

COMPARATIVE ASSESSMENT OF SUSTAINABLE COMPETITIVENESS OF ORGANIC AND CONVENTIONAL FARMS IN THE BALTIC STATES: INTEGRATING ECONOMIC AND AGRI-ENVIRONMENTAL DIMENSIONS

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Abstract

Agricultural policy requires farms to stay competitive while cutting their environmental burden, yet farm-level competitiveness is still assessed largely through economic indicators, leaving it unclear whether environmentally distinct systems differ in overall sustainable competitiveness. The purpose of this article is to compare the sustainable competitiveness of organic and conventional farms in the Baltic states and to reveal the economic and environmental dimensional trade-offs through which organic and conventional farms attain it. The farm sustainable competitiveness index was built on individual data for a pooled sample of 1,014 family farms from Lithuania, Latvia and Estonia (2014–2016 and 2020–2022), analysed as a single regional dataset, using principal component analysis and equal-weight aggregation. No statistically significant differences were observed in organic and conventional farms' sustainable competitiveness, but significant differences emerged in how the environmental and economic dimensions of the indices changed over time, showing a dimensional trade-off rather than the superiority of either system.

Keywords: *Baltic States, Conventional Farming, Economic Performance, Environmental Performance, FADN, Organic Farming, Sustainable Competitiveness.*

JEL Codes: *Q12; Q18; Q56; Q57.*

Introduction

The increasing emphasis on sustainability in discussions of competitiveness has attracted a distinct body of scholarship. Porter and van der Linde (1995) argued that appropriately designed environmental regulation can stimulate innovation and thereby strengthen, rather than erode, competitiveness. Building on such foundations, sustainable competitiveness has been conceptualised and measured mainly at the macro and mezo levels: as an economic category combining social, environmental and economic pillars (Cheba et al., 2020; Despotovic et al., 2016), as an adjustment of national competitiveness for social and environmental performance (Benítez-Márquez et al., 2022; Doyle & Perez-Alaniz, 2017; Doyle & Perez Alaniz, 2020), and, for regions, through spatial composite indices (Möbius & Althammer, 2020).

At the level of the firm, Herciu and Ogorean (2018) added a single sustainability indicator (Dow Jones Sustainability Index) to conventional performance indicators, while for agriculture Constantin et al. (2023) and Dabkienė (2025) developed sustainable economic competitiveness indices at the cereal farms level. Nowak and Kasztelan (2022) contrasted economic and “green” competitiveness of European agriculture and drew explicit attention to the scarcity of farm-level integrated assessment.

Agriculture depends on the natural environment more directly than any other economic sector, so an assessment of the sustainable competitiveness of farms ought to begin by integrating its economic and agri-environmental dimensions. The relationship between these two dimensions itself is contested. The traditional view holds that environmental requirements internalise external costs and

thereby raise costs and depress economic results, whereas the revisionist position argues that well-designed environmental effort can trigger innovation and become a source of competitive advantage (Porter & van der Linde, 1995). This tension is sharpest in farming, where output rests on soil, biodiversity and ecosystem services, so practices that protect these assets may lower short-run land productivity even as they secure long-run viability (Despotovic et al., 2016; Farah & Gómez-Ramos, 2014). Organic and conventional farming embody the two poles of this tension: organic systems restrict synthetic inputs to protect environmental assets, whereas conventional systems rely on those inputs to raise output and economic productivity. Whether the two differ in sustainable competitiveness is therefore, at root, a question of how the economic and agri-environmental dimensions combine within each farming system.

Empirical comparisons of organic and conventional farming have traditionally focused on particular dimensions of farm performance. A substantial strand of the literature has examined economic performance through productivity, profitability, efficiency, financial performance, and input–output competitiveness (Argilés-Bosch et al., 2026; Baraniak, 2024; Hampl, 2020; Komor et al., 2025; Martín-García et al., 2023; Nehring et al., 2021). The findings are not unequivocal. Conventional farms frequently achieve higher physical productivity or production intensity, whereas organic farms may compensate for lower output through lower input costs, price premiums, subsidies, or greater economic efficiency. Recent evidence based on 62,588 farm-year observations from the Spanish Farm Accountancy Data Network (FADN), for example, indicates that the financial performance of fully organic farms was generally comparable to or better than that of conventional farms (Argilés-Bosch et al., 2026). Similarly, recent evidence on organic farming competitiveness across EU countries demonstrates considerable heterogeneity in both input and output competitiveness (Komor et al., 2025). These findings suggest that the relative economic performance of organic and conventional farming depends on the performance measure

considered as well as on farm structure, production orientation and institutional conditions.

A parallel strand of research has compared the environmental performance of organic and conventional systems, focusing on indicators such as nutrient balances, energy use, greenhouse-gas emissions and other life-cycle environmental impacts (Boschiero et al., 2023; Chmelíková et al., 2024; Matovu et al., 2026). A smaller body of research has assessed economic and environmental outcomes simultaneously (Berbeć et al., 2018; Feledyn-Szewczyk & Kopiński, 2024), revealing that advantages in one dimension do not necessarily coincide with advantages in another. Comparative work on organic and conventional dairy farms has linked profitability to nitrogen surplus, greenhouse-gas emissions and energy intensity, showing that stronger environmental performance per unit of output can accompany, rather than preclude, profitability (Flaten et al., 2019). More broadly, studies of the economic-environmental interaction report that trade-offs between the two outnumber synergies (Arru et al., 2024; Grzelak et al., 2022; Sau et al., 2023; Sidhoum et al., 2022). Recent systematic evidence reinforces this conclusion: organic systems tend to show lower productivity but may achieve better financial performance, while results for other sustainability outcomes remain heterogeneous (Freeland et al., 2026). Thus, the existing literature increasingly points to trade-offs between different dimensions of farm performance rather than to the unequivocal superiority of either farming system.

Such comparisons, however, typically rest on isolated economic or environmental indicators rather than on a single integrated measure. They reveal where the systems diverge on particular dimensions without establishing whether their overall sustainable competitiveness differs. Because such trade-offs let a gain in one dimension offset a loss in the other, two systems may reach a similar aggregate level while striking a different balance between the dimensions. This possibility cannot be detected by comparison of isolated indicators. It also raises the question of how such trade-offs should be treated when the dimensions are combined into a single measure.

Sustainable competitiveness is inherently a matter of balance across dimensions, so its evaluation should not permit full trade-offs between them: strong economic performance should not fully offset a weak agri-environmental position, or the reverse. The aggregation strategy adopted in this study therefore limits compensation between dimensions (see Section 2).

Two gaps follow from this literature (Argilés-Bosch et al., 2026; Arru et al., 2024; Boschiero et al., 2023; Flaten et al., 2019; Freeland et al., 2026; Grzelak et al., 2022; Matovu et al., 2026; Sau et al., 2023). First, despite growing evidence on both the economic and environmental performance of farms, farm-level competitiveness assessments that integrate economic and agri-environmental variables within a common analytical framework remain limited. Second, comparative studies of organic and conventional farming generally evaluate individual indicators or sets of economic and environmental outcomes in parallel rather than integrating them into a composite measure of sustainable competitiveness. Consequently, it remains unclear whether the two farming systems differ in their overall sustainable competitiveness and whether similar levels of sustainable competitiveness may conceal different trade-offs between its economic and agri-environmental dimensions.

The three Baltic States provide a suitable common data pool for comparing the sustainable competitiveness of organic and conventional farms. Estonia, Latvia, and Lithuania share broadly comparable agro-climatic conditions, a common post-Soviet trajectory of agricultural restructuring, membership of the European Union and implementation of the Common Agricultural Policy (CAP), as well as a harmonised FADN reporting framework. These common characteristics provide a sufficiently consistent institutional and agricultural context for pooling farm-level observations from the three countries and analysing the two farming systems jointly. Pooling the data also provides a larger and more diverse sample covering a range of farming types and increases the number of organic holdings available for analysis, thereby enabling a more robust comparison of organic and conventional farms

while keeping the broader institutional setting relatively homogeneous.

The **scientific problem** addressed here is which economic and agri-environmental variables shape farm sustainable competitiveness, and whether organic systems perform better than conventional ones. The **purpose** of the article is to compare the sustainable competitiveness of organic and conventional farms in the Baltic states and to reveal the dimensional trade-offs behind it. In line with this purpose, the study (i) constructs a farm sustainable competitiveness index from economic and agri-environmental variables; (ii) compares its overall level between organic and conventional farms; and (iii) examines whether the economic and agri-environmental dimensions of these two groups of farms follow different developmental trajectories.

The **object** of the study is the differences of sustainable competitiveness between organic and conventional farms in the Baltic states. The assessment rests on a composite index built from individual farm accounting data and combines standardisation, correlation analysis, principal component analysis, equal-weight aggregation and non-parametric group comparisons.

This study delivers a reproducible farm-level measure that integrates economic and agri-environmental variables into sustainable competitiveness assessment. In addition, for policy and business, it clarifies that organic certification is not, in itself, a route to superior overall sustainable competitiveness, and that organic and conventional farms reach comparable levels while differing in how their two dimensions develop over time, a finding relevant to targeting support, monitoring the Common Agricultural Policy, and appraising farm investment.

Research methods

The empirical analysis uses individual farm-level data on family farms in Lithuania, Latvia, and Estonia obtained from FADN, now operating as the Farm Sustainability Data Network (FSDN). Farm-level observations from the three Baltic States were pooled into a single analytical sample to enable a comparative assessment of the sustainable competitiveness of organic and conventional farms. Data

for all farms reporting to FADN/FSDN in the three Baltic States during the analysed period were obtained from the European Commission under a data-supply agreement. Two three-year periods were analysed: 2014–2016 and 2020–2022. The latter was the most recent period available at the time of the study, while 2014 was selected as the starting point because it marks the beginning of the corresponding Common Agricultural Policy programming period and was the first year in which additional agri-environmental information relevant to this study, including data on artificial fertiliser use, was collected in FADN. This selection also provides the longest comparable observation window between the two periods, which is particularly relevant given the long-term nature of sustainable competitiveness.

Three-year averages were used to dampen single-year fluctuations caused by extreme weather or transient market shocks. There are 1172 holdings that reported to FADN in every year of both periods. Companies, landless holdings, wine-growers, holdings classified as livestock farms but keeping no animals, and outliers were removed, leaving a final analytical sample of 1,014 farms observed in both periods. Because the same holdings are present in 2014–2016 and in 2020–2022, every two-period comparison reported below rests on a balanced panel, so no entries or exits have to be handled.

FADN classifies holdings into four organic-status categories. The organic–conventional comparison uses only the two categories that contain at least 100 observations and that differ most sharply in production methods: holdings applying no organic production methods (801 farms) and holdings applying organic production methods to all their output (161 farms), giving 962 farms. The remaining 52 holdings fall into the two intermediate organic-status categories, each with fewer than 100 observations; they are retained in the analyses by farming type, economic size and country ($n = 1,014$) as well as for analysis carried out during the process of constructing the index. But they were excluded from the organic–conventional comparison ($n = 962$). Agricultural companies were excluded because the decision logic of family farms differs from that of corporate holdings. In family farms unpaid family labour predominates, and choices reflect household as well as profit considerations rather than profit-maximisation that is a feature of corporate holdings. Also, the few large companies in the sample would otherwise dominate the variance. Restricting the analysis to family farms also improves cross-country comparability and aligns the results with the family-farm orientation of agricultural policy. The composition of the sample is set out below (Table 1).

Table 1. Composition of the analysed farms sample

	Conventional farms				Organic farms			
Farming type	Estonia	Lithuania	Latvia	Total	Estonia	Lithuania	Latvia	Total
Fieldcrops (arable)	71	75	225	371	2	4	13	19
Horticulture	17	6	5	28	1			1
Other permanent crops	58	51	169	278	24	8	72	104
Dairy	1	1	3	5	3	-	1	4
Granivores	3	-	7	10	1	-	4	5
Mixed	23	20	66	109	4	3	21	28
Total	173	153	475	801	35	15	111	161

Note: Farming types follow the FADN type-of-farming classification (TF 1 fieldcrops, TF 2 horticulture, TF 4 other permanent crops, TF 5 dairy, TF 7 granivores, TF 8 mixed); wine-growers (TF 3) were removed at the screening stage. In the full 1,014-farm sample the country totals are Estonia 239, Lithuania 171 and Latvia 604.

The farm sustainable competitiveness index integrates an economic dimension and an agri-environmental dimension. Sustainable competitiveness

is understood here as the farms' ability to maintain or improve economic performance and market position over the long term while preserving

environmental resources and adapting to changing conditions, without compromising the productive potential of future generations. So the economic dimension captures competitive economic performance and the agri-environmental dimension captures the capacity to preserve environmental resources of farming.

Candidate indicators for the farm sustainable competitiveness index were selected by first compiling a preliminary list from the theoretical and empirical literature on farm and firm competitiveness and on sustainable competitiveness and matched against the variables available in FADN. Then the retained indicators were standardised as z-scores so that none would dominate through its scale (Greenacre et al., 2022; Pollesch & Dale, 2016). Indicators with an adverse direction, such as fertiliser and plant-protection intensity, greenhouse-gas, energy and water intensity, livestock density, and cost and labour intensities, were multiplied by -1 , so that a higher value of every indicator points towards higher sustainable competitiveness. Strongly correlated indicators ($r > 0.8$) were then removed to avoid multicollinearity (Kyriazos & Poga, 2023). Finally, principal component analysis (PCA) was applied to the remaining indicators, both to confirm that they grouped into coherent dimensions and to fix the final indicator set and its structure. PCA analysis was applied for economic and agri-environmental indicators separately. Sampling adequacy was acceptable for both indicator groups (Kaiser–Meyer–Olkin measures of 0.629 for the economic and 0.781 for the agri-environmental indicators; Bartlett's test of sphericity $p < 0.001$). The analysis was run on the 2020–2022 indicator values for all 1,014 farms. The full component matrices, the components retained and the variance they explain are reported in the Appendix (Tables A1 and A2).

For the economic indicators, PCA produced 5 components, which together explain 71% of the variance. The first component, accounting for 20% of the variance, loaded on intermediate consumption intensity (0.807), cost profitability (0.782), labour productivity (0.643), return on capital (0.597), wheat yield (0.548) and the equity ratio (−0.489), thereby capturing productivity, profitability, resource-use efficiency and financial resilience, that

is, the principal dimensions of economic performance (Table A1). As PCA was used to identify the structure of the indicator set rather than to use component scores directly as sub-index values, it alone was retained as the economic sub-index. Because this component explains a comparatively modest share of the variance, retaining it alone follows the recommendation to give precedence to theoretical coherence over statistical variance in composite construction (OECD, 2008). The second and third components were more specific and reflected particular farm types: the second loading more strongly on crop-production indicators and the third on livestock-production indicators. Rather than measuring the level of competitiveness, however, these components appeared to capture the farm's strategic orientation, that is, how competitiveness is pursued rather than the level attained, and were therefore not retained. The remaining components each loaded on no more than three indicators that did not form a theoretically meaningful grouping and were likewise excluded.

For the agri-environmental indicators, the analysis separated 4 components, which together explain 69.6% of the variance (Table A2). First component was considered as a pollution component (fertiliser, plant-protection, energy and net greenhouse-gas intensity, arable share and livestock density) while second component covered conservation practices indicators (Shannon evenness index, protein-crop share and nature-conservation subsidies). The third component comprised only two indicators, one of which is theoretically more closely associated with the first component, while the fourth component loaded on a single indicator. Neither was considered to constitute a coherent, self-standing dimension, and no sub-index was formed from them. The first two components, explaining approximately 29% and 12% of the variance respectively, therefore formed the two agri-environmental subgroups. Two indicators were relocated from the component with the largest loading: livestock density was placed in the pollution subgroup although its largest loading fell on the third component, because that is where it belongs on theoretical grounds; and the share of catch crops, which loaded on the first component, was dropped

because it has no theoretical basis for inclusion in a pollution measure. This structure matters for the organic–conventional comparison. Organic farms, which forgo synthetic fertilisers and chemical plant protection and draw more heavily on agri-

environmental support, would be expected to score more favourably on these agri-environmental components. Table 2 lists the selected indicators for composition of the farm sustainable competitiveness index.

Table 2. The groups of economic and agri-environmental indicators selected for constructing the index

Economic Variable Indicators Group	Agri-environmental Variable Indicators Group	
	Pollution Variable Indicators Subgroup	Conservation practices Variable Indicators Subgroup
Intermediate consumption intensity	Nitrogen fertilizer applied per hectare of utilized agricultural area	Shannon Evenness index for biodiversity assessment
Cost profitability	Share of arable land in utilized agricultural area	Share of protein crops in arable land
Labor productivity	Potassium fertilizer applied per hectare of utilized agricultural area	Share of all nature conservation–related subsidies in direct payments
Wheat yield	Greenhouse gas emissions intensity	
Equity ratio	Plant protection product costs per hectare of utilized agricultural area	
Return on capital	Energy use intensity	
	Livestock density	

The rationale for including each specific indicator is presented below, beginning with the economic dimension. Productivity indicators are the most widely applied in competitiveness assessments, as productivity and profitability are commonly regarded as principal performance indicators whose comparatively better results reflect higher farm efficiency and competitiveness (Bachev & Koteva, 2021; Cele et al., 2022). In agriculture, partial productivity indicators are widely used owing to their computational simplicity and ease of interpretation (Irz & Jansik, 2015); *labour productivity* was selected as the labour measure, and since the same authors found that dairy-farm labour productivity depended far more on labour intensity than on milk yield per cow, this indicator captures a key driver of farm performance. *Wheat yield* serves as the land productivity measure, as wheat accounts for about 40% of all crops in the Baltic states, the FADN-calculated wheat yield indicator reflects land productivity well. Complementing these, *intermediate consumption intensity* (as efficiency of variable costs and service use) shows how efficiently purchased and farm-produced inputs and farming overheads are used relative to output, revealing whether

competitiveness rests on technical efficiency and effective cost control.

Three further indicators address profitability and financial structure. Since asset accumulation is one of a farm's primary objectives (Farah & Gómez-Ramos, 2014), profitability — reflecting the relationship between profit and the resources used to generate it — is an essential element of competitiveness assessment, as rising profitability enables capital accumulation and investment in modernisation that further reduces production costs. *Cost profitability* serves a second function too, because net income is reduced by the subsidies received in its calculation, it captures market-earned income and thus partly reflects the farm's independence from direct payments. *Return on capital*, computed as farm net income over average total capital and frequently used in competitiveness research, shows how efficiently a farmer utilises assets (land, machinery, accumulated funds) to generate profit and is regarded as one of several indicators capable of assessing long-term enterprise performance (Šiška & Lizalová, 2011). Finally, the *equity ratio* serves both as an indicator of financial independence (Sulewski & Kłoczko-Gajewska, 2018) and of

competitive performance (Guo & Lu, 2023); characterising an entity's financial condition and used to assess leverage and solvency (Kliestik et al., 2020), a high ratio indicates operational sustainability and low risk.

Having outlined the economic indicators, the environmental dimension is considered next. The *intensity of nitrogen* (and *potassium oxide*) fertilisation and *plant protection product use* reveals whether farming practices compromise long-term competitiveness through their negative environmental impact. Excessive fertiliser use drives nutrient losses that contribute to the deterioration of water and air quality, rising GHG emissions, harm to biodiversity, and the unsustainable use of land and energy (Flaten et al., 2019), whereas reducing fertilisers and pesticides has a positive environmental effect (Pe'er et al., 2022). A similar environmental pressure is reflected in the *share of arable land* in a farm's utilised agricultural area: intensively cultivated plots emit GHGs, lose more organic carbon, and are more susceptible to erosion and soil degradation than carbon-sequestering permanent grasslands or forests, while growing monocultures poses an additional risk of biodiversity loss (Právělie et al., 2021).

GHG intensity measures the pollution caused by agriculture and at the same time reflects a farm's technological advancement — low intensity means that the same or greater output is produced using fewer resources, which correlates with lower production costs (Coderoni & Vanino, 2022); such farms will also be less vulnerable if pollution regulation tightens. *Livestock density* is likewise linked to pollution, as an excessive local concentration of nitrogen that the soil cannot absorb may contaminate groundwater and damage ecosystems. The *energy intensity* indicator, widely applied in sustainable competitiveness research (Dabkienė, 2025; Flaten et al., 2019), additionally captures both the

pollution generated by the activity and the efficiency of resource use.

The *Shannon evenness index* assesses the evenness of a farm's crop structure, which is important for sustainable competitiveness: a more diverse crop rotation supports biodiversity, naturally improves soil structure, and acts as a barrier preventing any single pathogen species from dominating, thereby requiring fewer future investments in soil improvement (liming, additional fertilisation) and lower expenditure on pesticides, whereas monoculture farms more often face chemical-resistant weeds and diseases (Schaak et al., 2023; Staniszewski et al., 2023). The same logic is reinforced by the *share of protein crops in arable land*: these crops fix atmospheric nitrogen and thus reduce the need for mineral fertilisers, the associated GHG emissions and costs, improve soil structure, break cereal disease cycles, and increase the farm's economic resilience by reducing dependence on expensive feed imports and volatile energy prices.

The share of all nature-conservation-related subsidies in direct payments indirectly indicates the extent of environmentally friendly practices applied on a farm. For example, during the 2014–2020 period, the “Agri-environment and climate” measure of Lithuania's Rural Development Programme provided for 13 activities aimed at biodiversity, water bodies, and climate change mitigation (e.g. extensive grassland management through grazing, growing catch crops, over-winter stubble fields, protection of water bodies from pollution and erosion), while Natura 2000 payments indicate the maintenance of protected areas. The more such payments a farm received, the more environmentally friendly activities it implemented, thereby strengthening its resilience and creating conditions for long-term competitiveness through preserved soil quality and biodiversity. The exact calculation formulas for all indicators discussed above are provided in Table 3.

Table 3. Farm's economic performance and agri-environmental variables

Variables	Indicators	Calculation
Economic Variable Indicators Group		
Productivity	Labor productivity	Farm net value added per annual work unit (EUR/AWU)
	Wheat yield	Wheat yield (kg/ha)
Resource intensity	Intermediate consumption intensity	Intermediate consumption per unit of total crop, livestock, and other agri-cultural output value (EUR/EUR)
Profitability	Cost profitability (excluding subsidies)	Ratio of farm net income, excluding all subsidies (except investment subsidies), to total costs (EUR/EUR)
	Return on capital	Ratio of farm net income to average capital value (EUR/EUR)
Financial independence	Equity ratio	Ratio of average equity value to average annual total asset value (EUR/EUR)
Agri-environmental Variable Indicators Group		
Use of industrial inputs	Nitrogen fertilizer per hectare of utilized agricultural area (UAA)	Ratio of nitrogen (N) fertilizer applied to utilized agricultural area (kg/ha)
	Plant protection product costs per hectare of UAA	Ratio of plant protection product costs to utilized agricultural area (EUR/ha)
	Potassium fertilizer per hectare of UAA	Ratio of potassium fertilizer (K ₂ O) applied to utilized agricultural area (kg/ha)
	Energy use intensity	Ratio of expenditure on fuel, lubricants, and heating fuel to the value of total crop, livestock, and other agricultural output (EUR/EUR)
Use of natural resources	Share of arable land in utilized agricultural area (UAA)	Ratio of arable land to utilized agricultural area (ha/ha)
Pollution	Greenhouse gas (GHG) emissions intensity	Ratio of net greenhouse gas emissions to the value of total crop, livestock, and other agricultural output (t CO ₂ eq./EUR)
	Livestock density	Livestock density (livestock units (LU) per hectare UAA) (LU/ha)
Biodiversity and ecosystems	Shannon evenness index	$H_S = -\sum_{l=1}^L \ln p_l$, $E_S = \frac{H_S}{\ln L}$ Where: (H _S) - Shannon Diversity index; p _l - proportion of land occupied by crop l; L - number of different crop types; E _S - Shannon Evenness index.
Nature-friendly farming	Share of all nature conservation-related subsidies in direct payments	Ratio of subsidies for Natura 2000, organic farming, environmentally and climate-friendly practices, agri-environmental measures, and animal welfare to total subsidies (excluding investment subsidies) (EUR/EUR)
	Share of protein crops in arable land	Ratio of the area under lentils, chickpeas, vetch, legumes harvested for green fodder, field peas, beans, lupins, and other protein crops to total arable land (ha/ha)

Indicators were combined using equal weights, chosen for transparency and stability across two periods, following the guidance that equal weighting is appropriate where the relative importance of indicators cannot be established and where component indicators are correlated yet capture different aspects of the phenomenon (Greco et al., 2019; Nardo et al., 2005; OECD, 2008). Sub-indices were aggregated as arithmetic means; the economic and agri-environmental sub-indices were combined into the overall index as a geometric mean, which limits compensation between the two

dimensions (Benítez-Márquez et al., 2022). Before geometric aggregation, z-scores were mapped to the (0,1) interval by a logistic transformation with scale parameter k = 4; reported index and sub-index values were multiplied by 100. The scale parameter was set empirically from the distribution of the transformed indicators: at k = 4 the transformed values cluster neither at 0 nor at 1, retain adequate dispersion (standard deviations of about 0.04–0.06) and have means close to 0.5, which preserves discrimination between farms while permitting geometric aggregation. A combined uncertainty and

sensitivity analysis, replacing equal weights with PCA-based weights and the geometric with the arithmetic mean, confirmed that the farm ranking was highly stable (Spearman's $\rho = 0.973\text{--}0.974$; $p < 0.001$). Substituting PCA-based weights shifted absolute index values systematically upwards for more than 99% of farms, but the median rank change was 32 positions out of 1,014 (31 positions when the aggregation rule was changed as well), and about half the farms moved no further than that. PCA-based weights were used only as a robustness device rather than as the primary scheme, because weights derived from the variance of indicators imply that stable, low-variance indicators matter less, which is not defensible for sustainable competitiveness, and because variance-based weights are not stable across periods or samples.

An index value was computed for every farm in each period. The overall level of sustainable competitiveness and the comparison of sub-indices were assessed for the recent period, while the dimensional trade-off was derived by comparing each farm's economic and agri-environmental sub-indices between the two periods. The analysis is carried out on the whole pooled regional sample, without treating the three states as separate units for comparison. Group comparisons used non-parametric tests, given unequal variances across sub-groups. The sustainable competitiveness indices of organic and conventional farms were compared with the Mann–Whitney U test. Differences across economic-size classes and farming types were assessed with the Kruskal–Wallis test, complemented by one-way ANOVA and by a two-way ANOVA of farming type and economic size. The distribution of two-period change trajectories across groups was tested with the Pearson χ^2 test. Trajectories were defined by assigning each farm's economic and agri-environmental sub-index to one of three change categories. Between-period differences range over $[-11.80, 9.01]$ index points for the agri-environmental sub-index and $[-14.46, 12.15]$ for the economic sub-index; against that spread, a change of no more than one index point in absolute value was treated as negligible and coded as stable (–), while larger changes were coded as a rise (↑) or a fall (↓). The nine combinations of the two sub-index

categories define the trajectories reported in Table 5. Levene's test gave no indication that variance homogeneity was violated across farming types ($p > 0.05$), so Tukey's HSD was used for post-hoc comparisons of types, whereas variances were unequal across economic size classes and the Games–Howell procedure was used there. Effect sizes are reported alongside the significance tests: the rank-biserial correlation for the Mann–Whitney U test, Cramér's V for the χ^2 test, ε^2 for the Kruskal–Wallis test and partial η^2 for the analysis of variance.

Research results and discussion

Sustainable competitiveness of organic and conventional farms

Organic production is often expected to yield a higher sustainable competitiveness, because its restrictions on synthetic inputs should improve agri-environmental performance while certification supports market position. If sustainable competitiveness is genuinely multidimensional, however, gains in one dimension may be offset by losses in another, leaving the overall level unchanged.

Across the whole sample of organic and conventional farms the index and its sub-indices were narrowly and symmetrically distributed, with the widest dispersion in the economic sub-index (Table 4). To test whether production system matters, two distinct groups were contrasted: farms applying only organic methods to their entire output, and conventional farms using synthetic fertilisers and chemical plant protection. The Mann–Whitney U test found no statistically significant difference between them in overall sustainable competitiveness ($U = 65,805$; $Z = 0.412$; $p = 0.681$), with almost identical mean ranks. The corresponding effect size is negligible. This shows that organic farming, in itself, is associated with neither a higher nor a lower overall sustainable competitiveness. For context, the same indices were differentiated by other structural factors; these analyses use the full sample of 1,014 farms, since they do not depend on organic status. Farming type was a significant differentiator (Kruskal–Wallis $H = 145.788$, $df = 5$, $p < 0.001$, $\varepsilon^2 = 0.14$), with field-crop and mixed farms attaining the highest values; and, once economic size was controlled in a two-way ANOVA, farming type

retained a significant effect ($F = 9.974$, $p < 0.001$, partial $\eta^2 = 0.048$) while economic size did not ($p = 0.095$). The absence of an organic–conventional

difference thus stands out against the presence of type-related differences.

Table 4. Descriptive statistics of the farm sustainable competitiveness index and its sub-indices, sample (n = 962), 2020–2022

Indicator	Organic farms (n=161)					Conventional farms (n=801)				
	Min.	Max.	Mean	SD	Median	Min.	Max.	Mean	SD	Median
Sustainable competitiveness index	43.82	55.62	50.08	1.93	50.058	42.20	55.85	49.95	1.82	49.993
Economic sub-index	39.61	58.19	48.34	2.87	47.898	36.90	60.53	50.48	3.295	50.345
Agri-environmental sub-index	45.20	58.86	51.95	2.38	51.699	40.01	55.86	49.51	1.86	49.355

The result cautions against treating organic certification as a proxy for sustainable competitiveness in support-targeting or benchmarking. Since the index can be recalculated for any accounts-keeping farm, it offers a system-neutral basis for such judgments. The interesting question is displaced from *level* to *composition* — how each system reaches a comparable level — which the following sections address.

The dimensional trade-off between organic and conventional farms

A single cross-sectional level cannot reveal *how* competitiveness is built. If organic and conventional farms reach comparable levels by different routes, the difference should appear in the direction in which their two dimensions change over time. The wider evidence that economic–environmental trade-offs outnumber synergies (Arru et al., 2024; Grzelak et al., 2022; Sau et al., 2023; Sidhoum et al., 2022) makes such a divergence plausible.

Between 2014–2016 and 2020–2022 the farm sustainable competitiveness indices were essentially stable (Wilcoxon $Z = -0.593$, $p = 0.553$), and similar numbers of farms improved and worsened. Classifying farms by the joint direction of their economic and agri-environmental sub-indices, and comparing organic with conventional farms, reveals a statistically significant difference in the distribution of trajectories ($\chi^2 = 31.197$, $df = 8$, $p < 0.001$; Table 5), although the association is modest in magnitude (Cramér's $V = 0.18$). Conventional farms most frequently combined a rising economic dimension with a stable agri-environmental one, whereas organic farms far more

often strengthened the agri-environmental dimension at the expense of the economic. The sharpest contrast is precisely on these two trajectories: economic growth with agri-environmental stability was roughly twice as common among conventional farms, while an agri-environmental gain accompanied by an economic decline was roughly three times as common among organic farms. Adjusted standardised residuals show that the association is concentrated in exactly these two cells and in no others: only economic decline with an agri-environmental gain (+4.5 for organic farms) and economic growth with agri-environmental stability (−2.9) exceed two in absolute value. Because the two groups do not differ in overall level (Section 3.1) yet differ significantly in trajectory, the results indicate a genuine dimensional trade-off: organic and conventional farms attain similar sustainable competitiveness by different strategic paths. This is consistent with evidence that environmentally more sustainable farms tend to display lower technical efficiency (Sidhoum et al., 2022) and that trade-offs between economic and environmental results are the more common pattern (Sau et al., 2023). Beyond these two contrasting trajectories the groups behaved similarly. Comparable shares of organic and conventional farms saw both dimensions stagnate or decline, so the divergence is specifically about *which* dimension advances when only one does. In organic farms an advancing agri-environmental dimension was repeatedly accompanied by a stalled or declining economic one, suggesting that the environmental orientation coincides with a constraint on economic growth rather than with a broad-based improvement across both dimensions.

Table 5. Distribution of two-period change trajectories in conventional and organic farms, 2014–2016 compared to 2020–2022. E = economic sub-index, A = agri-environmental sub-index; ↑ rose, ↓ fell, – stable

Trajectory	Conventional (n = 801), %	Organic (n = 161), %
Both dimensions rose (E↑ A↑)	9.9	6.8
Economic rose, agri-environmental fell (E↑ A↓)	6.6	3.7
Economic fell, agri-environmental rose (E↓ A↑)	5.5	15.5
Agri-environmental rose, economic stable (E– A↑)	7.7	9.9
Economic rose, agri-environmental stable (E↑ A–)	20.5	10.6
Both dimensions stable (E– A–)	17.0	16.1
Both dimensions fell (E↓ A↓)	10.9	12.4
Economic fell, agri-environmental stable (E↓ A–)	16.1	16.8
Economic stable, agri-environmental fell (E– A↓)	5.9	8.1
Total	100.0	100.0

Note: A sub-index change of no more than one index point in absolute value was coded as stable (–); larger changes were coded as a rise (↑) or a fall (↓). Underlying counts (conventional / organic) in row order: 79/11, 53/6, 44/25, 62/16, 164/17, 136/26, 87/20, 129/27, 47/13. $\chi^2 = 31.197$, $df = 8$, $p < 0.001$, Cramér's $V = 0.18$.

On the evidence assembled here, organic farming is better interpreted as an alternative model of building sustainable competitiveness, oriented towards the agri-environmental dimension, than as a universally superior one. Policy that seeks both economic viability and environmental gains should treat the two dimensions as jointly targetable rather than assume that one system delivers both. The environmental orientation of the 2023–2027 Common Agricultural Policy, through eco-schemes, agri-environmental measures and conditionality, may in later periods strengthen the standing of lower-intensity strategies (Guyomard et al., 2023), although earlier evidence shows that agri-environmental measures did not always translate into lower farming intensity (Azeda et al., 2021). Recalculating the indices once the expanded FSDN sustainability variables become available would allow the trade-off to be tracked as this policy takes effect.

Discussion

The analysis shows that organic and conventional farms do not differ in overall sustainable competitiveness, but they differ in the dimensional composition and dynamics of that competitiveness. When farms are followed over time, the organic and conventional groups diverge in the direction of change, with organic farms tending towards agri-environmental strengthening and conventional farms towards economic growth. The finding aligns

with the broader literature reporting that farm-level economic and environmental results more often trade off than reinforce each other (Arru et al., 2024; Grzelak et al., 2022), and it substantiates, at the level of an integrated measure, the intuition that sustainability and short-run economic performance need not point in the same direction (Flaten et al., 2019). This premium-dependence of parity is itself well established: a global meta-analysis spanning 55 crops on five continents found that, despite lower yields, organic agriculture was significantly less profitable than conventional without price premiums, but significantly more profitable once actual premiums were applied (Crowder & Reganold, 2015). It also answers the gap identified by Nowak and Kasztelan (2022): an integrated, farm-level measure shows that “green” and economic competitiveness coexist within, rather than across, comparable overall levels. But since sustainable competitiveness is inherently a matter of balance across dimensions rather than of a high score on any single one, the economic and agri-environmental dimensions are complements, and a critical deficiency in one cannot be redeemed by strength in the other. Limiting compensability between dimensions is therefore a conceptual requirement and the aggregation of sustainable competitiveness must penalise imbalance and preclude complete substitution, so that a system is judged competitive only when it performs adequately across all dimensions simultaneously. This

is why the two sub-indices are combined geometrically rather than arithmetically. In this sample the safeguard is a property of the measure rather than a driver of the result, because sub-index values are concentrated around the middle of the scale, so no holding is unbalanced enough for geometric and arithmetic aggregation to diverge materially, and the two produce near-identical rankings. The requirement matters for how the index would treat a genuinely unbalanced farm, and for what a score means, rather than for the comparison reported here.

Two groups that are indistinguishable on the aggregate index can still differ in the composition of their change, and a measure permitting full compensation between dimensions would have reported parity while concealing that difference. The finding therefore refines the organic–conventional debate rather than settling it: the two groups reach a similar standing while allocating effort differently across the two dimensions. This pattern is consistent with farm-level evidence that holdings within the same system separate into distinct performance profiles marked by their own economic–environmental synergies and trade-offs (Gómez-Limón et al., 2024); frontier-based evidence of lower technical efficiency among environmentally sustainable farms (Sidhoum et al., 2022) and trade-off analyses in which economic and environmental gains rarely coincide (Grzelak et al., 2022; Sau et al., 2023) point in the same direction. For policy, the same logic applies to instruments as to indices: if strength in one dimension cannot redeem a deficiency in the other, support that rewards a single dimension in isolation should not be expected to raise sustainable competitiveness as a whole. So instruments rewarding certification alone are unlikely to raise overall sustainable competitiveness whereas instruments that relieve the economic constraint on environmentally oriented farms or that reward economic and agri-environmental progress jointly, address the pattern that the trajectories describe. Farm-level evaluations of agri-environmental schemes point the same way. On average, participation in them has not significantly improved economic or environmental efficiency level at farm level, since many measures target objectives other than input reduction and can be met without substantially changing practices (Ait

Sidhoum, Canessa, et al., 2023; Ait Sidhoum, Mennig, et al., 2023).

Conclusions

1. This study moves beyond the traditional assessment of farm competitiveness based predominantly on economic outcomes by conceptualising sustainable competitiveness as the joint performance of its economic and agri-environmental dimensions. The study focuses on their coupling, thereby examining whether stronger economic performance is achieved together with, or at the expense of, agri-environmental performance. The comparison of organic and conventional farms provides an empirical setting in which this relationship can be examined across two farming systems characterised by different production constraints, environmental requirements and incentive structures.

2. It has been found that overall sustainable competitiveness of farms in Baltic states does not depend on the production system. In the integrated index built for a balanced panel of 1,014 family farms, the 161 fully organic and 801 fully conventional holdings did not differ significantly, so the expectation that organic farms attain a higher level was not supported. Support-targeting and benchmarking should therefore not treat organic certification as a proxy for higher sustainable competitiveness, and a system-neutral, accounts-based index is the more defensible instrument.

3. Organic and conventional farms reach comparable sustainable competitiveness while differing in the dimensional composition of their change, a pattern interpreted here as a dimensional trade-off. Their two-period change trajectories differed significantly: economic growth with a stable agri-environmental dimension was about twice as frequent among conventional farms, whereas agri-environmental improvement at the cost of economic decline was about three times as frequent among organic farms. Organic farming should thus be framed as an alternative, agri-environmentally oriented route to sustainable competitiveness rather than a universally superior one, and policy aiming at both viability and environmental gain should target the two dimensions jointly.

4. An important limitation of this study is that the pooled sample is unevenly distributed across countries and farming types, particularly among organic farms, which may partly influence the observed differences between organic and conventional farms. Therefore, the results should be interpreted at the pooled Baltic States level rather than as country-specific effects. Despite this limitation, this study is expected to make a significant contribution to the further development of the concept of

sustainable competitiveness and the methodology for its assessment at the farm level. Based on the results of the empirical analysis, decision-makers, including policymakers and farmers, will be able to identify areas for improvement and develop appropriate measures to strengthen the coupling between the economic and agri-environmental performance of sustainable farm competitiveness.

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Appendix

Table A1. Component matrix for the economic indicators, 2020–2022 (n = 1,014). Five components were extracted, together explaining 71% of the variance; the first component explains 20%. Loadings below 0.35 in absolute value are suppressed. Only the indicators loading on Component 1 enter the economic sub-index.

Indicator	1	2	3	4	5
Intermediate consumption intensity (EUR/EUR)	0.807				
Cost profitability (excluding subsidies) (EUR/EUR)	0.782				
Labour productivity(EUR/AWU)	0.643				
Return on capital (EUR/EUR)	0.597				0.547
Wheat yield (kg/ha)	0.548	0.387			–0.368
Equity ratio (EUR/EUR)	–0.489				
Land productivity (EUR/ha)		–0.875			
Resource-use intensity (per ha UAA) (EUR/ha)		0.857			
Labour-use intensity (per ha UAA) (AWU/ha)		0.755			
Labour-use intensity (per livestock unit) (AWU/LU)			0.932		
Investment per livestock unit (EUR/LU)			0.919		
Productivity of other gainful activities (EUR/EUR)			–0.816		
Milk yield per cow (kg/cow)				0.830	
Market participation (EUR/EUR)				0.781	
Net profit margin (EUR/EUR)					0.489

Table A2. Component matrix for the agri-environmental indicators, 2020–2022 (n = 1,014). Four components were extracted, together explaining 59.6% of the variance; the first two explain approximately 29% and 12%. Loadings below 0.35 in absolute value are suppressed. Component 1 forms the pollution subgroup and Component 2 the conservation-practices subgroup; Components 3 and 4 were not used, as explained in Section 2.

Indicator	1	2	3	4
Nitrogen fertiliser per ha UAA (kg/ha)	0.871			
Potassium fertiliser per ha UAA (kg/ha)	0.853			
Share of arable land in UAA (ha/ha)	0.755			
Plant protection product costs per ha UAA (EUR/ha)	0.710			
GHG emissions intensity (t CO ₂ eq./EUR)	–0.670			
Energy use intensity (EUR/EUR)	–0.480	–0.417		
Share of catch crops in UAA (ha/ha)	–0.387			
Livestock density (LU/ha)	–0.368	0.531	–0.563	
Share of forest (ha/ha)	0.348			0.360
Share of nature-conservation subsidies in direct payments (EUR/EUR)		0.683		
Shannon evenness index		0.412	0.653	
Share of protein crops in arable land (ha/ha)		0.368	0.371	–0.480
Water use intensity (EUR/EUR)				0.738

Note: Adverse-direction indicators were multiplied by –1 before the analysis, so a higher value of every indicator points towards higher sustainable competitiveness; loadings should be read with that transformation in mind.