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ECONOMIC, SOCIAL AND ENVIRONMENTAL SUSTAINABILITY OF FARMS IN POLAND. DOES A SHORT FOOD SUPPLY CHAIN MATTER?

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ABSTRACT: The aim of the article is to indicate how sustainable farms participating in short food supply chains are compared to farms not participating. A database of 199 farms from Poland was collected in 2023, of which 94 participated in 'short' selling, and the remaining 105 did not. The study was conducted in three steps. Firstly, synthetic measures of economic, social and environmental sustainability were constructed using the CRITIC-TOPSIS method. Secondly, the significance of differences between the mean values of the sustainability components for SFSC farms and non-SFSC farms was assessed. Thirdly, on the basis of logistic regression, the influence of selected variables on the probability of farms participating in short supply chains was determined. The study shows that farms participating in SFCS are clearly more sustainable in the social dimension compared to non-SFCS farms. In the case of the economic dimension, the differences were less marked but statistically significant, while no clear differences were noted for environmental sustainability.

KEYWORDS: short food supply chain, sustainability, farms, Poland

Introduction

Various forms of sales are being developed within short food supply chains (SFSCs) in Poland, including (Michniewicz, 2021): direct sales – sales of unprocessed agricultural products directly to consumers; marginal, local and limited activity – sales of processed animal, egg or dairy products in a specific region; agricultural retail trade – sale of unprocessed products and processed food (meat products, dairy products, composite products, fruit and vegetable preserves, and bread) intended for the final consumer or units conducting retail trade intended for the final consumer (e.g. shops, restaurants, canteens, etc.). Sales channels are also different, involving sales on farm, at markets and bazaars, during events, via social media and the internet, by cooperatives and producer-consumer communities. Unfortunately, detailed data on SFSCs are not formally included in Polish official statistics, we must be careful and rely only on selective information or estimates. The Ministry of Agriculture and Rural Development (2023) indicates that in 2023, over 36 thousand producers participated in short selling and were subject to the supervision of the sanitary and/or veterinary inspection. This number constituted 3% of all holdings, so it was relatively low. On the other hand, it can be assumed that a large group of farms carry out this activity informally or sporadically, mainly as part of inter-neighbour sales. For example, according to Gołębiewski and Bareja-Wawryszuk (2016), in 2010, there were more than 200,000 individual agricultural holdings, which sold their production through direct sales. They represented approximately 13.8% of all individual farms in Poland. Direct sales were the most popular form of SFSCs, used generally by small farms (1-5 ha), which accounted for 68% of all farms engaged in this type of activity. On the other hand, farms with 5 to 25 ha of UAA had the largest share (60.4%) of total direct sales. In turn, Green Seed Group's report (2024) estimated short food supply chains as 30-38% of the food market value, mainly consisting of local shops, direct sales, and some e-commerce models. But including all local stores in these estimates seems inappropriate, so the actual share of SFSCs in total food sales is certainly lower. In addition to traditional forms of short sales, community-based and business-led initiatives are starting to take off. According to official information, in 2025 there were more than 30 farms involved in community supported agriculture (Rolnictwo Wspierane Przez Społeczność, 2025). In every big city, farmers' markets have appeared with farmers (as opposed to intermediaries) selling to consumers. One thing is certain: SFSCs are gaining popularity. The question arises whether the development of this form of food sales will contribute to improving the sustainability of agriculture and rural areas.

The potential of short food supply chains (SFSCs) to contribute to the transition towards more sustainable food production both in urban and rural environments has been broadly acknowledged by policymakers and scientists (Filippini et al., 2023; Koncz et al., 2021; Körmendiová et al., 2023). The results by Chi Ffoleau & Dourian (2020) generally agree on the social benefits of SFSCs, but their economic and environmental impacts typically elicit more heterogeneous outcomes, while their health/nutrition and governance dimensions remain under-explored. In turn, a study of 486 chains across seven countries: France, Hungary, Italy, Norway, Poland, the United Kingdom, and Vietnam proved that participation in SFSCs is beneficial from an economic perspective, while ambiguous results are found regarding the social dimension, with significant differences across types of chains (Malak-Rawlikowska et al., 2019). These conclusions are in line with the results of Enthoven and Van der Broeck (2021), who claim that the impact of local food systems on different social, economic and environmental factors highly depends on the type of supply chain under assessment, with important differences across product types and countries. Another literature source highlights that the positive perception of SFSC sustainability is not rooted in scientific evidence, and the results are quite mixed (Evola et al., 2022).

While the social dimension is highly important in the case of farmers' markets and multi-chain farms, the environmental dimension is more significant for solidarity purchasing groups and farms selling directly. The economic dimension has a key role in each of the different types (Mastronardi et al., 2015). This conclusion is also present in the results of Menéndez i Molist et al. (2024), who showed that economic factors, particularly profitability and affordability, were the key driving factors in the decisions of stakeholders. The study of Helgheim et al. (2024) on local food producers' economic sustainability indicates that the lack of balance within the supply chain exerts a substantial influence on the economic sustainability of local food producers (Helgheim et al., 2024). However, the consid-

erable importance placed on strategic attributes, including local production, environmental sustainability, and product quality, particularly among consumers, seemed to present a chance to advocate for sustainable alternatives, such as short food supply chains (Menéndez i Molist et al., 2024; Muñoz Torres et al., 2022). Medici et al. (2021) highlighted that, in general, SFSCs, via the Community Supported Agriculture, meet sustainability goals, even with different levels of members' involvement, working conditions, economic viability, and environmental impact from one community to another, with desirable further improvements along all dimensions for most of them. Social transformations in which consumers take the role of producers and consumers at the same time, with increased responsibility, have been observed.

Many studies on SFSCs focus on the environmental impact of short selling. They refer, *inter alia*, to the cost of transportation and the greenhouse gas (GHG) emissions in SFSCs where consumers are directly connected to local farmers. One of the analyses shows that the number of food hubs, their location, and their design may considerably impact the total GHG emissions, depending on the input parameters and data (Cui et al., 2024). In the research on direct purchasing network, such environmental aspects as the circularity of resources, biodiversity, chemicals in the environment, seasonality and locality of diets, and the distance (food miles) were admitted as crucial ones by the specific short food supply chain actors. But the differences in results occur (Ušča & Aļeksējeva, 2023; Malak-Rawlikowska et al., 2019). To conclude, short food supply chains may have advantages over long ones; however, they are not sustainable *per se* (Lehtinen, 2012).

The ambiguity of opinions and analyses regarding the sustainability of short supply chains indicates a research gap in this area. The authors of this study decided to contribute to the considerations by presenting the example of Poland. Therefore, the aim of the article is to indicate how sustainable farms participating in short food supply chains (called SFSC farms) are compared to farms that do not belong to this sales system (non-SFSC farms). Hence, two independent groups are subjected to the study, which allows for a comparative analysis. Three sustainability components were taken into account: economic, social and environmental, while simultaneously defining the significance of the individual variables differentiating farms of both types. The added value of the article is the author's approach to the construction of sustainability indicators in three dimensions – economic, social and environmental, which takes into account a wide set of variables for each of the components. The measures are based on primary data of a quantitative and qualitative nature, originating from in-depth interviews. The study goes beyond constructing sustainability indicators across economic, social and environmental dimensions by combining primary survey data, an expert-based indicator selection process and the CRITIC-TOPSIS method, as well as applying logistic regression to small and medium-sized farms. Together, these elements may constitute a significant methodological contribution to the ongoing debate in the existing literature on the sustainability of short supply chains and their impact on small and medium-sized farms. The remainder of the article is organised as follows: the next subsection presents the data set and research methodology, then the results are presented and discussed, and the paper ends with a summary and conclusions.

Research methods

To collect data, we used the PAPI (Paper and Pencil Interview) method with an original survey questionnaire. Interviews were conducted in person by the collaborators of the study (50 interviews for each) between July and November 2023 in Poland. The PAPI method was chosen due to the complexity of the topic and the specific nature of the farm survey. The personal presence of research project members (authors of the publication) during interviews allowed, firstly, greater control over the research process, clarifying questions or helping respondents understand their content (which was sometimes the case), and also providing in-depth information when necessary. Secondly, the study covered a topic that was well-known to the interviewers; therefore, it was possible to structure the interview in such a way as to obtain not only quantitative but also qualitative information regarding opinions, attitudes, behaviours, etc. Thirdly, this type of interview builds a better relationship and trust between the respondent and the interviewer, which facilitates honest conversations. Literature on the topic indicates that farmers are generally distrustful of people they do not know (c.f. James, 2021 or Matthews et al., 2024), hence the information obtained by the authors is more reliable, as

members of the project team visited farms on recommendations from, for example, agricultural advisors. Last but not least, this approach enabled us to achieve a 100% questionnaire return rate.

Farms for the study were selected in a random-purpose manner. First, we randomly selected 8 of the 16 voivodeships in Poland to ensure representativeness for the country. We then contacted advisors from regional agricultural support centres to select a group of about a dozen farms, both participating and not participating in short supply chains. The remaining farms were selected using snowball sampling based on respondents' recommendations. Using agricultural advisors' contacts and the snowball sampling method allowed us to get to the difficult-to-reach SFSC farm population, for which there is no common public list. The goal was also to recruit credible interviewees willing to participate in the study. We recognise that this method is not fully representative of the farming population, but we attempted to mitigate this disadvantage by selecting units diverse in terms of physical and economic size, production type, and demographic characteristics. We also tried to maintain the proportion between farms participating and not participating in short supply chains. We applied the following formula to establish the minimum sample size:

$$n = \frac{Z^2 p (1-p)}{e^2},$$

where Z represents the value of the normal variable for the selected confidence level (1.96 for a 95% confidence level), p – estimated percentage of the trait in the population (0.15 in the case of the share of farms participating in SFSCs, Gołębiewski and Bareja-Wawryszuk, 2016), and e – acceptable margin of error of 0.05. After rounding, we got the result of 200.

Ultimately, a database of 199 farms (one farmer dropped out at the last minute) was collected, of which 94 farms participated in the SFSCs and the remaining 105 did not (data available at <https://doi.org/10.18150/UAATM3>). Due to the aim of the project realised by the authors, the surveys were to be addressed to small or medium farms, hence the following criteria were defined: agricultural area up to 30 ha UAA and Standard Output SO up to EUR 50,000. The area criterion was established as a result of a brainstorming session among experts (by the same people who took part in the subsequent selection of indicators, compare the information further in the article), while the economic size of SO results from the classification of farms used by the farm accountancy data network (FADN). The decision was made to include small and medium-sized farms in the study, as these are the types of farms that mostly participate in short food supply chains. This is confirmed by both Polish and international studies (e.g., Vitterso et al., 2019; Stępień et al., 2020; Sałata and Żakowska-Biemans, 2024; Chiaverina et al., 2024; Yuna et al., 2025; Mengoni et al., 2025). Small and medium-sized farms are characterised by greater operational flexibility and higher production diversification, which favours the development of short selling. The threshold of 30 ha of agricultural land was set at three times the average agricultural land area of a farm in Poland. Gołębiewski and Bareja-Wawryszuk (2016) indicated that farms up to 25 ha of UAA constitute approximately 80% of all farms involved in SFSCs. The 30-hectare threshold further increases this share, encompassing the vast majority of entities involved in short supply chains and, at the same time, over 90% of all farms in Poland (Statistics Poland, 2025). In turn, the €50,000 SO frontier, according to the EU FADN system, covers very small, small, and medium-small farms. As indicated by data from the European Parliament (Augère-Granier, 2016), the share of large and very large farms selling more than half of their production directly to consumers is less ca. 3%, so their omission from the analysis should not distort the results.

The study was conducted in three steps. In the first, synthetic measures of economic, social and environmental sustainability were constructed. The selection of a set of variables for each group was based on substantive premises, a discussion among experts, taking into account the literature on the subject and the availability of data collected in the surveys. Table 3 presents a list of variables. We employed the following procedure to establish the list of factors. First, an extensive review of the relevant literature was done, which allowed us to identify a set of numerous variables defining the three sustainability dimensions. We also relied on the recommendations of the Polish public statistics. In 2011, the Central Statistical Office (Statistics Poland, 2011) developed a list of variables to define social, economic, environmental, and political-institutional governance. From among the many indicators, we selected those that are microeconomic in nature and applicable to farm research. The

second stage included an expert opinion, which was the basis for selecting the final list of indicators. The group of experts comprised 16 scientists – agricultural economists – from five research centres in Poland and one each in Romania and Serbia. All individuals had expertise in research on the sustainability of agriculture and small farms, documented by a minimum of a PhD in economics, a list of scientific publications, and participation in research projects. Information about the experts is summarised in Table 1.

Table 1. Experts participating in the selection of variables for sustainability measures – basic information

Specification	Country		
	Poland	Romania	Serbia
Number of experts	11	3	2
Number of scientific centres	5	1	1
Scientific specialization	Agricultural economics, Macroeconomics, Agricultural policy	Agricultural economics, Marketing	Agricultural economics, Rural entrepreneurship
Academic title/degree	7 professors, 4 doctors of science	2 professors, 1 doctor of science	1 professor, 1 doctor of science

Expert opinions were collected in two phases. In the first phase, a Delphi method was used, sending questionnaires to experts to avoid the influence of dominant individuals within the group, and to make the opinions independent and anonymous. In the second phase, an online brainstorming session was held, which resulted in the final set of variables. Both the substantive reasons for selecting variables – adapting them to the conditions of agricultural operation in Poland, and practical guidelines for constructing the interview questionnaire – the need to limit the number of questions, were taken into account.

As a result, the economic component includes three classic variables describing productivity, i.e. production per ha of agricultural land, production per unit of family work (i.e. Family Work Unit), as all the labour input was provided by the members of the family farm, production per unit of productive assets, and also a subjective assessment of the financial situation, level of savings and debt. We thus utilised three classic variables for measuring economic performance, but supplemented them with variables related to subjective assessment, as factual data do not always align with the respondent's perception of the situation. This bilateral approach provides a better picture of reality. A similar approach was used by, among others, Noga (1996), Latruffe (2010), Bossel (1999), and FAO (2017). To determine the social component, housing conditions, health and physical condition, and the level of socialisation of the farm (the so-called socialisation index) were used, the latter measured by: 1) participation of the producer and/or another person working on the farm in continuing education (training, courses, workshops, postgraduate schools, etc.); 2) participation of the producer and/or another person working on the farm in cultural and social events (cinema, theatre, concerts, fairs, etc.); 3) membership of the producer and/or another person working in an organisation, association, producer group, cooperative, etc. The above-mentioned elements determine the quality of life of farm members. For example, housing conditions and educational needs are identified as some of the key human needs by authors such as Beckerman and Bacon (1966), Stępień et al. (2017) and Lebacqz et al. (2013). Last mentioned, as well as van Cauwenbergh et al. (2007), draw attention to cultural elements, traditions and ethical values as significant for this assessment. Moreover, the farmer's involvement in the functioning of the local community, the so-called socialisation, is considered an important factor of social order in rural areas. Data on this subject are not common, which increases the value of this factor in determining social sustainability (Vrolijk et al. 2016). The environmental component, in turn, consists of the following elements: monoculture index, degree of arable land coverage outside the season, share of permanent grasslands in the total area, share of forested land in total area, livestock Units index, expenditure on energy, fertilisers and pesticides. The justification for the selection of these variables can be found in the works of Baum (2011), Jaskulski et al. (2006), Duer et al. (2002), Harasim (2012), Kurowska and Kryszk (2017), Dębicki (2000), Fotyma and Kuś (2000), and Vereijken (1997).

Based on the selected variables, systematic measures of sustainability were determined in three domains: economic, social and environmental. The CRITIC-TOPSIS method was used for this purpose, determining the weight for those variables. In the CRITIC-TOPSIS, weights are determined based on standard deviations and correlations between variables (Madic and Radovanovic, 2015; Mitra and Kundu, 2018). In the second step of the analysis, the significance of differences between the mean values of the three sustainability components for SFSC-farms and non-SFSC farms was assessed. For this purpose, the nonparametric Mann-Whitney U test was used. Hypothesis H0 stated that there were no significant differences between the mean values of sustainability; the alternative hypothesis H1 assumed that such differences occurred. The choice of the nonparametric M-W test resulted from the fact that the values of the indicators did not have a normal distribution, which was checked by the Shapiro-Wilk test ($p < 0.05$). Additionally, the Leven test showed differences in variance between groups in some cases, which confirmed the need to use a test resistant to this variability.

In the third stage, the influence of selected variables shaping the components of sustainability on the probability of farms participating in short supply chains was determined. For this purpose, logistic regression was chosen, which is widely applied for modelling binary outcomes. The flexibility of logistic regression allows for the inclusion of predictor variables that are continuous, discrete or categorical, thus making it possible to incorporate a range of data from survey interviews. Moreover, it does not require normally distributed independent variables, linearity and homogeneity of variances for the predictors. The logistic regression model estimates the probability of an outcome using a nonlinear transformation of a linear equation. The predicted probability of belonging to a given category follows the sigmoid function:

$$\hat{Y}_i = \frac{e^u}{1+e^u} \quad (1)$$

where u represents the linear combination of predictors:

$$u = A + B_1X_1 + B_2X_2 + \dots + B_kX_k. \quad (2)$$

In this equation, A is the intercept, representing the baseline log-odds of the outcome occurring when all independent variables are equal to zero. The coefficients B_j (for $j=1, \dots, k$) measure the strength and direction of the relationship between each independent variable X_j and the dependent variable. This transformation ensures that probabilities remain within the (0,1) range. The model further expresses the relationship between predictors and the dependent variable using the logit function:

$$\ln\left(\frac{\hat{Y}}{1-\hat{Y}}\right) = A + \sum B_jX_{ij}, \quad (3)$$

where the log-odds of the event occurring are modelled as a function of the independent variables.

Parameter estimation in logistic regression is achieved through the maximum likelihood estimation (MLE) method. This iterative process starts with initial estimates of the coefficients and adjusts them in successive steps to maximise the likelihood of obtaining the observed data. The procedure continues until convergence is reached, meaning that further adjustments lead to minimal changes in the estimated coefficients. In the present study, logistic regression was applied to examine the probability of participation in short food supply chains, a binary dependent variable, which takes the value of 1 if a farm participates in SFSC or 0, otherwise. The independent variables included in the model represent key economic, social, and environmental factors that may influence SFSC participation. Table 3 presents the codes of variables adopted for function estimation (in brackets). Before beginning the logit regression analysis, the mentioned assumptions were tested: absence of multicollinearity, linearity, predictive variables standard errors, VIF values. Statistical analyses were performed using R (v. 4.4.2), Stata (v. 16.1/IC), and Excel (v. 2016). The research concept is presented in Figure 1.

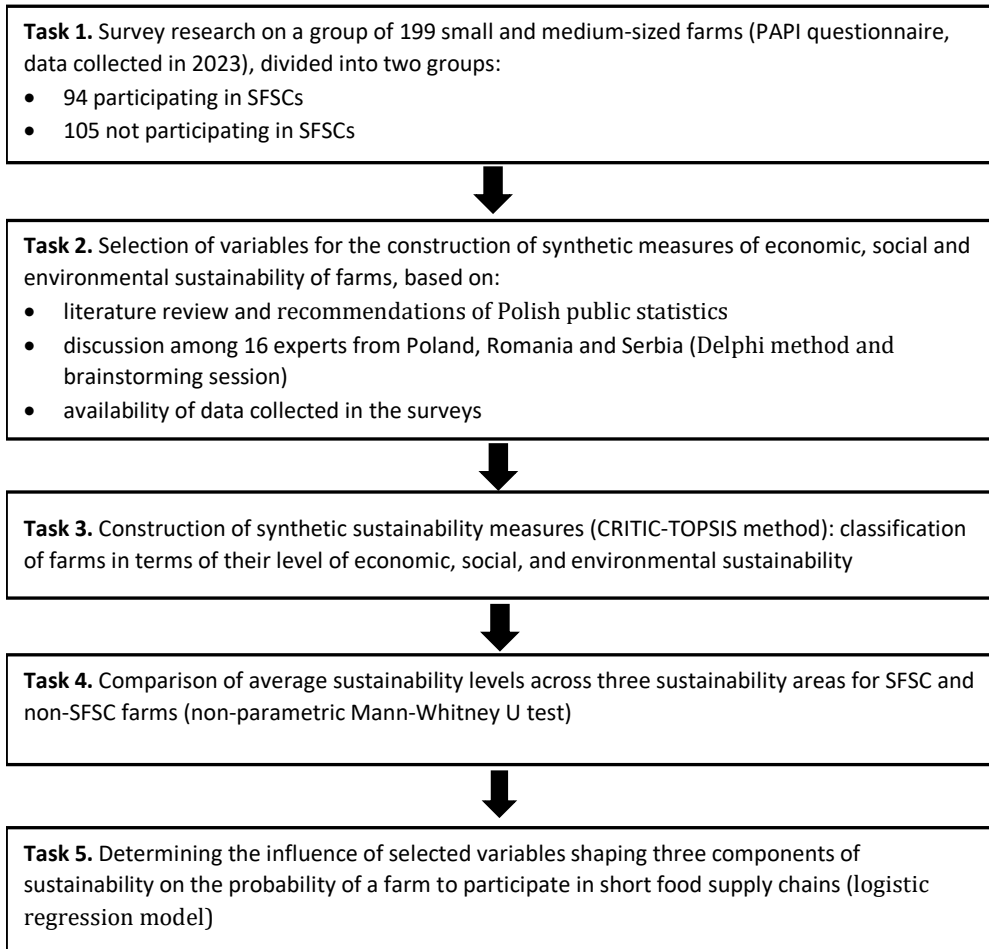


Figure 1. The concept of research methodology

Results

Before presenting the results of the analysis of sustainability, we would like to introduce basic information about the farms studied (see Table 2). The average area was 17 ha of agricultural land, and the average annual production was €39,500, with farms participating in SFSCs characterised by a smaller area and lower production. Both SFSCs and non-SFSCs farms were managed by individuals aged 47, and the number of family members in both cases was just under four. In terms of education and gender, farms participating in short supply chains were, on average, better educated and had a higher proportion of female managers. Among farms participating in short supply chains, direct sales from the farm predominated, with 85% of respondents indicating this method. Farms in this group sold an average of two-thirds of their products through this channel. The second most common method was delivery to customers (41% of respondents), followed by bazaars and markets (31%), and fourth by events, fairs, festivals, etc. (24%). The Internet is becoming an increasingly popular food supply chain in Poland; in our case, this form was indicated by 17% of respondents. The most frequently sold products through short selling were fruit and processed products (28%), vegetables and processed products (21%), and milk and dairy products (14%).

Table 2. Basic characteristics of farms studied

Specification	All farms	SFSCs farms	Non-SFSCs farms
Average farm size (ha of UAA)	17.0	13.4	20.2
Annual production (thous. euro)	38.0	34.9	40.7
Farmer age	47.2	47.3	47.1
Average number of household members	3.9	3.8	3.9
Education structure (%)			
• primary and vocational	28	23	33
• secondary	41	39	42
• higher	31	38	25
Share of female managers (%)	24	38	11
SFSCs farms			
The most common short selling channel		The most frequently sold product	
<ul style="list-style-type: none"> • direct sale on farm 85% • delivery to customers 41% • bazaars, markets 31% • events, fairs, festivals 24% • online sale (Internet) 17% • delivery to external units 16% 		<ul style="list-style-type: none"> • fruits and processed 28% • vegetables and processed 21% • milk and dairy products 14% • honey 12% • meat and processed products 7% • eggs 5% 	

Table 3 shows the values of variables shaping three sustainability components of the farms studied. Those that are more favourable from the point of view of sustainability are marked in bold. Among the economic elements, farms belonging to short supply chains gain an advantage in land and fixed asset productivity, as well as a subjective assessment of the financial situation. Non-SFSC farms record higher values in labour productivity and subjective assessment of savings, as well as a lower level of debt. For the social component, all three variables are more favourable for SFSC farms. In the case of environmental balance, short-chain farms obtain better results for the monoculture index, the share of permanent grassland and forest land, animal density and expenditure on chemical fertilisers and pesticides. Non-SFSCs have a higher degree of arable land coverage outside the season, and they also record lower energy expenditure per unit area. The data indicate that it is actually only in the case of the social component that we can be sure of the higher sustainability of SFSC farms. In the other two cases, the answer is not so obvious. Therefore, in the next stage, synthetic sustainability measures were estimated, and it was examined whether there were statistically significant differences between the two groups of farms.

Table 3. Variables used to construct synthetic sustainability measures and their values (codes of variables in a logistic regression in brackets)

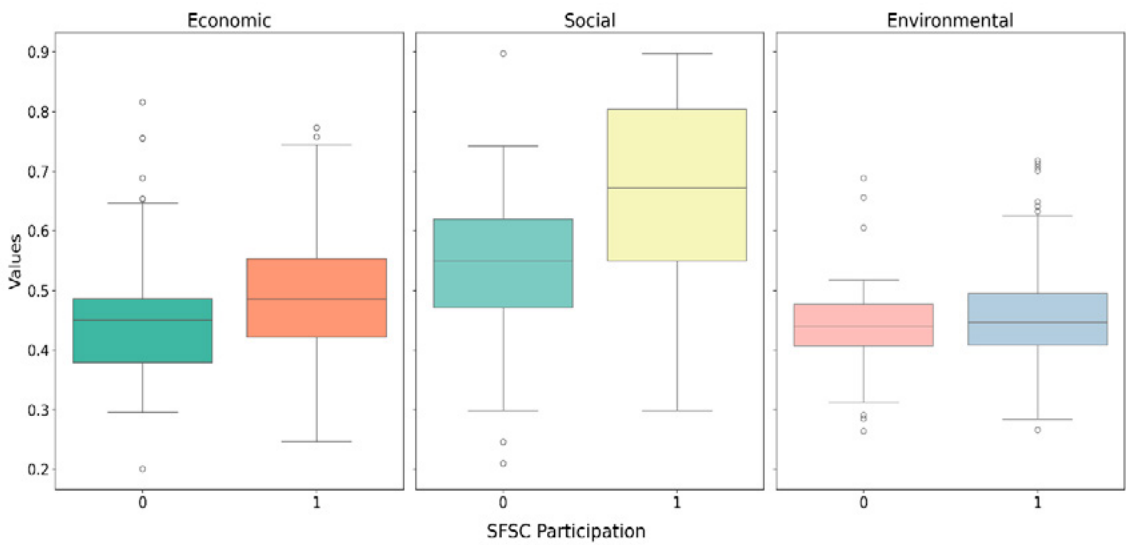
Variables	References to literature	SFSC farms	non-SFSC farms
Economic sustainability variables			
Land productivity: agricultural production/land area in; thous. EUR/ha $S(e1_prod_eurha)$	Chenavaz and Escobar (2012); Colwell & Munneke (2009); Huddleston (2017); Radeloff et al. (2000); Swader et al. (1970).	5,701	3,061
Labour productivity: agricultural production/FWU; thous. EUR/FWU $S(e2_prod_eurfwu)$	Baker and Mather (2025); Chen et al. (2022); Lass and Gempesaw (1992); Sabasi et al. (2019)	20,091	28,916
Fixed assets productivity: agricultural production/fixed assets value $S(e3_prod_eurasset)$	Onofri (2024); Pechrova and Simpach (2019); Pokharel and Featherstone (2019); Timková and Bobriková (2023).	0.08	0.07
Financial performance subjective assessment; Likert scale from 1 to 5, where 1 – very bad, 5 – very good $S(e4_finsit_househ)$	Beadle et al. (2024); Gaeta et al. (2011); Orbán et al. (2015); Tcaci (2021).	3.48	3.28

Variables	References to literature	SFSC farms	non-SFSC farms
Savings level subjective assessment (Likert scale from 1 to 5, where 1 – very low, 5 – very high) S (e5_savingshoush)	Bellemare and Manski (2011); Clark, et al. (2018); Matsunaga and Nakazawa (1998); Muckler and Seven (1992); Tang (2019).	2.56	2.70
Debt level subjective assessment (Likert scale from 1 to 5, where 1 – very high, 5 – very low) S (e6_debt_househ)	Brown et al. (2005); Gerald et al. (2025); Grable et al. (2013); Pearson et al. (2024).	4.24	4.49
Social sustainability variables			
Housing conditions (Likert scale from 1 to 5, where 1 – very bad, 5 – very good) S (s1_acc_condit)	Röös et al. (2019); Głowicka-Wołoszyn et al. (2022); Gražulevičiūtė-Vilenišké et al. (2013); Zahm et al. (2006); Caxaj et al. (2023); Sannou et al. (2023)	4.54	4.12
Health and physical condition (from 1 to 5, where 1 – very bad, 5 – very good) S (s2_healtcond)	Caxaj et al. (2023); Courmut and Balay (2021); Fraser (2005); Asai and Anton (2024); Sannou et al. (2023).	4.20	3.85
Socialisation Index (from 0 to 3, where 0 means very low level of socialisation, 3 – very high level) S (s3_socialis)	Chase et al. (2021); Njegić et al. (2025); Saleh and Ehlers(2025); Thiery et al. (2023); Gaviglio et al. (2016).	1.62	1.15
Environmental sustainability variables			
Monoculture index (from 0 to 1, the higher, the higher monoculture) D (v1_monoind)	Franco et al. (2023); Widjaja et al. (2024); Kaur et al. (2024); FAO (2018); Häni et al. (2006); Bojarszczuk (2008).	0.481	0.665
Degree of arable land coverage outside the season (from 0% to 100%) S (v2_arable_land)	Niewęglowski et al. (2020); Janowska-Biernat (2007); Harasim (2013); Wrzaszcz (2012).	59.8	68.1
Share of permanent grasslands in the total area (from 0% to 100%) S (v3_perm_grass)	European Environment Agency (2020); Reed et al. (2014); Stoate et al. (2009)	23.0	22.0
Share of forested land in total area (from 0% to 100%) S (v4_forest)	FAO (2016); Nair (2012); Turner et al. (2007)	4.45	2.03
Livestock Units index (from 0 to 1, the higher, the higher the animal density per unit area) D (v5_LU)	Leip et al. (2023); OECD (2021); Leip et al. (2014); Tilman et al. (2011)	0.09	0.14
Expenditure on energy (EUR/ha) D (v6_expen_energy)	European Commission, Directorate-General for Agriculture and Rural Development. (Annual); Tomaš Simin et al. (2025); van Passel et al. (2007); de Molina. (2017); Giampietro et al. (1992)	21.26	12.41
Expenditure on fertilisers (EUR/ha) D (v7_expen_fert)	Tomaš Simin et al. (2025); Szymańska et al. (2025); Walling (2022); OECD (2021)	209.24	230.73
Expenditure on pesticides (EUR/ha) D (v8_expen_pest)	Gensch et al. (2024); López-Ballesteros et al. (2022); Helepciuc & Todor (2021); Möhring et al. (2020); Kudsk et al. (2018).	98.64	110.17

*1 PLN = 0,22 EUR; **D/S – Stimulant/Destimulant

Figure 2 presents the distribution of synthetic measure results for the three sustainability components, divided into farms participating in short supply chains (1) and non-participating (0). For the social component, both the mean (0.665) and the entire area for SFSC farms results are clearly above the mean (0.542) and the area for non-SFSC farms. In the case of the economic component, the difference is also present, although it is not as visible (the mean values are 0.502 and 0.456, respectively). The areas for the environmental component are located at a similar height, with a slight upward deviation for SFSC, and the mean values are 0.462 for SFSC and 0.437 for non-SFSC. The results of the Mann-Whitney U test confirm the conclusions from visual observations (Table 4). The values indicate that statistically significant differences between SFSC and non-SFSC farms occur in the case of the

economic and social component – farms participating in short supply chains are more sustainable in economic and social terms. Such a relationship does not occur in the case of environmental sustainability (no statistically significant difference).



*0 – non-SFSC farms, 1 – SFSC farms.

Figure 2. Boxplots of economic, social and environmental components of sustainability for SFSC farms (1) and non-SFSC farms (0)

Table 4. Comparison between the groups (SFSC=1,nonSFSC=0) univariate analysis

Synthetic Variable	U Mann-Whitney	p-Value
Economic	-2,897	0.0038**
Social	-5.572	0.0000***
Environmental	-1.45	0.147

Statistical significance levels are indicated as follows: *** p < 0.001, ** p < 0.01, * p < 0.05, . p<0.1

In the next step, the impact of individual variables on the likelihood of participating in short supply chains was determined. Table 5 presents the results of logistic regression. The variables that were statistically significant were retained. The analysis demonstrates that five out of six economic and financial variables significantly influence participation in short food supply chains factors (fixed assets productivity turned out to be statistically insignificant). The model for economic variables is statistically significant (LR $\chi^2 = 34.72$, $p < 0.001$). The log-likelihood value of -120.27 suggests a moderate fit, while the pseudo R^2 of 0.1261 indicates that the model explains approximately 12.61% of the variance in the dependent variable. Among the independent variables, output per hectare (e1_prod_eurha) has the strongest positive effect (the highest Odds Ratio value, the lowest p-value), increasing the likelihood of participation farm in SFSC. A similar impact was observed in the case of subjective assessment of the financial situation (e4_finsit_househ). It can be said that the higher the land productivity and the better the assessment of the material situation, the greater the probability that the farm participates in short supply chains. Conversely, labour productivity (e2_prod_eurfwu) and debt level (e6_debt_househ) reduce the probability of getting involved in SFSC. In terms of labour productivity, the negative relationship may be due to the fact that farms involved in short supply chains require more working hours to prepare for short sales. As a result, they have a lower value of

production per unit of labour. The level of household savings (e5_savingshoush) appears to have a slight negative effect, but its significance is marginal ($p = 0.067$).

Table 5. Results of logistic regression analysis for SFSC participation (1 = Yes, 0 = No) and economic, social and environmental variables

Predictor	Odds Ratio	Lower 95% CI	Upper 95% CI	p-Value
Regression for economic variables				
e1_prod_eurha	2.7281	1.4235	5.2284	0.002**
e2_prod_eurfwu	0.4784	0.2919	0.7842	0.003**
e4_finsit_househ	1.7482	1.1910	2.5453	0.004**
e5_savingshoush	0.7078	0.4893	1.0239	0.067
e6_debt_househ	0.6762	0.4907	0.9320	0.017*
intercept	0.9310	0.6769	1.2770	0.653
Regression for social variables				
s1_acc_condit	1.7180	1.2189	2.4217	0.002**
s3_socialis	1.4918	1.0806	2.0596	0.015*
intercept	0.8689	0.6451	1.1703	0.355
Regression for environmental variables				
v1_monoinde	0.5588	0.4046	0.7717	0.000***
v5_LU	0.5794	0.3903	0.8601	0.007**
v6_expen_energy	1.9391	1.3028	2.8863	0.001***
intercept	0.8959	0.6608	1.2148	0.479

Statistical significance levels are indicated as follows: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, . $p < 0.1$

The logistic regression model for social factors is statistically significant ($p < 0.001$). With a classification accuracy of 61.31%, the model demonstrates moderate predictive power. The analysis reveals that better housing conditions (s1_acc_condit) and higher socialisation (s3_socialis) significantly increase the likelihood of participation in SFSC, which is consistent with the authors' previous expectations. The quality of health and physical condition had no significant impact. Finally, the model for the environmental part is statistically significant ($p < 0.001$) and explains 11.56% of the variability in SFSC participation (pseudo $R^2 = 0.1156$). The results indicate that the monoculture index (v1_monoinde) and livestock density (v5_LU) decrease the probability of participation in SFSC. It can be assumed that too narrow a specialisation of production and too high animal density make it difficult for farms to enter short supply chains. In contrast, expenditures on energy (v6_expen_energy) significantly increase the likelihood of participation in SFSC. This may be due to the fact that SFSC farms may use the energy for activities related to short selling, e.g. storage, processing of agricultural commodities, etc. At the end, it is worth adding that for all regression models, no multicollinearity issues were detected (checked by the Variance Inflation Factor VIF). The absence of strong multicollinearity ensures the model's robustness and reliability.

Discussion

Within agri-food supply chains, Galli and Brunori (2013) identified SFSC as a 'driver of change' acting simultaneously across all pillars of sustainability. In the case of our study, this can be confirmed with regard to the economic and social dimensions of sustainability. The results presented in the article are also confirmed by the findings of other studies. Menéndez i Molist et al. (2021), examining a tomato supply chain in Catalonia, showed that economic factors such as profitability and

affordability were key drivers of stakeholders' decisions within the supply chain. In turn, Hoang (2022), based on a farm survey in Vietnam, indicates that SFSCs can increase farmers' incomes. This, therefore, implies that short supply chains promote economic sustainability. Our research shows that the economic elements of sustainability for SFSC farms reach a higher level than for the non-SFSC group. However, some sub-measures in the group surveyed farms belonging to SFSC were found to be lower compared to non-SFSC farms – for example, labour productivity. This factor reduces the likelihood of engaging in SFSCs (Table 5). This is also confirmed by another study conducted among Canadian farms (Mundler and Jean-Gagnon, 2020). Their research highlights that farmers involved in SFSCs reported lower labour productivity, although this was often offset by higher productivity levels in other segments of the business.

For the social component of sustainability, there was a clear difference between SFSC and non-SFSC units. This finding is also supported by the research of Geoffroy and Magali (2018). They showed that SFSCs in France contribute to increased social sustainability. As Todorova (2020) points out, short food supply chains can create conditions that foster a sense of community and 'living together' and affect the quality of life in rural areas. An interesting conclusion was also presented by Mastronardi et al. (2015). They found that short chains in Italy provide good opportunities for young entrepreneurs to develop their business and to create additional employment for rural residents. Similar conclusions were also reached by Barry (2012). In turn, Malak-Rawlikowska et al. (2019) highlighted differences in the social sustainability of SFSCs across various types of networks.

As signalled earlier, there were no statistically significant differences between the studied farm groups in Poland in terms of environmental sustainability. It is worth noting here that of the eight environmental measures analysed in our study, as many as six showed more favourable values for farms belonging to SFCS. How can this be explained? Perhaps it is only when the specific threshold of production scale is exceeded that the difference in environmental sustainability between the study groups can be increased. This is all the more justifiable as our analyses involved farms with Standard Output up to EUR 50,000.

Meanwhile, the dominant approach in the literature on the topic suggests that short chains promote environmental sustainability (Jarzębowski et al., 2020; Malak-Rawlikowska et al., 2019). This is most often reflected in the promotion of less polluting production methods (e.g. organic farming), the reduction of GHG emissions and carbon footprint, and lower energy consumption. Also, in the case of Mastronardi et al. (2015) study, it has been confirmed that farms that operate within the SFSC are more environmentally sustainable and develop more environmental practices impacting on biodiversity, landscape and the natural resources of the land. In contrast, a study by Loiseau et al. (2020) on apple supply chains in France highlighted the relatively strong environmental performance of the national long food supply chain. It is possible that the lack of clear correlations regarding the impact of SFSC on environmental sustainability, which also appeared in our study, was due both to the stage of development of the farms operating within these systems and to the selection of environmental variables used in the study. Reducing a farm's environmental pressure requires time, awareness, and economic improvement. On the other hand, from the perspective of the logistic regression analysis we conducted, it was evident that among the environmental variables, both the monoculture index and livestock density decrease the probability of participation in SFSC (Table 5). This conclusion would have been stronger if the model had shown a better fit (pseudo $R^2=0.1156$), although it is consistent with the studies we have already cited (Mastronardi et al., 2015).

Conclusions

This study examined the economic, social and environmental sustainability of small and medium-sized farms in Poland, paying particular attention to the role of participation in short food supply chains (SFSCs). The results suggest that farms involved in SFSCs demonstrate a notably higher level of social sustainability than those not involved in SFSCs. Differences in economic sustainability were also statistically significant, albeit less pronounced, while no statistically significant differences were identified in the environmental dimension. These findings confirm that the effects of SFSC participation on sustainability are multidimensional and uneven across pillars, reflecting the complexity of farm-level sustainability processes.

A key strength of this study is its methodological approach, which combines synthetic sustainability measure construction using the CRITIC-TOPSIS method with nonparametric statistical testing and logistic regression analysis. This integrated framework enables not only the comparison of sustainability outcomes between SFSC and non-SFSC farms, but also the identification of the specific economic, social and environmental factors influencing the probability of SFSC participation. By jointly addressing outcome differentiation and participation drivers, the study provides a more comprehensive empirical assessment of SFSCs than analyses focused on single indicators or dimensions.

Logistic regression analysis shows that higher output per hectare, better housing conditions and greater energy expenditure significantly increase the likelihood of farms participating in short supply chains (SFSCs). Conversely, lower labour productivity, a higher monoculture index and greater livestock density reduce the probability of engagement in short supply chains. These relationships reflect the structural differences between SFSC and non-SFSC farms, suggesting that participation in SFSCs is associated with particular production, organisational and social characteristics, rather than overall environmental performance.

At the same time, the study has several important limitations that must be explicitly acknowledged. Firstly, some sustainability indicators – particularly those relating to financial situation, savings, debt, housing conditions and health – are based on subjective self-assessments. Although these were included intentionally to complement objective measures with farmers' perceptions, they may be influenced by individual biases and should therefore be interpreted with caution. Secondly, the results are sensitive to the selection of indicators and the weighting scheme applied when constructing the synthetic sustainability measures. Alternative indicator sets or methodological choices could lead to different sustainability rankings and regression outcomes, which is a broader challenge inherent in composite sustainability assessment. Thirdly, the relatively low pseudo R^2 values obtained in the logistic regression models suggest moderate explanatory power. While several statistically significant relationships were identified, this suggests that SFSC participation is influenced by additional factors not captured by the present models, such as institutional conditions, market access, local infrastructure, social networks and individual entrepreneurial motivations. Consequently, the regression results should be interpreted as identifying meaningful associations rather than providing a complete explanation of participation decisions. Thirdly, the relatively low pseudo R^2 values obtained in the logistic regression models suggest moderate explanatory power. While several statistically significant relationships were identified, this suggests that SFSC participation is influenced by additional factors not captured by the present models, such as institutional conditions, market access, local infrastructure, social networks and individual entrepreneurial motivations. Consequently, the regression results should be interpreted as identifying meaningful associations rather than providing a complete explanation of participation decisions.

Despite these limitations, the findings support the conclusion that SFSCs can play an important role in enhancing the social, and to a lesser extent economic, sustainability of farms. From a policy perspective, this justifies the further development of incentive systems that encourage SFSC participation, as well as targeted education and advisory services for farmers. Future research should incorporate long-term data, explore alternative indicator configurations and apply more advanced modelling approaches, such as structural equation modelling, to better capture the complex, dynamic relationships between SFSC participation and farm sustainability.

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The contribution of the authors

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GOSPODARCZA, SPOŁECZNA I ŚRODOWISKOWA ZRÓWNOWAŻONOŚĆ GOSPODARSTW ROLNYCH W POLSCE. CZY KRÓTKI ŁAŃCUCH DOSTAW ŻYWNOCÍ MA ZNACZENIE?

STRESZCZENIE: Celem artykułu jest wskazanie, jak zrównoważone są gospodarstwa uczestniczące w krótkich łańcuchach dostaw żywności w porównaniu do gospodarstw nieuczestniczących w nich. Zebrano bazę danych 199 gospodarstw z Polski, z których 94 uczestniczyło w „krótkiej” sprzedaży, a pozostałe 105 nie. Badanie przeprowadzono w trzech etapach. Po pierwsze, skonstruowano syntetyczne miary zrównoważenia ekonomicznego, społecznego i środowiskowego przy użyciu metody CRITIC-TOPSIS. Po drugie, oceniono istotność różnic między średnimi wartościami składników zrównoważenia dla gospodarstw SFCS i gospodarstw nie-SFCS. Po trzecie, na podstawie regresji logistycznej określono wpływ wybranych zmiennych na prawdopodobieństwo uczestnictwa gospodarstw w krótkich łańcuchach dostaw. Badanie pokazuje, że gospodarstwa uczestniczące w SFCS są wyraźnie bardziej zrównoważone w wymiarze społecznym w porównaniu do gospodarstw nie-SFCS. W przypadku wymiaru ekonomicznego różnice były mniej wyraźne, ale statystycznie istotne, podczas gdy nie odnotowano wyraźnych różnic w zakresie zrównoważenia środowiskowego.

SŁOWA KLUCZOWE: krótki łańcuch dostaw żywności, zrównoważony rozwój, gospodarstwa rolne, Polska