7	8.3/5.7
Family labour, % of total labour input	68	67	71	81
Farms in sample	286–309	258–287	285–318	267–286
Farms represented, thousand	18.3–19.2	14.7–23.8	23.7–23.8	33.4

Notes: Period means of annual values; ratios are means of annual ratios. The 2006–2009 editions apply the earlier typology based on European size units and are not strictly comparable (n.c.: not comparable). The number of farms represented changes with the revisions of the field of observation and sampling plan in 2013 and 2020, not with the number of fruit farms. (a) 2020–2023; economic size is not reported for 2024. (b) Excluding 2014, when family farm income was lower than the balance of subsidies and taxes. In 2014 income per FWU net of subsidies and taxes was negative on fruit farms; computed as ratios of period means, the market income ratios are 2.16, 1.00, and 1.11 for 2010–2013, 2014–2019, and 2020–2024. Abbreviations: CPI, consumer price index; FWU, family work unit. Source: own calculations based on [60,61,77,78].

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