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Greening of Polish Agriculture and Public Expenditure – Empirical Research Results

Abstract. The aim of this article is to diagnose the factors determining the greening of agriculture in Poland and to assess the system of ecological payments for organic agriculture according to farmers' opinions and the degree to which current forms of financing for the greening of agriculture are utilised. The research method adopted in the article was a questionnaire survey conducted among organic farmers from all voivodeships in Poland. The research procedure involved comparing the survey results and performing a statistical analysis of the responses using the $\chi 2$ independence test. As a result of the analysis, it was possible to assess the degree of subsidy utilisation by Polish farmers in stimulating ecological behaviour. The level of satisfaction of Polish farmers with support systems was also determined, and the greatest obstacles to the development of organic agricultural production were identified.

Keywords: public expenditures, greening, organic farming, renewable energy sources

JEL Classification:H59, Q14, Q38, Q42

Introduction

The increasing global imperative for sustainable agricultural practices, driven by population growth and the pursuit of socio-economic and environmental sustainability, requires more sustainable agricultural inputs. Enhanced seeds, fertilisers, labour and machinery, among other aspects of farming inputs, are now expected to align with sustainability goals (Sannou et al., 2025). Agriculture, the basis of a country's economic and social development, is constrained by natural climate conditions. Characteristic agriculture varies as different regions have diverse climate conditions (Shen et al., 2023). Agriculture is an especially important area of the economy because it provides society with essential food products. Agricultural production is closely related to resources, the state of the environment and climate and, at the same time, also affects the environment. These environmental conditions have been incorporated into the Common Agricultural Policy of the European Union. This is reflected in, among other things, promoting organic farming (Brelik et al., 2020).

Understanding the attitude of Polish farmers towards the greening of agriculture is undoubtedly very important. Identifying this attitude would allow for the adjustment of public authorities' actions in encouraging farmers to undertake pro-ecological activities such as investing in installations using renewable energy sources, engaging in ecological agricultural production or modernising farms with modern low-emission facilities.

The aim of this article is to identify the factors determining the greening of agriculture in Poland, to recognise the potential and expected ways of financing organic farms in Poland as perceived by farmers, to assess the system of ecological payments for organic agriculture and to evaluate the degree of use of current forms of financing the greening of agriculture

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(e.g. investments in renewable energy sources). In connection with the set aim, a survey was conducted among Polish organic farmers, which provided primary data for analysis. The process of greening agriculture consists of a number of decisions made by farmers, including the decision to undertake organic production, the decision to use renewable energy sources on the farm and the decision on how to manage the surplus biomass generated on the farm. The impact of public finances on farmers' decision-making in this area is a topic that has not been explored in domestic and foreign literature. This has been identified as a research gap.

The study covered organic farms in Poland in a specific proportion to the number of organic farms located in individual provinces. The time frame covered by the questions in the questionnaire was the period of receiving payments from the Rural Development Programme 2014-2020. The choice of this period was determined by the fact that it is a closed pool of financing and an assessment can be made for this period. The study assumed the hypothesis that public spending encourages Polish farmers to engage in pro-ecological behaviour. So far, no similar studies have been conducted in the indicated area, which would link public expenditure with the pro-ecological behaviour of farmers. It should be underlined that in Polish literature there is no similar research.

Problem Statement

Despite various government poverty reduction initiatives, poverty remains widespread and severe in rural areas of North-West Nigeria, where insecurity has further compounded socioeconomic challenges (UNICEF, 2023). Previous studies have mostly focused on income-based poverty, overlooking non-monetary aspects such as education, health and social well-being that are critical in rural settings (Alkire, Foster, 2021). Additionally, there is limited research on how armed banditry influences the Multidimensional Poverty Index (MPI) across different states in the North-West region. While Sokoto State experienced a decline in poverty intensity, Katsina and Zamfara States saw worsening poverty conditions, suggesting regional variations in poverty response to insecurity. Furthermore, rural communities have been disproportionately affected, as they lack the institutional support, security infrastructure and economic resilience of urban centres. Therefore, an empirical investigation is necessary to determine how armed banditry has altered multidimensional poverty in the region and to inform targeted policy responses.

An overview of the literature

Since the mid-1980s, ecological economics has been developing on the basis of a critique of the shortcomings of neoclassical environmental economics, which was initiated in the United States as ecological economics. In the autumn of 1987, the International Society for Ecological Economics (ISEE) was founded and, since 1980, the journal "Ecological Economics" has been published. Since then, several books in this field have been published, institutes of ecological economics have been established and several congresses have been organised (Rogall, 2010, p. 116). Ecological economics, as well as the concept of sustainable development, has given rise to the greening of agriculture and all the elements that contribute to the inclusion of the environmental aspect in agricultural production.

In recent decades, dangers related to changes in the structure and functioning of the agricultural landscape and its individual components have been noted. Mechanisation,

chemicalisation and changes in crop structure have a particularly significant impact (Richling and Solon, 2011).

Rural areas, which in Poland occupy over 93% of the area, were identified in the last century with agriculture and the production of food or raw materials mainly for the needs of the food industry. Although the role of agriculture is not decreasing, as incomes are growing in relatively poor countries and with high elasticity of demand for food, these areas will increasingly perform many other important functions, such as economic (other than agricultural), social, cultural and mainly ecological, because the importance of the natural environment is systematically increasing. Due to their quantitative and qualitative potential, they already significantly participate in the implementation of the indicator goals resulting from the climate package and, in the near future, also the global climate agreement. It is thanks to the produced energy raw materials, and increasingly also energy, that the share of renewable energy sources (RES) in final energy consumption has significantly increased (Gradziuk P. and Gradziuk B., 2017, p. 73).

The problem of renewable energy sources is related to Polish agriculture. It is worth noting that the use of renewable energy by the modern economy determines the civilisational development of the state and its economy (Pająk et al., 2013). Agriculture is particularly predisposed to the use of alternative energy sources, especially due to its large space, dispersed reception, demand for relatively small capacities and unmet energy needs resulting from the difficulties encountered during the modernisation of transmission lines (Kuciński, 2006).

The effects of increased energy consumption cause a significant burden on the ecosystem and the environment. The growing demand for energy and concerns about climate change caused by the widespread use of fossil fuels have prompted several countries to switch to renewable energy in order to improve the quality of the environment (Filipiak et al., 2023). According to various models of RES development, by 2030 the main source of renewable energy in the EU will be solar energy. So far, the most important among RES has been biomass from agricultural areas, used mainly in heating, biogas plants and power generation (Pilżys, 2018).

The most important economic benefit of using biological renewable energy sources is the increase in local entrepreneurship and the creation of many new jobs (Pająk et al., 2013, p. 98). For many years, the Polish tradition and policy of promoting energy production from coal, subsidies for mining and low coal prices meant that renewable energy sources were not an alternative source of energy production. A gradual increase in the share of energy from renewable sources occurred in the 1990s (Mrozowska, 2016, p. 307). Renewable energy sources are playing an increasingly important role in the structure of energy supplies worldwide. Some renewable energy technologies have reached a level of competitiveness similar to fossil fuel-based technologies (Graczyk A. and Graczyk A.M., 2011, p. 122). Groups such as farmers or agricultural companies that control wind and biomass resources are generally absent from early policy debates, which indicates that this group does not identify itself and is difficult to mobilise. For example, when someone buys a solar water heater, they effectively become a renewable energy enthusiast and are part of the renewable industry (Mallon, 2006, p. 107). Poland is placed in a group of seven countries, along with Bulgaria, Croatia, Hungary, Portugal, Romania and Slovenia, which are characterised by negative growth rates of renewable energy production in agriculture and forestry (Janiszewska and Ossowska, 2018, p. 100). The countries with the largest production of

energy from renewable sources include Germany, Italy, France, Spain and Sweden (Frodyma, 2017, p. 39).

Referring to A. Klepacka's research, it can be expected that the production of wood biomass will become increasingly important in reducing the dependence of rural households on non-renewable fossil fuels, due to the potential for increasing the production of wood pellets and installing pellet furnaces (Klepacka, 2019, p. 80). The structure of energy generation from renewable sources in the EU shows that biomass has so far been the most significant, as it is generally available and can be used for direct combustion (e.g. wood, straw, sewage sludge) or processed into liquid fuels (e.g. rapeseed oil esters, alcohol) or gaseous fuels (e.g. agricultural fuel, biogas from sewage treatment plants, landfill gas) (Bańkowska and Gradziuk, 2017, p. 132). The energy contained in biomass is the least capital-intensive source of renewable energy. High energy efficiency during combustion and low greenhouse gas emissions mean that interest in biomass is constantly growing (Sadowska et al., 2007, pp. 414-416). Biomass is one of the most promising energy sources in the EU, especially in Poland. The arguments for the EU accession agreement indicate the need to increase renewable energy production, including raw materials based on the use of biomass (Jasiulewicz, 2020, p. 145). Typical agricultural biogas plants operate on a mixture of animal excrement (liquid manure, possibly manure) and plant materials (mainly corn silage) (Zapałowska, 2012, pp. 242-243).

An important element of the principle of sustainable development in Poland is to increase the share of renewable sources in the fuel and energy balance. This will enable the achievement of the goals set in the state's ecological policy regarding the reduction of pollutants affecting climate change (Słupik, 2007, p. 184). Considering natural conditions, agriculture is undoubtedly the privileged sector in the field of using solar energy in Poland. High demand for heat for drying agricultural crops occurs in the summer and aligns with the period of the strongest solar radiation (Ruszkowski, 1999, p. 65). The productive functions of agriculture are well described in scientific literature. This field interests both agricultural and economic sciences. For several decades, some external effects of agriculture have also been analysed, especially those related to the negative impact of agricultural production on the quality of the natural environment (Wilkin, 2008). The development of renewable energy can be supported by the state. Investments without regulations and support systems for their financing are unprofitable due to high investment costs, business risk and unit costs of energy production (Bartoszczuk, 2018, p. 144). Here, it is important to indicate the role of public finance in the ecologisation of Polish farms.

Agriculture in Poland is undoubtedly an important issue in both economic and environmental aspects. Polish food has been characterised by high quality for years. As the first link in the supply chain, the Polish farmer is a very important market participant for the economy (Jarczok-Guzy, 2020). Both agriculture and the entire agribusiness are constantly changing. Subsequent paradigms related to globalisation or sustainable development are emerging and being modified. Maryniak and Stefko, following Zawojska and Coleman, stated that so far in the area of agriculture, four basic paradigms have been distinguished, referring to different models of regulations used by the state: dependent agriculture, competitive agriculture, multifunctional agriculture and global agriculture (Stefko and Łącka, 2017). In the face of climate change and the concept of sustainable development, ecological agriculture, also known as organic farming, is becoming particularly significant.

Research methods

The first stage of the research procedure was to obtain a database of addresses of organic farming producers in Poland. The table with data is available for public information and can be downloaded directly from the website of the Agricultural and Food Quality Inspection (https://www.gov.pl/web/ijhars/dane-o-rolnictwie-ekologicznym). The Table shows 21,194 organic producers. Due to the nature of the respondents, who are farmers, whose work requires special commitment and is related to the seasonality of crops, the study was conducted in the autumn-winter period to ensure the highest possible return rate of the surveys. It was decided to conduct the survey using a questionnaire sent by traditional mail together with a pre-addressed return envelope with a postage stamp. This method should ensure that the return rate of the surveys is at the desired level. A random sample selection was used, maintaining the proportion to obtain 1.3% of respondents from each voivodeship. The research sample was assumed to be 1.3% of the total number of farms. The calculation is illustrated in Table 1. A total of 276 questionnaires were sent by post in full sets with a return envelope inside and a postage stamp. In the period from 02.11.2022 to 28.02.2023, 91 completed valid questionnaires were received. The return rate in this case was 32.97%. This rate was assessed as satisfactory.

Table 1. Calculation of organic farms by voivodeships in Poland

Voivodeship	Number of producers included in the research sample
Dolnośląskie	10
Kujawsko-pomorskie	6
Lubelskie	26
Lubuskie	14
Łódzkie	8
Małopolskie	11
Mazowieckie	36
Opolskie	1
Podkarpackie	12
Podlaskie	44
Pomorskie	8
Śląskie	3
Świętokrzyskie	8
Warmińsko-mazurskie	44
Wielkopolskie	13
Zachodniopomorskie	31
Total	276

Source:own elaboration on the base https://www.gov.pl/web/ijhars/dane-o-rolnictwie-ekologicznym.

Of the 276 surveys sent, 91 respondents returned completed questionnaires. Ninety per cent of the research sample were individual farms. Nine per cent of respondents declared that they were running a business as a company or legal entity. The majority of the sample were also small farms employing up to five people (90% of the sample). The area of agricultural land cultivated by the surveyed farmers ranged from 10 to 50 ha, as declared by 58.5% of respondents. Farms with an area of over 50 ha constituted 24% of the sample. The vast majority of agricultural producers have been operating as certified organic farms for more than 10 years (74%). 11% of farms have been operating for more than five years. Most of the surveyed respondents were experienced organic producers. The surveyed farms were very

diverse in terms of the type of agricultural production – starting from animal production (34%), through cereal crops (27%), vegetable crops (13%), fruit growing (10%) and milk production (12%). Farmers in the research sample were distributed proportionally in terms of the range of sales of their products. Farms with a local sales market constituted 36% of the sample, those with a regional range 26% and those with a national range 30%. International sales of agricultural products were declared by 8% of the respondents. The majority of the respondents were men (66%). The age structure of the respondents indicates that the largest share in the study was held by people aged 36-80 – in total, 90% of the sample. People aged 61-80 constituted 35% of the sample, while in the previous age group (46-60) it was 29% of the respondents. In terms of the representation of voivodeships, the sample is distributed evenly with a slight advantage of respondents from the Warmian-Masurian voivodeship (18%) and the Podlaskie voivodeship (14%). This advantage is justified by the fact that there are many organic farms in these voivodeships. The detailed distribution of the sample is presented in Table 2.

Table 2.Characteristics of the research sample

Criterion	Number	% investigated
Structure by the legal form		
Natural person running the business	82	90%
Partnership	2	2%
General partnership	0	-
Legal person	6	7%
Another form	1	1%
Structure by number of people working on the farm		
Up to 5 people	82	90%
6 - 10 people	6	7%
11 - 20 people	3	3%
21 - 50 people	0	-
More than 50 people	0	-
Structure by area of agricultural land		
Up to 1 ha	0	-
1.1 ha to 3.0 ha	5	5.5%
3.1 ha to 10 ha	11	12%
10.1 to 20 ha	25	27.5%
20.1 to 50 ha	28	31%
50.1 ha to 100 ha	13	14%
Over 100 ha	9	10%
Structure by the years of holding the ecological certificate of agriculture		
Less than 1 year	0	-
1 to 3 years	7	8%
3 to 5 years	7	8%
5 to 10 years	10	11%
Over 10 years	67	74%
Structure by type of agricultural production (number and % of responses)		
Cereal crops	54	27%
Vegetable crops	26	13%
Fruit crops	20	10%
Animal production	68	34%
Milk production	25	12%
Aquaculture	2	1%
Other	6	3%
Structure by the type of sales market		
Local	33	36%
Regional	24	26%
National	27	30%
International	7	8%
Structure by the gender of farmer		
Women	31	34%
Men	60	66%
Structure by the age of farmer		
Up to 25 years	1	1%
26 to 35 years	8	9%
36 to 45 years	24	26%
46 to 60 years	26	29%
61 to 80 years	32	35%
Over 81 years	0	-
Structure by voivodships		
Zachodniopomorskie	7	8%
Małopolskie	4	4%
Lubelskie	9	10%
Mazowieckie	10	11%
Warmińsko-mazurskie	16	18%
Pomorskie	2	2%
Podlaskie	13	14%
Wielkopolskie	3	3%
Dolnośląskie	5	5%
Podkarpackie	5	5%
Śląskie	2	2%
Lubuskie	5	5%
Świętokrzyskie	3	3%
Kujawsko-pomorskie	3	3%
Łódzkie	4	4%
Opolskie	0	0%

Source: own elaboration.

Results of the research

The respondents' answers in the survey were divided into three groups of substantively coherent issues. The first of the examined areas was the potential of farms in terms of production and use of renewable energy sources on organic farms.

Among the surveyed farmers, 43% admitted that they use renewable energy sources on their farms. This response rate should be viewed positively, as it is desirable for as many entities as possible to use natural sources to produce energy or heat their farms from the perspective of sustainable development and greening.

Biomass is undoubtedly a renewable energy source, and farms produce it in many forms (straw, hay, animal waste, etc.). When asked whether they produce biomass on their farms, the vast majority of respondents declared that biomass is produced on their farms (65% of respondents). This result should also be viewed positively, as it is associated with the significant potential of the farms surveyed in terms of renewable energy production. In addition, 27% of the farms that produce biomass admitted that they have a surplus of this material on their farms.

In the next question, respondents who have a surplus of biomass indicated ways of using this surplus on their farms. Here, very interesting answers were obtained from the respondents. It turned out that the most frequently indicated way of dealing with the surplus of biomass is to store it for the following years (60% of responses). A large number of respondents declared that they transfer the surplus of biomass to other farms (32.5% of responses). These answers should also be assessed positively, as they show that valuable renewable resources are not being wasted. The only imperfection in the respondents' answers is the lack of indications of using the surplus of biomass for energy production. However, among the open responses (7.5% of indications), there were phrases such as animal feed, mulching crops or fertilisation.

In organic farms, the ecological method of soil fertilisation is of particular importance. Natural fertilisers are responsible for this stage of production. In connection with the above, the surveyed farms were asked what type of natural fertilisers are produced on their farms. The majority of the responses indicated the production of solid fertiliser (manure, bird droppings) – 64.5% of responses. 27.5% of responses indicated the production of liquid fertiliser (slurry, liquid manure), while 10 farms do not use natural fertilisers (8% of responses).

Next, respondents were asked to declare whether there is a surplus of natural fertilisers on their farms and how they use it. Farmers in as many as 82% of the sample unanimously indicated that there is no such surplus on their farms. The remaining 18% of the sample were asked to indicate ways of dealing with any surplus of natural fertilisers.

The vast majority of respondents indicated that they transfer the surplus of natural fertilisers to other farms. This response was given by as many as 95% of the sample. Again, there were no indications of the use of natural fertilisers for energy production, which means that none of the surveyed farms invest in biogas plants.

Referring to the previous question, farmers indicated what types of RES installations they use on their farms. Unfortunately, as many as 55% of respondents do not use this type of equipment. However, photovoltaic cells and solar panels have been employed. Almost a quarter of respondents indicated solar panels (23%) and photovoltaic cells (22%). This trend should be viewed very positively.

The second group of questions in the survey concerned the role of public finances in the functioning of the surveyed organic farms. The questions focused in particular on public expenditure, but also on non-financial support from the state in promoting organic food. Thus, in the first question, farmers commented on the use of information materials from the Ministry of Agriculture – both those promoting organic farming and the consumption of organic food. A large part of the respondents did not use these materials (81.3%), and 5.5% were unable to comment. Only 13.2% of respondents declared that they used this type of support.

The next questions concerned strictly public expenditure in the field of support for organic farming in Poland. One of the forms of support offered to farmers in Poland is subsidies from the Rural Development Programme. Since the research period fell in 2022, farmers were asked to evaluate the programme for the years 2014-2020, as this is a programme in which they could participate. The next edition of the programme, i.e. the years 2023-2027, will be assessed after its validity period. Of the farmers surveyed, as many as 78% indicated that they participated in the programme, while 22% did not utilise the subsidy.

Then, all farmers were asked to assess the support for organic farming guaranteed under the Rural Development Programme 2014-2020. The responses were very diverse. Only 24% of respondents gave a positive assessment of the subsidies from the programme, while 29% described the support as neutral. On the other hand, 33% expressed a negative opinion on the subsidies for organic farming in the programme, assessing them as bad (25%) or very bad (8%). 14% of respondents did not express their opinion.

Another form of support that farmers in Poland can count on is co-financing for the modernisation of farms, which allows them to develop their farms by purchasing installations that use renewable energy sources. In connection with this, the surveyed farms – those that had previously indicated in response to the question that they use renewable energy installations on their farms (43% of the surveyed, or 39 farms) – were asked to identify the sources of financing for their investments. The vast majority of those surveyed did not use public forms of co-financing for installations – 62% of farms. On the other hand, 33% opted to use state aid, and 5% contributed their own private funds to the state aid. Farmers who undertook investments in installations using renewable energy sources primarily financed their purchases with private funds. Despite the fact that the majority of those surveyed chose to finance these investments themselves, there are still a considerable number of farms that utilised public support, and these results should be viewed positively.

However, all farmers were then asked to assess the financial support offered to them under the Rural Development Programme 2014-2020 in terms of co-financing installations using renewable energy sources. Forty and half per cent of respondents did not express an opinion, which may be related to the fact that the majority of respondents did not utilise the subsidy itself. For the same reason, 17.5% of respondents assessed this type of support at a neutral level. Only 8% of farms expressed their satisfaction. As mentioned earlier, only 38% of respondents used the subsidy; the rest of the respondents did not undertake this type of investment on their farms. The opinions of those who used the support seem to be important, which is why an in-depth analysis of the statements was carried out, selecting the answers of only the group of respondents who used the support. The following connections were obtained: out of 15 people who used the support, nine did not express their opinion and only two assessed the support as good. On the other hand, four people showed a negative

attitude. These statements clearly indicate that farmers do not assess the support in the aforementioned scope positively.

From 2020, which marked the beginning of the COVID-19 pandemic, to 2022, when the war broke out on Poland's eastern border, the economy and agriculture in Poland faced various problems. Most of these issues have an impact on the economic and financial conditions of farms, especially organic ones. Therefore, in the next question, respondents were offered several different forms of public support that, in their opinion, would assist in the management of their organic farms. The proposed fiscal instruments cover not only the expenditure side but also the income side of public finances and are related to tax preferences. In addition to the author's proposal, respondents had the opportunity to express their own suggestions in the open item "other". Of the proposals, the most popular was the increase in the number of direct payments (39% of indications). This result can be justified by the statements of farmers in the previous questions, which concerned the level of assessment of financing under the Rural Development Programme, where the majority did not assess the subsidies positively. The second most frequently indicated proposal is relief for farmers using renewable energy sources on the farm, with 25% of responses advocating such a solution. This is a very high result and indicates that farmers would like to invest in renewable energy sources or have already invested and would like to be appreciated for these activities that are pro-ecological and fall within the concept of sustainable development, directly related to the greening of agriculture in Poland. The respondents were also interested in the introduction of simplified procedures for taking out preferential loans (10% of responses). They also expressed their acceptance for the deferral or cancellation of social contributions (8% of responses) and the shortening of the VAT refund period (7% of responses). The next question will show how many of the farmers surveyed use the flat-rate VAT refund and for whom such a solution would be beneficial. In the open-ended response option, as many as 15 people expressed their proposals.

As a result of the respondents' answers to the last question in this group, it turned out that the so-called "flat-rate farmers" constitute as much as 44% of the sample. That is why they indicated an interest in a shortened VAT refund period. An equally large part of the sample consists of active VAT payers (37%), who settle this tax in a slightly different way than flat-rate taxpayers, and in connection with the amendment to the Act on Value Added Tax from 2022, they can count on additional preferential terms for refunds of overpaid tax. The research sample included 9% of farmers exempt from VAT, and 10% did not demonstrate knowledge of the status of their farm's value added tax.

The last group of issues related to the topic of this paper is the obstacles to the development of organic farms in Poland, with particular emphasis on economic and financial factors. In the first question in this category, farmers were asked to indicate the forms of distribution of agricultural products produced on their farms. Knowledge of the distribution system of organic food products can help suggest solutions supporting organic farms. Among the surveyed farms, direct sales were most frequently indicated (37%). It turns out that many farmers still do not use intermediaries in trade and sell on their own. The offers of wholesalers and intermediaries are used by 29 and 28 farmers, respectively. Twenty farmers, i.e. 12% of the responses, decide to sell at the marketplace. Mail order sales (5%), online sales (4%) and sales to retailers (4%) are still sporadically used forms of selling organic food. Among other forms of sale, farmers declared: "to processing plants", "to other farmers", "no sale", "meat plants", "industrial processing" or "sale to processing plants".

Another economic factor that helps to characterise the market for organic agricultural products is the assessment of the level of demand for these products as formulated by the surveyed farms. Unfortunately, as many as 38.5% of the research sample assessed the level of products sold as low. 36.2% of respondents indicate an average level of sales. Only 20.9% are satisfied with the high level of sales of their products. At this point, it is necessary to remember the subjective nature of the respondents' statements, which could have arisen because they were asked about the level of sales on their farms. These doubts will be dispelled by the answers to the next question, where the respondents will assess the general level of demand for organic food in Poland.

Farmers, as experts in the field of organic food production, unfortunately once again indicated a low level of demand for organic food in Poland (53%). Only 13% indicated a high demand, and 32% of the sample assessed it as average. Taking into account the answers to the previous question, the opinions of farmers in both areas are unfortunately duplicated. A rather pessimistic view of the development prospects of the organic food market in Poland emerges here, along with the associated threat of a decrease in interest in organic farming by potential organic farms.

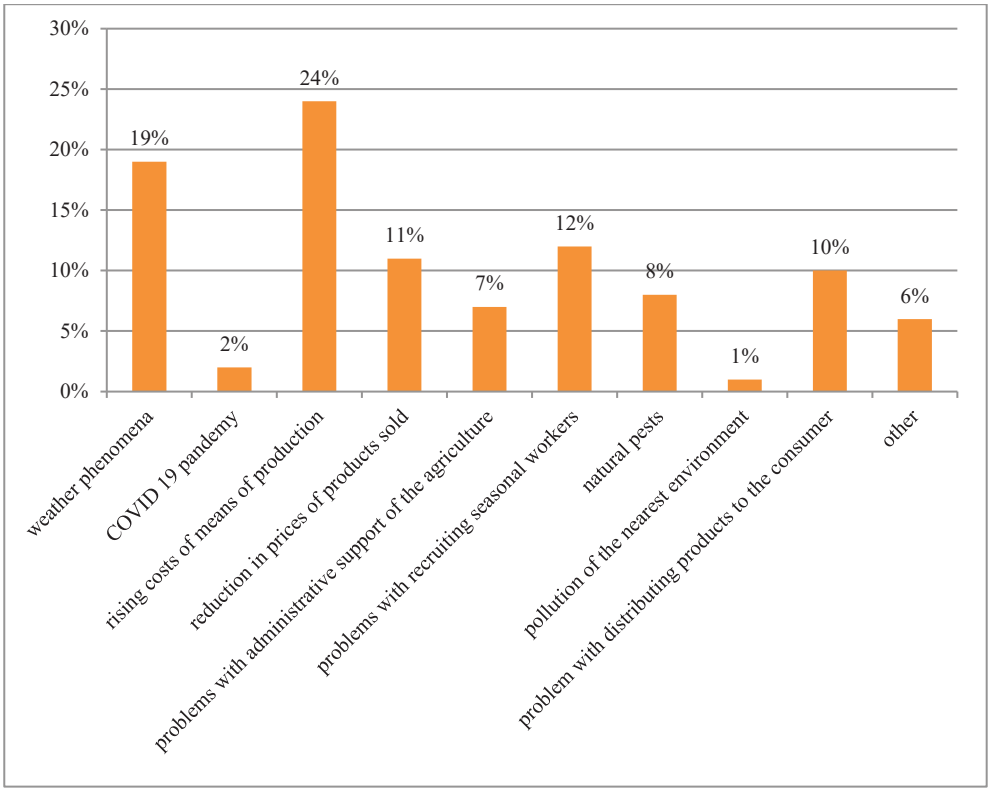

Fig. 1. The biggest obstacles to the development of an organic farm in the opinion of respondents

Source: own elaboration.

In reference to the rather pessimistic situation in the market for organic agricultural products, in the next question, farmers were asked to indicate the greatest obstacles that, in their opinion, hinder the development of their organic farms. The most important problem, in the respondents' view, was the rising costs of means of production (24% of responses), i.e. the economic factor. The second obstacle, as indicated by the farmers, was significant weather phenomena (19% of responses). Unfortunately, this is a factor on which humans have no direct influence. However, it should be remembered that some of the unusual weather phenomena occurring in Poland may be related to climate warming and global issues that are anchored in the concept of sustainable development. The following obstacles ranked as follows: problems with obtaining seasonal workers (12% of responses), reduction in the prices of sold products (11%), problems with the distribution of products to consumers (10%), natural pests (8%) and the COVID-19 pandemic (2%) (Figure 1).

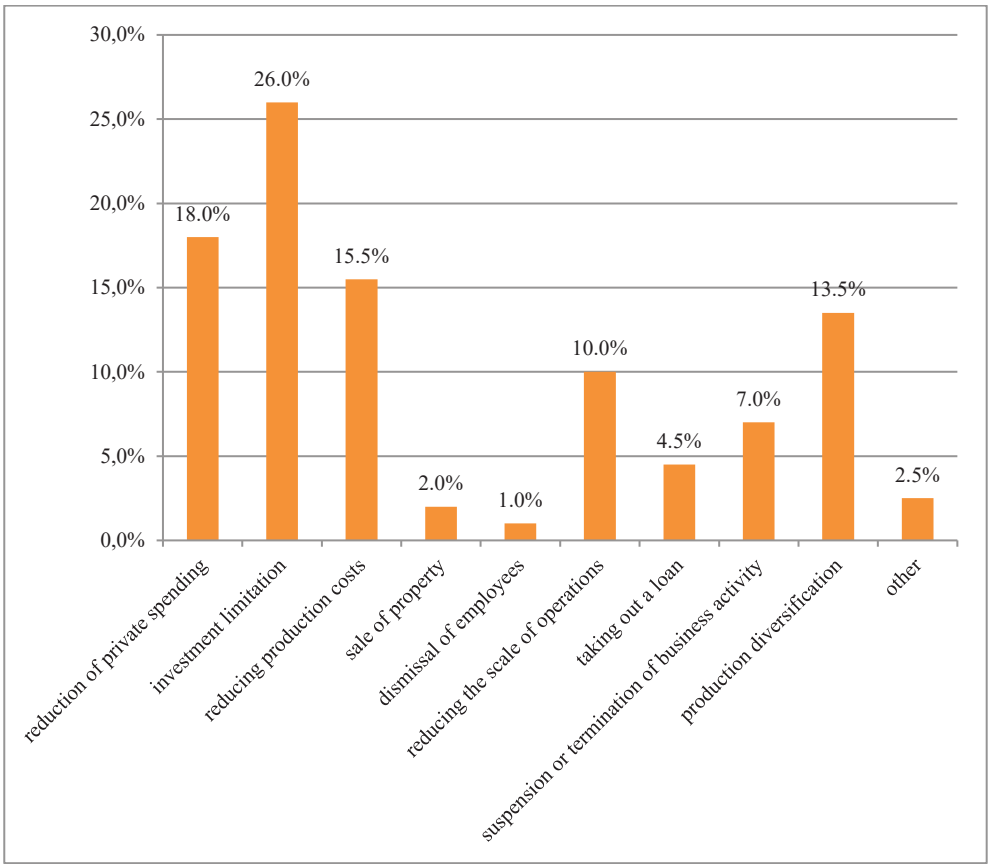

Fig. 2. Methods of coping with obstacles in the development of organic farms in the opinion of respondents

Source: own elaboration.

Having already acquired knowledge about the biggest ecological problems of farms in Poland, in the next question farmers were asked to indicate ways to reduce these obstacles.

Among the options proposed by the author, the most frequently indicated option was investment limitation (26%). This result seems quite rational, because the first action in the face of financial problems, even in a company, is to refrain from investing. In second place, the respondents indicated limiting private expenses (18%) and production expenses (15.5%). The latter option may result in lower yields, and consequently worsening the financial situation of the farmer in the long term. Another way that may help in the difficult situation of the farm is diversification of production (13.5%) or reduction of the scale of activity (10%). It should be mentioned here that diversification of production in each farm can bring many benefits in the overall calculation, and also contribute positively towards environmental protection if only it is practiced in accordance with the principles of sustainable agriculture. Only 15 people out of 91 respondents would decide to suspend or terminate their activity, and 5 people would decide to sell their assets (Figure 2).

Research conducted by the author several years earlier in a similar scope showed that organic farmers indicated low demand for organic food as the greatest barrier to undertaking organic production (42.5% of indications). In turn, they identified excessive bureaucracy (20.2% of indications) and poorly developed distribution channels for this food (18.7% of indications) as the greatest obstacle to the development of the organic food market (Jarczok-Guzy, 2018a, pp. 22-23).

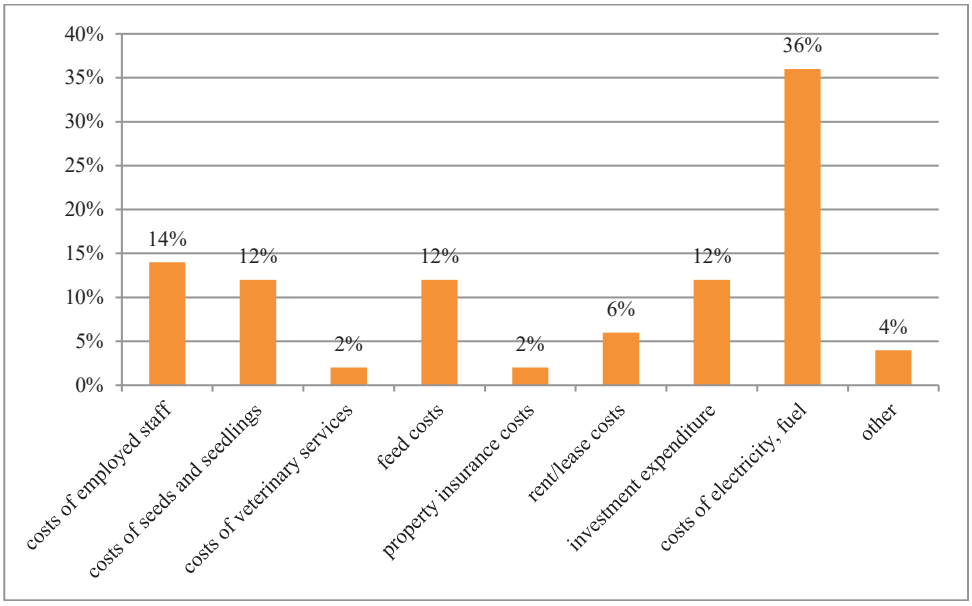

Fig. 3. Costs according to the largest share in the surveyed farms

Source: own elaboration.

The last question regarding the obstacles to developing one's own organic farm concerned the cost structure in these farms. The respondents quite unanimously indicated the costs of electricity and fuels as those that have the largest share in the cost structure in their farms. 69 people and 36% of indications indicate a high rank of the problem. Therefore, taking into account the increase in electricity prices in 2023 and the opinions of farmers, their

statements here are very justified. However, it is necessary to remember the actions of the Polish government, which at the beginning of 2023 mitigated the effects of the increase in electricity prices for individual groups of recipients, with particular emphasis on farmers, by introducing an increased limit of electricity consumption to 3000 kWh [https://www.tauron.pl/zamrozenie-pradu]. And this factor is the biggest financial problem for Polish farmers, probably not only organic ones. However, the above-mentioned government interventions should be indicated here as an example of the positive impact of state policy on the functioning of organic farms. The costs that received much fewer percentage points in the indications were the costs of employed staff (14%), the costs of seeds and seedlings (12%), the costs of feed (12%), investment expenditure (12%), lease costs (6%) and the costs of veterinary services (2%) and property insurance costs (2%) (Figure 3).

Discussion/Limitation and future research

Acording to research by Brelik, Gołębiewska and Franc-Dąbrowska the area of arable land occupied by organic farms in individual European Union countries varies and ranges from less than 0.5% in Malta to about 25% in Austria. Poland with a share of slightly over 3% belongs to countries with a low share of such area. In addition, the number of organic producers who actually produce and deliver to the market has decreased in recent years. This indicates that some of these farms were not involved in production for the market, but only collecting subsidies. Therefore, a better organisation of support is needed to ensure subsidies for those farms that provide organic food in real terms. Co-financing is also needed to promote organic food and educate consumers, because in order to produce, demand must be guaranteed. The growing consumer awareness has been reflected in market results for several years. The area of ecological land in the EU has increased in all the countries except for Poland and the UK, and therefore, the ecological products find the buyers. That is why it is generally expected in the EU that the area of ecologically used land will grow in the coming years. The organic sector responds to the growing demand for sustainable food production, and as such it perfectly fits into the objectives of the CAP (Brelik et al., 2020). Another study, made for chinese agriculture revealed that subsidy policies should be implemented and the development of organic agriculture should be encouraged. The survey results showed that economic benefits have a significant impact on organic agricultural production behavior. The adoption of organic production technology has led to increased costs, yet income has not increased enough in the short term to compensate for the loss of income. The government can reduce the production costs for farmers and guide their organic production behavior through financial subsidies, encouraging farmers to join the new business market and facilitating the development of local brands and the certification of organic products (Zhou and Ding, 2022).

The biggest limitation in the conducted study is the specificity of agricultural activity. Individual variables were selected and compared with features from the metrics in an attempt to check the relationship between selected features. The sets of selected variables are presented in Table 3. Independence tests were performed for the significance level $\alpha = 0.01$.

Table 3.Results for chi^2 test

No.	Feature X	Feature Y	χ^2	Df	$\chi^2_{0.01}$
1.	Obstacles to farm development	Age of farmers	9.919516	32	53.4858
2.	Receivingsubsidies for organicfarming	Farm area	8.682939	5	15.0863
3.	Receivingsubsidies for organicfarming	Age of farmers	4.128820	4	13.2770
4.	Using renewableenergysources	Age of farmers	2.894839	4	13.2770
5.	Using renewableenergysources	Farm area	5.761194	5	15.0863
6.	Support for farmers for investments in renewableenergy	Age of farmers	5.578519	16	31.9999
7.	Assessment of support for organicfarming	Age of farmers	6.280502	12	26.2170
8.	Assessment of support for organicfarming	Farm area	8.339647	20	37.5662

Source: own elaboration.

The calculations carried out clearly show that no dependencies were detected in any of the adopted sets of features. The biggest obstacle to conducting research on a group of farmers is limited access to them and the specifics of their work. They are reluctant to participate in research. It would be beneficial to conduct the author's research on a larger research sample and check the results in 2 years when the next perspective of Rural Development Programme funding ends.

Conclusions

The conducted study provided knowledge on the attitude of Polish organic farmers towards pro-ecological activities and allowed us to learn about the assessment of the financing system for greening agriculture in their opinion. The most important conclusions provided by the analysis of the obtained results can be presented as follows:

- Farms are reluctant to use renewable energy sources on their farms.
- Biomass is generated in many organic farms.
- Most organic farms do not use installations using renewable energy sources.
- Most organic farms benefited from subsidies under the Rural Development Programme 2014-2020.
- Farmers who decided to invest in installations using renewable energy sources mostly finance purchases from private funds.
- The most expected form of support for organic farms by farmers is an increase in the amount of direct payments.
- The biggest obstacle to the development of organic farms in Poland is the rising costs of means of production.

These conclusions contribute to the confirmation of the adopted hypothesis. Organic farmers directly admitted that they expect an increase in the amount of financial support.

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Przepływy międzygałęziowe w polskim rolnictwie w 2000 i 2020 roku

Input-Output Flows in Polish Agriculture in 2000 and 2020

Synopsis. Współczesny sektor rolny funkcjonuje w warunkach rosnącej integracji z gospodarką narodową. Zmieniająca się struktura zużycia pośredniego w rolnictwie odzwierciedla procesy modernizacji sektora rolnego. Celem opracowania była ocena przepływów materiałowych w polskim rolnictwie w 2000 i 2020 roku, ze szczególnym uwzględnieniem zmian w strukturze napływów z pierwszej sfery agrobiznesu. Zastosowano metodę input-output bazującą na macierzach przepływów międzygałęziowych, która pozwala na identyfikację powiązań międzysektorowych oraz ocenę wielkości i strukturę zużycia pośredniego w rolnictwie. W analizowanym okresie zauważalny był wzrost udziału napływów z przemysłów wytwarzających środki produkcji i usługi, w tym głównie nowoczesnych maszyn i urządzeń rolniczych, produktów przemysłu chemicznego oraz usług. W ramach zużycia pośredniego w rolnictwie wzrósł również udział produktów III sfery, czyli pasz przemysłowych i produktów ubocznych z przemysłu spożywczego. Jednocześnie odnotowano spadek znaczenia obrotów wewnętrznych w rolnictwie, co wskazuje na postępującą modernizację sektora rolnego oraz jego rosnącą integrację z całą gospodarką narodową.

Słowa kluczowe: rolnictwo, przepływy międzygałęziowe, sfery agrobiznesu, współzależności międzygałęziowe

Abstract. The modern agricultural sector operates in conditions of increasing integration with the national economy. The changing structure of intermediate consumption in agriculture reflects the modernisation processes in the agricultural sector. The aim of the study was to assess material flows in Polish agriculture in 2000 and 2020, with particular emphasis on changes in the structure of inflows from the primary agribusiness sector. The input-output method based on inter-industry flow matrices was used, which allows for the identification of inter-sectoral links and the assessment of the size and structure of intermediate consumption in agriculture. During the analysed period, there was a noticeable increase in the share of inflows from industries producing means of production and services, including mainly modern agricultural machinery and equipment, chemical industry products, and services. The share of tertiary sector products, i.e., industrial feed and by-products from the food industry, also increased in indirect consumption in agriculture. At the same time, there was a decline in the importance of internal trade in agriculture, which indicates the ongoing modernisation of the agricultural sector and its growing integration with the entire national economy.

Key words: agriculture, input-output flows, agribusiness spheres, inter-industry interdependencies

JEL Classification: Q1, Q13, R15

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Wstęp

Analiza przepływów międzygałęziowych jest jednym z podstawowych narzędzi służących do oceny stanu gospodarki. Twórcą tej metody jest F. Quesnay, który analizował rolnictwo, sferę pozarolniczą i właścicieli za pomocą odpowiedniej tablicy ekonomicznej, aby wyjaśnić ogólne zależności zachodzące w gospodarce. Usystematyzowanie metody obliczania przepływów międzygałęziowych zostały opisane w 1936 r. przez W. Leontiefa, który dokonał podziału gospodarki na sektory i opisał zachodzące między nimi relacje za pomocą nakładów i wyników (Czyżewski, 2011; Prandecki, 2016). Pieniężny model przepływów międzygałęziowych poprzez analizę typu dostawca-odbiorca (input-output) konkretyzuje idee funkcjonowania mechanizmu gospodarczego (rynkowego i budżetowego), jego wewnętrzne powiązania, zależności oraz efekty decydujące o procesach reprodukcji (Leontief, 1936; Leontief, 1949; Czyżewski, 2008; Mrówczyńska-Kamińska 2010). Model ten jest użytecznym instrumentem pozwalającym ocenić funkcjonowanie gospodarki państwa. Pozwala wskazać faktyczny i ilościowy obraz gospodarki, co przekłada się na podejmowanie trafnych decyzji rozwojowych, a zrozumienie zmian strukturalnych i trendów wynikających z przepływów międzygałęziowych jest ważne w kształtowaniu polityki gospodarczej państwa (Tomaszewicz, 1994; Prandecki, 2016; Czyżewski i Grzelak 2018). W gospodarce narodowej produkty jednych gałęzi zużywane są jako nakłady w innych, które bez nich w ogóle nie mogłyby prowadzić działalności produkcyjnej. Rolnictwo nie może rozwijać się bez strumieni różnych zasobów płynących do niego z zewnątrz, a gospodarka narodowa potrzebuje wydajnego i nowoczesnego rolnictwa dla odpowiedniego funkcjonowania (Baer-Nawrocka i Mrówczyńska-Kamińska, 2015; Mrówczyńska-Kamińska, 2010). Istnienie przepływów produktów między gałęziami gospodarki narodowej uzasadnia prowadzenie analizy nakładów i wyników w skali poszczególnych gałęzi (grup przedsiębiorstw) oraz całej gospodarki.

Przegląd literatury

Szczególnie interesujące wydaje się wykorzystanie analiz przepływów międzygałęziowych w przypadku rolnictwa. Opierając się na założeniach teorii równowagi ogólnej, można przeprowadzić analizę związków rolnictwa z otoczeniem oraz oddziaływania procesów globalnych na rolnictwo poprzez eksport i import (Leontief, 1936; Leontief, 1949; Czyżewski, 2001). Rolnictwo nie może obyć się m.in. bez środków ochrony roślin, nawozów, energii, wszelkiego rodzaju usług, budownictwa, przemysłu maszyn i urządzeń. Jedynym dostępnym materiałem statystycznym, na podstawie którego można przeanalizować wielkość i strukturę przepływów materialnych w rolnictwie są tablice przepływów międzygałęziowych (Woś, 1979; Woś i Zegar 1983; Mrówczyńska-Kamińska, 2014; Mrówczyńska-Kamińska, 2010). Proces wytwarzania żywności opiera się na współdziałaniu wszystkich sektorów i działów gospodarki narodowej, przy zachowaniu określonych proporcji ich udziału. Strukturalne powiązania między tymi sektorami stanowią podstawę do identyfikacji oraz pomiaru napływów i wypływów środków pomiędzy sferami sektora rolno-żywnościowego. Analiza przepływów materiałowych umożliwia ocenę zarówno bieżącej struktury alokacji zasobów, jak i kierunków ich zmian w ujęciu czasowym (Kowalski, 2010). Z punktu widzenia efektywności funkcjonowania sektora rolnego, kluczowe znaczenie ma identyfikacja sprzężeń zwrotnych w układzie gospodarki

żywnościowej, które odzwierciedlają relacje pomiędzy poszczególnymi podsystemami kompleksu rolno-spożywczego, jak również jego powiązania z otoczeniem makroekonomicznym. Ujęcie to pozwala na diagnozę tendencji rozwojowych w strukturze sektora oraz ocenę jego roli w szerszym kontekście gospodarki narodowej (Grabowski, 1997; Woś, 1979; Tomczak, 2000). Polskie rolnictwo od początku wejścia do Unii Europejskiej rozwijało się stopniowo i charakteryzowało się dużą dynamiką zmian (Matyka i in., 2016; Miniszewski, 2021). Mimo ciągle spadającej liczby gospodarstw rolnych, produktywność polskiego rolnictwa w latach 2000-2020 wzrosła dwukrotnie, a dochody rolniczych gospodarstw trzykrotnie (Miniszewski, 2021). Rozwój sektora rolnego przynosi korzyści dla całej gospodarki. Wewnętrzna struktura przepływów w rolnictwie również ulega ciągłym zmianom. Ogólna tendencja pokazuje, że wraz ze wzrostem rozwoju gospodarczego, rolnictwo staje się coraz bardziej zależne od innych sektorów gospodarki ze względu na rosnące udziały zasobów zewnętrznych, co zwiększa złożoność ekonomicznych powiązań towarzyszących produkcji żywności (Baer-Nawrocka i Mrówczyńska-Kamińska, 2019). Po wejściu Polski do Unii Europejskiej sektor rolny znajduje się w fazie przemian strukturalnych, wynikającej zarówno z przemian wewnętrznych, jak i z rosnącego wpływu czynników zewnętrznych, takich jak integracja z rynkiem unijnym, zmiany popytu czy globalizacja łańcuchów dostaw. W związku z tym konieczne są kompleksowe analizy ukierunkowane na ocenę wpływu otoczenia makroekonomicznego na funkcjonowanie sektora rolno-żywnościowego oraz jego oddziaływanie zwrotne na pozostałe obszary gospodarki narodowej (Zegar, 2012; Miniszewski, 2021). Z tego względu, szczególnego znaczenia nabierają badania przepływów międzygałęziowych, które pozwalają na precyzyjne określenie relacji pomiędzy sektorem rolnym a innymi działami gospodarki. Analiza przepływów rzeczowych i wartościowych w ujęciu międzygałęziowym (input-output) umożliwia identyfikację ogniw pośredniczących w procesie przetwarzania i dystrybucji żywności oraz ocenę struktury popytu pośredniego i końcowego (Schiff i Valdes 1998; Góral i in., 2017). Wyniki tego typu analiz dostarczają również podstaw do kształtowania polityki rolnej i przemysłowej, wspierającej integrację pionową w agrobiznesie oraz wzmacniającej powiązania kooperacyjne między rolnictwem a sektorami przetwórczymi i usługowymi (Zegar, 2012).

Celem artykułu była ocena wielkości i struktury przepływów materiałowych w polskim rolnictwie w 2000 i 2020, ze szczególnym uwzględnieniem zmian w strukturze napływów z przemysłów wytwarzających środki produkcji oraz sektora usług (pierwsza sfera agrobiznesu). W pierwszej części przedstawiono wielkość i strukturę zużycia pośredniego w rolnictwie na podstawie tabel przepływów międzygałęziowych. W drugiej części omówiono wielkość produkcji globalnej, zużycia pośredniego i wartości dodanej brutto. Na tej podstawie obliczono podstawowe współzależności międzygałęziowe w polskim rolnictwie.

Dane i metody badawcze

Głównymi materiałami źródłowymi były bilanse przepływów międzygałęziowych w Polsce za 2000 i 2020 rok, opublikowane przez Główny Urząd Statystyczny w Warszawie. Analiza obejmowała trzy sfery agrobiznesu: przemysł wytwarzający środki produkcji i usługi

dla rolnictwa oraz przemysłu spożywczego (sfera zaopatrzeniowa I), rolnictwo (sfera II), przemysł spożywczy (sfera III)[4]. Zakres czasowy badań dotyczył 2000 i 2020 roku[5].

Do określenia wartości i struktury przepływów materiałowych w polskim rolnictwie wykorzystana została metoda analizy nakładów i wyników (*input-output analysis*, analiza przepływów międzygałęziowych). Metoda input-output pozwala określić powiązania produkcyjne między sektorami gospodarki. W tabeli przepływów międzygałęziowych dla każdej z gałęzi układu zachodzi równanie bilansowe podziału produkcji (Leontief, 1941; Leontief, 1953; Leontief, 1963):

$$\boldsymbol{X_i = (x_{i1} + x_{i2} + \cdots + x_{in}) + Y_i}$$

gdzie:
X_i - produkcja globalna gałęzi;
$x_{i1....}x_{in}$ - zużycie produkcyjne wyrobów i-tej gałęzi;
Y_i - produkcja końcowa gałęzi.

Z drugiej strony na podstawie tablic przepływów międzygałęziowych wyznaczyć można dla dowolnej j-gałęzi równanie bilansowe kosztów (Leontief, 1941; Leontief, 1953; Leontief, 1963):

$$X_j = (x_{1j} + x_{2j} + \cdots + x_{nj}) + D_j$$

gdzie:
X_j - produkcja globalna;
$x_{1j....}x_{nj}$ - koszty materiałowe;
D_j - wartość dodana.

Wyniki badań

Rolnictwo jest jednym z agregatów agrobiznesu. W Polsce w zaopatrzeniu materiałowym (surowcowym) produkcji rolnej istotną pozycję stanowi samozaopatrzenie, natomiast pozostała część zużycia pośredniego trafia ze sfery pierwszej i trzeciej. W 2000 roku udział rolnictwa w zaopatrzeniu rolnictwa wynosił blisko 40,0%, natomiast w 2020 roku udział ten zmniejszył się o około 10 p.p. i wyniósł prawie 30,0%. Wynik ten wskazuje, że rolnictwo w Polsce w dalszym ciągu odgrywa istotną rolę jako wewnętrzny dostawca środków produkcji, wytwarzając znaczną część pasz, nawozów naturalnych i materiału hodowlanego, które obniżają zależność sektora od zewnętrznych źródeł zaopatrzenia

[4] Podstawowa praca z zakresu teorii agrobiznesu, struktury wewnętrznej i powiązań z gospodarką narodową to dzieło Davisa J.H. i Goldberga R.A. (Davis i Goldberg, 1967). Według autorów książki, agrobiznes jako dział gospodarki narodowej składa się z trzech głównych agregatów (zespołów) ekonomicznych, wykorzystanych w niniejszej analizie.

[5] Celowo wybrano do analizy dwa skrajne lata, aby uchwycić obraz zmiany struktury zużycia pośredniego w polskim rolnictwie. Rok 2000 to czas tuż przed akcesją Polski do UE, wciąż z dominującym tradycyjnym modelem rolnictwa (rozdrobnieniem gospodarstw, słabszym wyposażeniem technicznych czy ograniczonym dostępem do nowoczesnych środków produkcji). Rok 2020 to 20 lat później, kiedy rolnictwo przeszło modernizację i konsolidację, związaną przede wszystkim z integracją z WPR (dofinansowania, dopłaty, programy rozwoju obszarów wiejskich) (Miniszewski, 2021). Porównanie wyników w dwóch skrajnych latach pozwoli na wskazanie, czy zmiany w poziomie rozwoju rolnictwa w latach 2000-2020 znajdują odzwierciedlenie w zmianie struktury zużycia pośredniego obliczonej na podstawie tabel przepływów międzygałęziowych. Tabele te są jedynym materiałem statystycznym na podstawie którego, można ocenić szczegółowa strukturę zużycia pośredniego.

(tabela 1, 2; rys. 1). Wynik ten wskazuje na powolny proces dochodzenia do nowoczesności w zakresie struktury zużycia pośredniego w rolnictwie (por. Mrówczyńska-Kamińska 2010).

Tabela 1. Przepływy materiałowe w rolnictwie w Polsce w 2000 i 2020 roku (ceny bieżące; mln zł)

Table 1. Material flows in agriculture in Poland in 2000 and 2020 (current prices; PLN million)

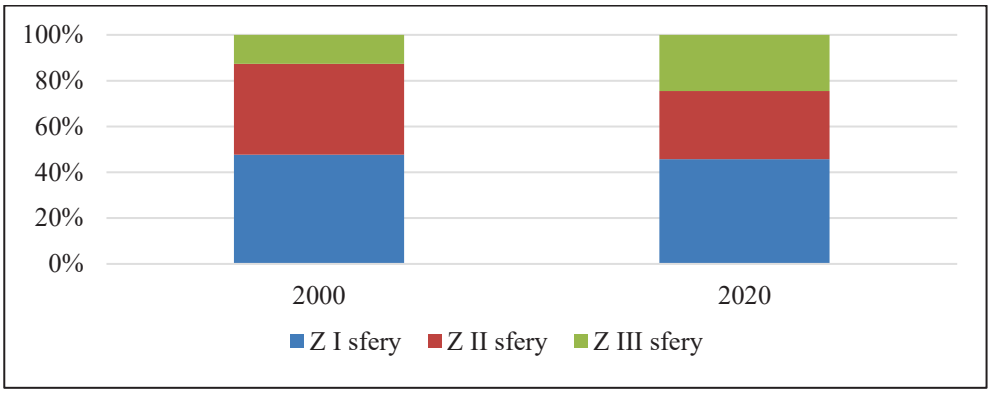
Wyszczególnienie	2000	2020
Z I sfery	**20 246**	**35 849**
Przemysł paliwowo-energetyczny	3525	3 887
Przemysł metalurgiczny	515	945
Przemysł elektromaszynowy	244	189
Przemysł środków transportu	1288	1 959
Przemysł chemiczny	2833	8 982
Przemysł mat. budowlanych	502	497
Usługi	1492	6 480
Handel	8445	9 270
Budownictwo	169	739
Transport i łączność	1012	2 114
Leśnictwo	13	93
Pozostałe gałęzie	209	694
Z II sfery	**16 881**	**23 338**
Z III sfery	**5 368**	**19 226**
Razem	**42 495**	**78 413**

Źródło: obliczenia własne na podstawie danych Głównego Urzędu Statystycznego.

Spadek udziału samozaopatrzenia w rolnictwie w badanym okresie spowodowany był przede wszystkim wzrostem udziału przemysłu spożywczego (III sfery) w strukturze zużycia pośredniego. W ciągu dwóch dekad udział ten zwiększył się o 12 pp. i w 2020 roku wyniósł 24,5%. Miał na to wpływ przede wszystkim zwiększony strumień produktów przemysłu paszowo-utylizacyjnego. W 2020 roku wartość produkcji sprzedanej gotowych pasz i gotowej karmy dla zwierząt wyniosła 18,4 mld zł[6]. Pasze przemysłowe stanowią specyficzny i istotny strumień przepływu dóbr w gospodarce rolnej. W praktyce są to produkty rolnicze, które przeszły etap przetwórstwa przemysłowego. Analiza danych dotyczących sprzedaży przemysłu paszowo-utylizacyjnego pozwala stwierdzić, że pasze odgrywają kluczową rolę wśród dóbr dostarczanych do sektora rolniczego z tzw. trzeciej sfery gospodarki żywnościowej, czyli przemysłu spożywczego (Szymańska, 2001). W przeciwieństwie do nich, pozostałe produkty przemysłu rolno-spożywczego trafiające do rolnictwa mają znaczenie marginalne i nie stanowią istotnego czynnika wpływającego na wzrost produkcji rolniczej. Główną formą ich obecności w gospodarstwach są odpady poprodukcyjne, wykorzystywane jako pasza, pochodzące m.in. z przemysłu mleczarskiego czy piekarniczego. Należy jednak podkreślić, że skala tego zjawiska jest stosunkowo niewielka. Wyniki te wskazują, że w zakresie udziału pasz przemysłowych w zużyciu

[6] Główny Urząd Statystyczny (2021). Produkcja wyrobów przemysłowych w latach 2016-2020, Analizy statystyczne; Warszawa.

pośrednim w rolnictwie w Polsce nastąpiły zmiany charakterystyczne dla krajów wysokorozwiniętych (por. Mrówczyńska-Kamińska 2010).



Rys. 1. Struktura przepływów materiałowych w sferze produkcji rolnej w Polsce w 2000 i 2020 roku (%)

Fig. 1. Structure of material flows in agricultural production in Poland in 2000 and 2020 (%)

Źródło: opracowanie własne na podstawie tabeli 2.

Tabela 2. Struktura przepływów materiałowych w sferze produkcji rolnej w Polsce w 2000 i 2020 roku (%)

Table 2. Structure of material flows in agricultural production in Poland in 2000 and 2020 (%)

Wyszczególnienie	2000	2020
Z I sfery	47,6	45,7
Przemysł paliwowo-energetyczny	8,3	5,0
Przemysł metalurgiczny	1,2	1,2
Przemysł elektromaszynowy	0,6	0,2
Przemysł środków transportu	3,0	2,5
Przemysł chemiczny	6,7	11,5
Przemysł mat. budowlanych	1,2	0,6
Usługi	3,5	8,3
Handel	19,9	11,8
Budownictwo	0,4	0,9
Transport i łączność	2,4	2,7
Leśnictwo	0,0	0,1
Pozostałe gałęzie	0,5	0,9
Z II sfery	39,7	29,8
Z III sfery	12,6	24,5
Razem	**100,0**	**100,0**

Źródło: obliczenia własne na podstawie danych z tabeli 1.

Rozwój gospodarczy w Polsce od 2000 roku[7] znajduje odzwierciedlenie we wzroście znaczenia sektorów zaopatrujących rolnictwo w środki produkcji oraz usługi, co znajduje potwierdzenie w analizie powiązań międzygałęziowych w sektorze rolnym (Ambroziak, 2021; Góral i in., 2017; Czyżewski i Kryszak, 2016). W Polsce znaczenie sfery pierwszej w zaopatrzeniu materiałowym rolnictwa kształtowało się w badanym okresie na bardzo podobnym poziomie tj. średnio 46-47% (36 mld zł w 2020 roku). Zdefiniowanie roli tzw. sfery pierwszej – obejmującej sektory przemysłowe dostarczające środki produkcji i usługi zarówno dla rolnictwa, jak i przemysłu spożywczego – stanowi istotny element analizy funkcjonowania systemu agrobiznesu. Gałęzie te odgrywają kluczową rolę w zapewnianiu nowoczesnych nakładów niezbędnych dla produkcji surowców rolnych oraz przetwórstwa żywności, co w bezpośredni sposób wpływa na wzrost społecznej wydajności pracy i modernizację sektora rolnego (por. Mrówczyńska-Kamińska 2010). Szczególnego znaczenia w strukturze powiązań pomiędzy rolnictwem a gospodarką narodową nabiera właśnie czynnik kapitału, który w rolnictwie materializuje się poprzez stosowanie nowoczesnych środków produkcji: maszyn i urządzeń rolniczych, nawozów mineralnych, środków ochrony roślin, a także postępu biologicznego – w postaci wysokoplennych odmian roślin uprawnych i wysokowydajnych ras zwierząt gospodarskich. Istotną rolę pełnią również profesjonalne usługi doradcze, technologiczne i serwisowe, integrujące rolnictwo z sektorami pozarolniczymi, co wskazuje na jego silne osadzenie w strukturze całej gospodarki narodowej[8] (Alston i Pardey, 2014; Woś, 1979; Grabowski, 1997).

Od roku 2000 roku zmieniła się struktura napływów z poszczególnych gałęzi gospodarki narodowej, tworzących sferę pierwszą do rolnictwa. W latach 2000-2020 wśród najważniejszych gałęzi, które zaopatrywały polskie rolnictwo w środki produkcji i usługi, należy wymienić niezmiennie przemysł paliwowo-energetyczny, chemiczny, sektor usług, środków transportu oraz handel. W badanym okresie wypływy z tych sektorów stanowiły blisko 80,0% wszystkich napływów do rolnictwa z pierwszej sfery agrobiznesu.

Miernikiem określającym stopień rozwoju sektora rolnego jest zużycie energii elektrycznej i paliw płynnych. Są to główne źródła energii, znajdujące zastosowanie niemal we wszystkich procesach produkcyjnych. W badanym okresie udział przemysłu paliwowo-energetycznego zmniejszył się z 8,3% w 2000 roku do 5,0% w 2020 roku. Spadek tego udziału może być interpretowany jako efekt rosnących inwestycji w nowoczesne technologie i środki trwałe w polskim rolnictwie (por. Dziwulski, Szymańska 2020). Stabilność wartości nominalnej tych przepływów (około 3,6-3,8 mld zł w 2000 i 2020 roku) w warunkach silnego wzrostu cen paliw i energii wskazuje na realny spadek udziału sektora paliwowo-energetycznego w zużyciu pośrednim w rolnictwie. W latach 2000-2020 poprzez zmiany gospodarcze nastąpił znaczny wzrost cen nośników energii. Ceny węgla w przeliczeniu na tonę od roku 2000 do 2020 wzrosły ponad dwukrotnie. W roku 2000 cena tony węgla kosztowała 386 zł, a w 2020 roku była to już wartość 888 zł. Wzrosły również ceny energii elektrycznej za kWh, z 0,29 zł w 2000 r. do 0,69 w 2020 roku. Podobnie cena oleju napędowego na przestrzeni lat dynamicznie rosła. W badanym okresie wartości te zwiększyły się prawie dwukrotnie (Wąs i in., 2024; GUS). Z drugiej strony, intensyfikacja nakładów na B+R oraz wdrażanie technologii Rolnictwa 4.0, mogą świadczyć o mniejszym zapotrzebowaniu na energię i paliwa (Wysokiński i in., 2020a; Wysokiński i in., 2020b)

[7] Główny Urząd Statystyczny. (2023). *Rocznik Statystyczny Rzeczypospolitej Polskiej 2023*. Warszawa: GUS. Pozyskano z: https://stat.gov.pl.

[8] Wszystkie wymienione sektory stanowią sferę pierwszą agrobiznesu (por. Mrówczyńska-Kamińska, 2010).

i wpływie na środowisko (Kabato i in., 2025; Balafoutis i in., 2017; Borychowski, Grzelak, Popławski, 2022).

Kolejnym istotnym produktem w zaopatrzeniu materiałowym rolnictwa są wyroby przemysłu chemicznego. W tym zakresie udział napływów z tej sfery gospodarki narodowej w badanym okresie znacznie wzrósł, z 6,7% w 2000 roku do 11,5% w 2020 roku. W cenach bieżących w 2020 roku wartość napływów do rolnictwa wyniosła blisko 9,0 mld zł. Wzrost tych przepływów związany jest przede wszystkim z tym, że w polskim rolnictwie od 2000 roku systematycznie zwiększa się zużycie nawozów mineralnych, głównie azotowych, potasowo fosforowych oraz wieloskładnikowych (Piwowar, 2022). Z jednej strony umożliwia to wzrost plonów i modernizację produkcji rolnej, ponieważ zrównoważone, racjonalne nawożenie decyduje o wysokich i wartościowych plonach upraw. Rolnictwo polskie od wielu dziesięcioleci uważane jest za tradycyjne, proekologiczne, charakteryzowało się stosunkowo niskim zużyciem środków agrochemicznych. Z kolei przemiany gospodarcze i społeczne, a w szczególności przystąpienie Polski do Unii Europejskiej, znacząco zmieniły ten obraz. W polskim rolnictwie nastąpił wzrost poziomu nawożenia mineralnego, który należy obecnie do najwyższych w Unii Europejskiej. Dominuje nawożenie azotowe, a jego intensywność znacznie różni się w zależności od regionu kraju. Sytuacja ta wymaga wdrożenia skutecznych programów i polityk wspierających zrównoważone nawożenie, które ograniczy negatywny wpływ na środowisko, np. eutrofizację. W tym celu niezbędne są zmiany w praktykach rolniczych, wśród których należy wymienić np. dostosowanie dawek, form i terminów stosowania nawozów do warunków glebowo-klimatycznych oraz wykorzystanie technologii Rolnictwa 4.0. Innowacyjne nawozy o kontrolowanym uwalnianiu składników mogą poprawić efektywność nawożenia przy jednoczesnym ograniczeniu strat środowiskowych. Konieczne są również inwestycje w sprzęt i rozwój doradztwa rolniczego, a także edukacja rolników w zakresie wpływu nawozów na środowisko i zdrowie. Dodatkowym wyzwaniem jest postępujące zakwaszenie gleb i niedostateczne ich wapnowanie, które pogłębiają problem niezrównoważonego gospodarowania składnikami pokarmowymi (Piwowar, 2022).

Kolejnym ważnym nakładem w zużyciu pośrednim w rolnictwie są produkty przemysłu środków transportu. W latach 2000-2020 udział tego sektora wynosił 2,5-3,0% (1,9 mld zł w 2020 roku). W ramach tych przemysłów są to głównie nowoczesne środki transportu i maszyny rolnicze, które trafiły do polskiego rolnictwa. Realizacja inwestycji w tego rodzaju środki trwałe pozwala na zwiększenie konkurencyjności i możliwości rozwoju gospodarstwa rolnego. Inwestycje w kapitał trwały przyczyniają się również do maksymalizacji zdolności produkcyjnych jednostki, wprowadzają postęp w rolnictwie poprzez nowe technologie i nowoczesne środki, co zwykle prowadzi do trwałych zmian między czynnikami produkcji (Czubak i Pawłowski, 2024).

Ważne miejsce w zaopatrzeniu sektora rolnego zajmują usługi. W analizie struktury zużycia pośredniego w rolnictwie w Polsce w latach 2000–2020 ma podstawie danych z bilansów przepływów międzygałęziowych Głównego Urzędu Statystycznego (tablice input-output) można zauważyć wzrost udziału usług. W ujęciu wartościowym nakłady sektora rolniczego na usługi wzrosły z poziomu ok. 1,5 mld zł w 2000 roku (3,5%) do 6,5 mld zł w 2020 roku (8,3%), co stanowi ponad czterokrotny wzrost wartościowy oraz ponad dwukrotny wzrost udziału procentowego (tabela, 1, 2). W strukturze usług dominują pozycje związane z prowadzeniem działalności gospodarczej – m.in. działalność rachunkowo-księgowa, ubezpieczeniowa, pośrednictwa finansowego, doradztwo podatkowe i prawnicze, analizy techniczne oraz działalność reklamowa, a także wynajem i dzierżawa maszyn

i urządzeń rolniczych bez operatora, które w warunkach zmiennego zapotrzebowania i sezonowości produkcji pozwalają na optymalizację kosztów operacyjnych. Ważne miejsce w rolnictwie zajmują usługi weterynaryjne. Wzrost znaczenia usług jako elementu nakładów produkcyjnych rolnictwa jest konsekwencją szeregu zmian strukturalnych i organizacyjnych w gospodarce narodowej, a także transformacji samego sektora rolnego. W szczególności należy podkreślić rosnące wyspecjalizowanie funkcji zarządczych w gospodarstwach, skutkujące większym zapotrzebowaniem na usługi doradcze, księgowe i prawnicze; outsourcing funkcji pomocniczych, takich jak badania techniczne, reklama czy usługi analityczne, które zastępują wcześniejsze rozwiązania realizowane wewnątrz gospodarstw czy rozbudowę zaplecza usługowego wokół rolnictwa, w tym rozwój rynku najmu sprzętu rolniczego bez obsługi operatorskiej, co pozwala gospodarstwom ograniczać nakłady inwestycyjne przy zachowaniu elastyczności operacyjnej. Tendencja ta odzwierciedla ogólnoświatowy proces „*servicification of agriculture*", czyli stopniowego zwiększania się znaczenia usług jako czynnika wspomagającego efektywność i konkurencyjność produkcji rolnej (Gereffi i Fernandez-Stark, 2011). Potwierdzają to także analizy intensywności korzystania z usług rolniczych (np. prac maszynowych, usług doradczych) i ich udział w zużyciu pośrednim. Wyniki ukazują, że w rozwiniętych regionach UE udział kosztów usług zakupionych przekracza 4–6% kosztów rolnictwa (Kołodziejczak, 2024). Wzrastający udział usług w przepływach ze sfery pierwszej do sektora rolniczego można interpretować również jako objaw postępującej integracji sektora rolno-żywnościowego z nowoczesnymi sektorami usługowymi, co z kolei świadczy o systemowym wzmocnieniu powiązań międzygałęziowych i roli rolnictwa jako ogniwa w coraz bardziej złożonym łańcuchu wartości. Zjawisko to zasługuje na dalszą analizę z perspektywy modeli przepływów międzygałęziowych, szczególnie w kontekście oceny wpływu modernizacji rolnictwa na zmiany struktury popytu pośredniego oraz oceny mnożnikowych efektów popytowych generowanych przez sektor rolny na sferę usługową.

Kolejnym ważnym działem w ramach sfery zaopatrzenia w środki produkcji i usługi dla rolnictwa był handel hurtowy i detaliczny, W badanym okresie udział ten zmniejszył się z około 20,0% (8,4 mld zł) do około 12,0% (9,3 mld zł). W sektorze rolnym kluczowy wpływ ma handel hurtowy, ponieważ to tam klasyfikowany jest import i dystrybucja maszyn, urządzeń i technologii rolniczych — czyli działalność wspierająca modernizację i inwestycje w gospodarstwach. Ważne miejsce w ramach tego działu zajmuje również sprzedaż zbóż, nasion oleistych i pasz dla zwierząt gospodarskich jako surowców dla sektora rolnego; handel nawozami mineralnymi, produktami chemicznymi istotnymi dla rolnictwa oraz pośrednictwo w handlu sprzętem rolniczym (m.in. ciągniki, sprzęt biurowy, maszyny specjalistyczne)[9]. Zjawisko wzrostu znaczenia handlu hurtowego w zaopatrzeniu rolnictwa można uznać za korzystne, jeśli przekłada się ono na lepszą jakość usług, dostępność innowacji i efektywność dostaw. Z drugiej jednak strony może być obarczone pewnymi negatywnymi konsekwencjami, ponieważ może prowadzić do wzrostu marż handlowych, a tym samym – zwiększenia kosztów zakupu dla gospodarstw rolnych. Może także ograniczać możliwość bezpośredniego kontaktu rolnika z producentem i tym samym wpływać na ograniczony dostęp do informacji o nowych rozwiązaniach technologicznych. Nadmierna koncentracja na rynku hurtowym może dodatkowo sprzyjać zależności od dużych dystrybutorów i osłabiać siłę negocjacyjną mniejszych gospodarstw (por. OECD, 2022; Kołodziejczak, 2024).

[9] PKWiU, 2015; GUS, pkwiu_04, (data dostępu: 20.07.2025).

Tabela 3. Produkcja globalna, zużycie pośrednie i wartość dodana brutto w rolnictwie w Polsce w 2000 i 2020 roku (mln zł)

Table 3. Global production, intermediate consumption, and gross value added in agriculture in Poland in 2000 and 2020 (PLN million)

Wyszczególnienie		2000	2020
Napływy materiałowe z:			
przemysłów produkujących środki dla rolnictwa i przemysłu spożywczego (sfera I)	a	20 246	35 849
rolnictwa (sfera II)	b	16 881	23 338
przemysłu spożywczego (sfera III)	c	5 368	19 226
Razem napływy do rolnictwa:	(a + b + c) = d	42 495	78 416
Podatki od produktów pomniejszone o dot. do produktów	e	1 372	9 014
Razem zużycie pośrednie w rolnictwie	f = d + e	43 867	87 427
Produkcja globalna	g	77 989	130 650
Wartość dodana brutto	h = g - f	34 121	43 222

Źródło: obliczenia własne na podstawie (Bilanse przepływów międzygałęziowych GUS, 2004 i 2024).

Przemysły produkujące środki produkcji i usługi odgrywają największą rolę w pobudzaniu rozwoju rolnictwa. Dzięki tym środkom następuje modernizacja i rozbudowa gałęzi biorących bezpośredni udział w produkcji żywności. Napływy materiałowe z pierwszej, drugiej i trzeciej sfery agrobiznesu do rolnictwa plus podatki od produktów pomniejszone o dotacje do produktów stanowią łącznie zużycie pośrednie w tym sektorze (por. Mrówczyńska-Kamińska, 2010). W Polsce w 2020 roku w cenach bieżących wyniosło około 97,4 mld zł. Pozwoliło to na wytworzenie produkcji globalnej rolnictwa w wysokości 130,6 mld zł. W związku z tym wartość dodana brutto w rolnictwie wyniosła w 2020 roku około 43,2 mld zł (tabela 3). Na podstawie tych wielkości można określić efektywność poszczególnych rodzajów nakładów oraz efektywność makroekonomiczną rolnictwa. Tą pierwszą można określić za pomocą m.in. współczynników produktochłonności (materiałochłonności), majątkochłonności, inwestochłonności (Czyżewski i Grzelak, 2007; Mrówczyńska-Kamińska, 2010; Baer-Nawrocka i Mrówczyńska-Kamińska, 2019; Mrówczyńska-Kamińska, 2010). Najczęściej stosowany jest współczynnik bezpośredniej materiałochłonności, zwany technicznym współczynnikiem produkcji. Oblicza się go jako stosunek zużytych, bezpośrednio przez badaną gałąź, dóbr do wartości wytworzonej produkcji globalnej. Natomiast efektywność makroekonomiczna rozumiana jest jako udział wartości dodanej brutto w produkcji globalnej (efektywność powiązań międzygałęziowych). W latach 2000-2020 w Polsce odnotowano wzrost współczynnika bezpośredniej materiałochłonności z poziomu 0,56 do 0,67. Spowodowało to zmniejszenie dochodowości produkcji globalnej z 0,44 w 2000 roku do poziomu 0,33 w 2020 roku. Spadek dochodowości nastąpił jednak przy istotnym wzroście produkcji globalnej w polskim sektorze rolnym w 2020 roku i jednocześnie wzroście skali produkcji. Zmiany tych wskaźników mogą świadczyć o polepszeniu pozycji rolnictwa w świetle mechanizmu przepływów międzygałęziowych oraz bardziej racjonalnym wykorzystaniu nakładów z innych sektorów.

Podsumowanie

Wyniki analizy przepływów materiałowych w polskim rolnictwie w 2000 i 2020 roku wskazały na zmiany w powiązaniu tego sektora z gospodarką narodową. Szczególnie wyraźne są zmiany w strukturze zużycia pośredniego, co świadczy o rosnącym dostosowaniu się rolnictwa do wymogów nowoczesnej gospodarki rynkowej.

W ciągu 20 lat w strukturze zużycia pośredniego w rolnictwie wzrosły napływy z pierwszej sfery agrobiznesu, obejmującej przemysł środków produkcji i usługi. Oprócz tradycyjnych komponentów, takich jak nawozy mineralne, środki ochrony roślin czy paliwa, coraz większe znaczenie mają produkty przemysłu środków transportu. Rosnący udział napływów materiałowych z tych przemysłów jednoznacznie wskazuje na to, że do rolnictwa trafiają nowoczesne maszyny i urządzenia.

Ważną zmianą w strukturze zaopatrzenia materiałowego rolnictwa w badanym okresie jest wzrastający udział sfery usługowej. Zjawisko to wskazuje na ewolucję modelu funkcjonowania gospodarstw rolnych, które coraz częściej opierają swoją działalność nie tylko na tradycyjnych nakładach materiałowych (np. obrotach wewnętrznych), lecz także na wyspecjalizowanych usługach wspomagających proces produkcji. W konsekwencji rolnictwo staje się bardziej zintegrowane z gospodarką narodową, co sprzyja jego modernizacji oraz umożliwia szersze wykorzystanie nowoczesnych technologii.

Pozytywne zmiany w zaopatrzeniu materiałowym w rolnictwie potwierdza wzrastający udział produktów przemysku spożywczego (III sfera agrobiznesu). Chodzi tutaj głównie o pasze przemysłowe oraz produkty uboczne przetwórstwa rolno spożywczego, które trafiają do gospodarstw jako nakłady, zwłaszcza w produkcji zwierzęcej. Świadczy to o coraz silniejszych związkach między rolnictwem a przetwórstwem oraz o poprawie integracji w łańcuchu produkcji żywności.

Ważnym kierunkiem zmian w strukturze napływów materiałowych w rolnictwie jest zmniejszanie się udziału obrotów wewnętrznych. Jest to pozytywny sygnał świadczący o większym otwarciu sektora rolnego na zewnętrzne źródła zaopatrzenia. Potwierdzają to zmiany współzależności międzygałęziowych, które wskazują na polepszenie pozycji rolnictwa w świetle mechanizmu przepływów międzygałęziowych oraz bardziej racjonalne wykorzystanie nakładów z innych sektorów.

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Knowledge and Attitude of Extension Educators Towards Digitising Agricultural Extension Services in Kwara State, Nigeria

Abstract. This study assessed the knowledge, attitudes and constraints of agricultural extension educators regarding the integration of digital tools in agricultural extension services in Kwara State, Nigeria, by examining the extent to which extension educators are knowledgeable about and favourably disposed to using digital tools in agricultural extension services, as well as ascertaining the barriers to their effective adoption. A survey design was employed using a two-stage sampling technique. Data were collected via a structured interview schedule and analysed using descriptive statistics. The results showed that 57% of respondents were male, 71% were married and 40% held PhDs – with a mean age of 45.3 years and 11.3 years of teaching experience. A significant majority (77%) demonstrated high knowledge and a favourable attitude towards digital extension services. Although 82% were aware of digital tools, only 48.2% reported high usage. The main constraints were poor orientation, high internet connectivity costs and the expense of digital equipment. Correlation analysis indicated a statistically significant relationship between digital literacy and willingness to adopt digital extension tools ($r = 0.72$, $p < 0.05$), emphasising the role of technical capacity-building in accelerating adoption. These findings underscore the need for targeted capacity-building, financial incentives and infrastructure improvements to enhance digital adoption in agricultural extension services.

Keywords: knowledge, attitude, digital extension, extension services, educators

JEL Classification: O33, Q16

Introduction

Agricultural extension services play a crucial role in improving agricultural productivity, promoting sustainable practices and ensuring food security. Traditionally delivered through face-to-face interactions and group meetings, these services have undergone significant transformations due to advancements in digitisation. The introduction of mobile-based platforms, automated technologies and information and communication

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technologies (ICTs) has enabled timelier, focused and cost-effective delivery of knowledge and advisory services to farmers (Awad, 2021). These digitised systems provide farmers with actionable information, enhancing decision-making and increasing productivity while fostering inclusivity by attracting younger generations to agriculture through technology-driven innovations. However, despite the growing adoption of digital tools, several challenges persist, including limited infrastructure, connectivity issues and varying levels of digital literacy among farmers and extension personnel. Mohammed et al. (2023) and Vincent & Iyobhebhe (2025) reinforce that the pace of digital transformation in rural African agriculture remains uneven due to infrastructural bottlenecks and capacity gaps among extension personnel.

This study is grounded in the Technology Acceptance Model (TAM) (Davis, 1989), which provides a framework for understanding how individuals perceive and adopt technological innovations. TAM suggests that perceived usefulness and perceived ease of use are critical factors influencing the acceptance of new technologies. In the context of digitising agricultural extension, educators' willingness to integrate digital tools depends on their perception of the benefits these technologies provide in enhancing extension services. Furthermore, the Diffusion of Innovation Theory (Rogers, 2003) is relevant because it explains how new technologies spread within a social system. Extension educators serve as key change agents in the diffusion process, and their ability to adopt digital platforms determines the successful transmission of agricultural knowledge.

Understanding educators' attitudes towards digital tools is essential, as their readiness to incorporate ICTs influences agricultural extension outcomes. Factors such as digital literacy, accessibility, institutional support and socio-economic challenges significantly impact their adoption rate. Kwara State presents a compelling case for studying these dynamics due to its diverse socio-economic and geographical landscape, comprising both urbanised areas with strong digital infrastructure and rural communities facing broadband limitations and socio-economic constraints. Agriculture remains a significant livelihood for many within the state, making it essential to explore how digital extension systems can bridge gaps between knowledge dissemination and field implementation. While existing studies examine digital agricultural extension across Nigeria and globally, there remains a critical gap in understanding extension educators' preparedness, attitude and adoption of digital tools specifically in Kwara State. The ability of extension educators to efficiently utilise digital platforms is fundamental in ensuring the seamless transmission of agricultural innovations to farmers; yet, their perspectives on digitisation are underexplored (Kurdyś-Kujawska et al., 2021). Additionally, Okafor & Ekong (2024) argue that digital extension success in Nigeria depends heavily on the digital competencies and behavioural orientation of educators who act as intermediaries between innovation creators and end-users.

The COVID-19 pandemic underscored the significance of digital extension tools in maintaining resilience across agricultural systems. During the crisis, digital technologies were pivotal in mitigating disruptions in agri-food supply chains, facilitating access to financial aid and agricultural inputs and ensuring continuous communication between farmers and extension agents (FAO, 2020a; FAO, 2020b). These advancements emphasise the need for scalable digital solutions that can enhance agricultural extension services and ensure food security, particularly in regions where traditional extension methods are becoming increasingly challenging (Grote et al., 2021). The development of virtual networks and digital platforms has enabled global interaction and knowledge exchange among farmers,

extension agents and agricultural stakeholders, offering smallholder farmers access to innovative techniques, market intelligence and climate adaptation strategies (Ajaegbu et al., 2019). Mulungua et al. (2025) also confirm that countries with decentralised digital networks and multi-lingual content delivery achieved better extension continuity during the pandemic. However, realising the full potential of these systems in Kwara State necessitates addressing key barriers such as limited ICT infrastructure, affordability constraints and the need for continuous capacity building among extension educators.

Extension educators serve as the backbone of digitised agricultural extension systems. As intermediaries between agricultural researchers and farmers, they disseminate knowledge, facilitate innovation adoption and respond to evolving challenges in the agricultural landscape. Over time, their roles have evolved beyond technical advisory functions to include responsibilities such as monitoring disease outbreaks, assessing climate variability and analysing market trends. Despite their importance, extension educators in Kwara State face challenges such as insufficient training in ICT usage, restricted access to digital tools and motivational setbacks due to resource constraints (Saiz-Rubio & Rovira-Más, 2020; Savary et al., 2020). Addressing these limitations is essential to ensuring that e-extension services are effectively deployed and contribute to sustainable agricultural growth. This study focuses specifically on extension educators (lecturers) within the academic community who train future field-level advisors, thus indirectly shaping how advisory services are delivered to farmers. The aims are to:

1. Assess the knowledge of extension educators in Kwara State regarding the digitisation of agricultural extension services;
2. Examine the attitudes of extension educators regarding the digitisation of agricultural extension services;
3. Examine the capabilities of extension educators in Kwara State regarding the digitisation of agricultural extension services;
4. Identify key constraints to effective e-extension systems.

This research seeks to provide actionable insights that will inform policy directions, enhance service provision and bridge the identified research gaps. Specifically, the study will evaluate extension educators' familiarity with digital tools, examine their attitudes towards adopting these technologies and explore the infrastructural and socio-economic barriers affecting digital extension services within the state. To empirically test educators' engagement with digital extension services, this study posits that there is no significant relationship between extension educators' knowledge of digital tools and their attitude towards adopting digitised agricultural extension services in Kwara State. This hypothesis enables an objective analysis of whether educators' knowledge of digital platforms affects their willingness to implement such technologies in their extension practices. Given the urban-agricultural duality of Kwara State, this research offers a valuable case study for understanding the challenges and opportunities surrounding digital agricultural extension in Nigeria. By addressing disparities in access, infrastructure and training, the study contributes to broader goals of advancing sustainable agricultural practices, strengthening food security and fostering resilience amid global agricultural uncertainties.

Methodology

This study was conducted in Kwara State, Nigeria. The region was selected due to its strategic importance in agricultural development, characterised by a diverse mix of urban and rural settings with varying levels of digital accessibility. Kwara State serves as a representative case for examining digital agricultural extension services, as its extension educators encounter challenges related to infrastructure, digital literacy and adoption readiness. A survey research design was employed to systematically assess lecturers' knowledge, attitudes and constraints regarding digital extension services. The target population comprised lecturers in the departments of Agricultural Extension across state universities, selected for their direct involvement in training extension educators who ultimately implement digital extension services. These lecturers serve as key stakeholders in shaping the digital readiness of future extension personnel, making their perspectives essential for understanding the state of digitisation within agricultural extension programmes. This focus on university lecturers underscores their indirect but influential role in shaping front-line advisory services delivered by extension practitioners who interact directly with farmers.

A two-stage sampling procedure was used. In the first stage, higher education institutions offering Agricultural Extension programmes were purposively selected based on their relevance, research reputation and contribution to extension education. The selection criteria were the accreditation status of the Agricultural Extension department, active participation in extension training and research and institutional capacity in adopting digital extension technologies. In the second stage, 42 lecturers were randomly selected from these institutions, ensuring stratification by academic rank, years of teaching experience and areas of specialisation. This approach provided diversity in expertise and minimised biases related to knowledge and experience disparities. The final sample consisted of 42 respondents, with demographic and professional characteristics detailed in Table 1, including age distribution, household size, alternative occupations, teaching experience and professional affiliations. This comprehensive profile enables a clearer understanding of the sample's representativeness within the broader academic extension educator community in Kwara State.

Data were collected using a structured interview schedule developed with validated questions addressing key study variables such as digital literacy, attitudes towards digitisation and institutional challenges. The reliability of the instrument was confirmed through a pilot test conducted with agricultural extension educators outside the study area, achieving a Cronbach's alpha of 0.85, indicating high internal consistency. The validity of the instrument was established through expert review by specialists in agricultural extension and ICT, ensuring that the questions accurately captured the intended research concepts. Descriptive statistical tools, such as percentages and charts, were employed to present demographic characteristics and insights into respondents' digital literacy and attitudes towards digitisation. Additionally, correlation analysis was conducted to examine potential relationships between lecturers' familiarity with digital tools and their attitudes towards digital extension services. This statistical approach provided empirical evidence on whether educators' exposure to technology significantly influenced their adoption of digital innovations. Correlation analysis was used to understand the relationships between demographics, knowledge, attitude, constraints and the adoption of digitalisation of

agricultural extension services, to identify patterns, validate assumptions and make informed decisions. The correlation analysis does not establish causation but explores data and uncovers potential connections between variables.

Results and Discussions

Table 1 presents the results on the demographic characteristics of the respondents, providing significant insights into their potential readiness for the digitisation of agricultural extension services. The respondents' mean age of 45 ± 11 years indicates that the majority are within their productive years, with 69% under the age of 50. Younger individuals tend to be more receptive to innovation and technological advancements, which could facilitate their willingness to integrate digital tools into extension practices. This observation is supported by Aja et al. (2024), who emphasise that agricultural extension personnel in similar age brackets exhibit higher levels of adaptability, risk tolerance and enthusiasm for technological shifts. Such attributes could significantly influence their responsiveness to digital extension services. Marital status and household size provide additional insights into the professional engagement of respondents. With 76.2% of respondents married and an average household size of 6 ± 2 persons, their socioeconomic responsibilities may incentivise them to seek professional stability and innovation. The national average household size in Nigeria is approximately five persons (Statista, 2019), suggesting that the respondents manage slightly larger households, which may necessitate financial security and career advancements. The willingness to embrace digitisation may be influenced by a need for improved productivity and income diversification. Prior studies, such as those by Mustapha et al. (2022), highlight that individuals with extensive familial responsibilities often engage more proactively with professional opportunities that promise efficiency and long-term sustainability.

Table 1. Respondents by demographic characteristics (n = 42)

Variables	Percentage	$\bar{X}$ ± SD	Variables	Percentage	$\bar{X}$ ± SD
Age Interval			**Household Size**		
<41	33.3		1-5	45.2	
41-50	35.7	45.3 ± 11	6-10	45.2	5.94 ± 2
>50	31.0		11-15	9.5	
Alternative Occupation			**Years of Teaching Experience**		
Artisan	35.7		5-10	45.2	
Trading	54.7		11-15	38.1	11.25 ± 5
Others	9.5		16-20	14.3	
Membership of Professional Association			21-30	2.4	
Yes	57.0				
Others	42.9				

Source: Authors' computation, 2024.

The educational qualification plays a significant role in shaping attitudes towards agricultural digitisation, with 57% of respondents reporting membership in professional organisations. Such affiliations create platforms for knowledge exchange, networking and exposure to technological innovations, equipping extension personnel with the skills necessary to navigate digital extension successfully. The importance of professional networking in knowledge sharing has been well documented (Aja et al., 2024), illustrating how engagement in professional communities enhances the ability of extension personnel to collaborate, learn collectively and embrace new technologies. Additionally, higher educational qualifications contribute significantly to digital readiness, with 76% of respondents holding postgraduate degrees. Advanced education provides individuals with analytical skills, problem-solving capabilities and exposure to complex technological ecosystems, making them better equipped to integrate ICTs into agricultural extension services. This finding aligns with Mustapha et al. (2022), who argue that postgraduate education enhances the cognitive ability to interpret and apply digital innovations within professional contexts.

The respondents demonstrated a high degree of multifunctionality, with 54.7% reporting engagement in trading as an alternative occupation. This entrepreneurial spirit suggests adaptability, which could extend to their willingness to adopt digital tools for agricultural extension services. A strong entrepreneurial mindset can drive digital innovation, as extension personnel who engage in multiple income streams may recognise the efficiency and financial advantages of technology in their core profession. The gender distribution from Figure 2 revealed that 57% of respondents were male, reflecting a traditional trend where men dominate leadership roles in agricultural extension. While this may indicate established gender norms, fostering a more inclusive environment for female extension personnel could introduce diverse perspectives and enrich the adoption of digital tools in agricultural extension. Gender-responsive strategies have been increasingly advocated by scholars such as Mwangi et al. (2022), who highlight the critical contributions of women in agricultural knowledge dissemination, particularly in regions where gender disparities persist. Meena & Kumar (2025) emphasise that gender-inclusive extension services, such as tailoring training schedules to women's availability and promoting female leadership, significantly improve technology adoption and agricultural productivity among rural women. Similarly, Bamanyaki (2022) advocates for a gender equality and social inclusion approach in agricultural advisory services, noting that increasing female participation in extension roles enhances the relevance and reach of agricultural innovations. The Nigeria Gender Innovation Lab (2025) of the World Bank also reports that engaging more female extension agents and designing gender-sensitive programmes can close productivity gaps and boost national GDP by billions of dollars.

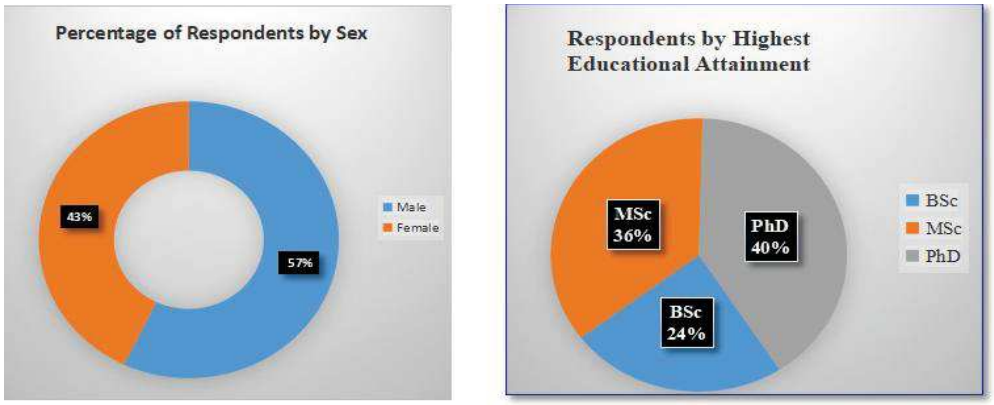

Fig. 1. Distribution of respondents by sex and highest educational attainment

Source: Authors' computation, 2024.

Educational qualification plays a significant role in shaping attitudes towards agricultural digitisation, with 57% of respondents reporting membership in professional organisations. Such affiliations create platforms for knowledge exchange, networking and exposure to technological innovations, equipping extension personnel with the skills necessary to navigate digital extension successfully. The importance of professional networking in knowledge sharing has been well documented (Aja et al., 2024), illustrating how engagement in professional communities enhances the ability of extension personnel to collaborate, learn collectively and embrace new technologies. Additionally, higher educational qualifications contribute significantly to digital readiness, with 76% of respondents holding postgraduate degrees. Advanced education provides individuals with analytical skills, problem-solving capabilities and exposure to complex technological ecosystems, making them better equipped to integrate ICTs into agricultural extension services. This finding aligns with Mustapha et al. (2022), who argue that postgraduate education enhances the cognitive ability to interpret and apply digital innovations within professional contexts.

A comparative analysis with international contexts highlights both shared challenges and unique opportunities in the digitisation of agricultural extension services. Studies from India (Singh et al., 2021) and Kenya (Mwangi et al., 2022) illustrate the effectiveness of structured training programmes and professional networks in enhancing digital literacy among extension personnel. However, challenges such as limited ICT infrastructure and inconsistent internet access, common in developing regions, require context-specific interventions. For instance, India has developed government-led digitisation training programmes that significantly boost technology adoption among extension personnel, whereas Kenya has implemented collaborative learning platforms that enable peer-to-peer engagement. Drawing lessons from both countries, Kwara State could benefit from a hybrid model that merges formal training programmes with collaborative, experience-based learning.

Respondents' knowledge on digital extension service delivery

The results from Table 2 demonstrate a strong awareness among respondents regarding the use of digital tools in agricultural extension services. The majority (81%, 83% and 81%) acknowledged the functionality of digital tools as websites, programs or online platforms, operating both offline and online to facilitate the dissemination of agricultural information. Their familiarity with social media platforms such as Facebook, Twitter and YouTube, as well as communication tools like Google Meet, WhatsApp and Email, alongside knowledge repositories such as Wikipedia, indicates that agricultural extension educators in Kwara State are relatively well-versed in digital technologies. This substantial level of digital awareness suggests that they possess the foundational competencies necessary for integrating digital tools into extension practices. However, the effective deployment of these tools depends on institutional support, sustained professional training and policy-driven incentives that facilitate seamless adoption.

Table 2. Respondents' knowledge on digital extension service delivery

Items	Yes (%)	No (%)
Digital tools can be programs, websites or online	81.0	19.0
They can be used online or offline	83.3	16.9
Digital tools must be downloaded before use	73.8	26.2
Digital e-extension support delivery of information in different ways?	81.0	19.0
Facebook is one of digital e-extension channels?	73.8	26.2
Twitter is one of digital e-extension channels?	78.6	21.4
YouTube is one of digital e-extension channels?	71.4	28.6
Google meet is one of e-extension channels?	83.3	16.9
Wikipedia is one of digital e-extension channels?	69.0	31.0
Email is one of digital e-extension channels?	78.6	21.4
WhatsApp is one of digital e-extension channels?	83.3	16.9
Can Radio be classified as a digital e-extension channels?	83.3	16.9
Digital tools allow for feedback	73.8	26.2
Data and information in digital tools can be edited	73.8	26.2

Source: Authors' computation, 2024.

These findings are consistent with Phillip and Ndirpaya (2020), who reported that agricultural extension agents (AEAs) in Nigeria exhibit baseline digital literacy and competency in ICT usage. Nonetheless, they cautioned that periodic training and retraining remain essential for ensuring that AEAs can fully leverage digital tools in their professional roles. Likewise, Ajah and Chigozie-Okwum (2019) highlighted that despite AEAs' knowledge of digital tools, strategic investment in capacity-building programmes is crucial to optimising their functionality in agricultural extension delivery. The convergence of findings underscores the reality that knowledge alone does not automatically translate into effective application. Without structured digital literacy programmes, educators may struggle

to adapt to rapidly evolving digital extension mechanisms, leading to suboptimal utilisation of available technological resources. The Pearson correlation analysis indicated a statistically significant positive correlation ($r = 0.72$, $p < 0.05$) between educators' knowledge of digital tools and their attitude towards digitisation. This suggests that increased exposure to technology enhances the willingness to integrate digital tools into agricultural extension services. However, several institutional barriers persist, including insufficient funding, weak ICT infrastructure and gaps in digital literacy training, which can hinder full-scale adoption. These challenges reflect broader structural limitations observed in other developing agricultural economies, where underinvestment in digital agriculture impedes the effectiveness of extension programmes. Mustapha et al. (2022) corroborate these findings, asserting that digital extension services in African agricultural systems often suffer from inadequate policy support, financial constraints and technological gaps, necessitating government-backed initiatives to bridge existing disparities. Furthermore, these findings align with Singh et al. (2021), who documented similar correlations among extension personnel in India, emphasising the necessity of capacity-building initiatives to bridge the gap between knowledge and adoption. Findings from this study also resonate with international perspectives, particularly research from India (Singh et al., 2021) and Kenya (Mwangi et al., 2022), where digital extension frameworks have been successfully integrated into agricultural advisory systems. In India, targeted government-led ICT training programs have substantially increased extension personnel's digital adoption rates, enabling more effective communication between farmers and educators. Similarly, Kenya's collaborative e-extension models have facilitated peer-to-peer learning, ensuring that extension personnel are not only digitally competent but also actively engage in knowledge-sharing networks to refine their expertise. Applying these models to Kwara State could yield similar benefits, particularly if policymakers prioritise structured capacity-building programs that blend formal digital training with hands-on experiential learning.

Respondents' attitude to digital extension service delivery

The results from Table 3 indicate that respondents generally hold a favourable attitude towards digital extension service delivery, with 73.3% expressing openness to its adoption. This suggests that extension educators recognise the value of digital tools in facilitating timely dissemination of agricultural information, enhancing extension outreach and empowering both farmers and extension agents. The increasing reliance on digital technologies in agricultural extension reflects global trends, as ICT-driven extension models have gained traction in recent years. Adebayo et al. (2023) emphasise that digital extension platforms have the potential to enhance agricultural productivity by enabling real-time knowledge transfer and decision-making support. Mukherjee et al. (2025) further confirm that e-agriculture and e-extension are dominant themes in global agricultural research, indicating a growing consensus on the transformative role of ICTs in extension services.

Despite this optimistic outlook, respondents identified specific barriers that could hinder the full-scale adoption of digital tools. Sixty-nine per cent noted that digital platforms often lack flexibility in accommodating local languages, posing a communication challenge for farmers in rural communities. Language accessibility has been a critical issue in ICT-driven extension systems, as standardised digital platforms may not always align with the linguistic diversity of farming populations. Singh et al. (2022) argue that the effectiveness of digital extension services is contingent on linguistic inclusivity, as farmers are more likely to engage with technologies that reflect their native language. Addressing this issue calls for the

localisation of digital tools, ensuring that extension resources, mobile applications and advisory services are available in multiple languages relevant to the target communities. Okolo & Tano (2024) emphasise that inclusive language technologies must go beyond translation to address power dynamics and cultural representation, advocating for participatory design in digital extension platforms to ensure equitable access for marginalised communities.

Table 3. Respondents' attitude on digital extension service delivery

Items	Yes (%)	No (%)
Digital tools are too rigid and do not allow the use of local languages	69.0	31.0
Farmers can be taught to use digital tools	83.3	16.9
Digital tools help both the farmers and extension agents to get an updated information about agriculture	83.3	16.9
They are not important in the dissemination of agricultural information	78.6	21.4
Digital tools are efficient but not consistent	83.3	16.7
They have disadvantage of data insecurity	78.6	21.4
All digital tools are complex and require special training to use	78.6	21.4
Power supply can be a major setback for the use of digital tools in rural Nigeria	64.3	35.7

Source: Authors' computation, 2024.

Additionally, 64.3% of respondents cited an unreliable power supply as a major constraint, particularly in rural areas where electricity access remains inconsistent. This finding aligns with Mwangi and Ouma (2021), who found that infrastructural deficits, including electricity and broadband limitations, negatively impact the adoption of digital agricultural extension services in sub-Saharan Africa. Extension educators in Kwara State face similar challenges, as digital tools require stable internet connectivity, adequate power infrastructure and affordable access to ICT devices to be effectively deployed. Power disruptions undermine the reliability of digital extension delivery, making it difficult for educators to maintain uninterrupted communication with farmers. Mustapha et al. (2022) advocate for hybrid ICT models, including offline-accessible digital resources and SMS-based advisory services, as viable solutions to mitigate power-related constraints. Vincent et al. (2024) and Iyobhebhe & Abiodun (2025) corroborate this, highlighting that hybrid renewable energy systems and decentralised ICT hubs can significantly improve rural electrification and digital service delivery in Nigeria, especially when integrated with solar-powered extension centres.

The findings resonate with international studies that highlight both the opportunities and challenges associated with digital agricultural extension. In India, for example, Patel et al. (2022) examined the effectiveness of mobile-based extension platforms and found that educators exhibit positive attitudes towards digital tools when institutional support is strong. This underscores the importance of policy-driven interventions that incentivise digital adoption while addressing infrastructural gaps. In Kenya, Kimani et al. (2023) identified financial limitations and inadequate ICT training as primary barriers to digital extension implementation. The study recommended structured training programmes that equip

extension educators with practical digital skills, ensuring that they can effectively navigate technological advancements. Similarly, Mulungua et al. (2025) found that ICT-based extension services significantly improve awareness, adoption and yield outcomes when tailored to local contexts and supported by capacity-building initiatives. Their review revealed that well-designed messaging and integration with complementary interventions are key to success.

Awareness and usage level of digital extension tools by the respondents

The data from Table 4 highlights a substantial gap between awareness and usage of digital extension tools among respondents. While 82% of respondents demonstrated high awareness of digital tools, only 48.2% reported actively using them. This disparity is particularly evident with tools such as USSD and interactive voice response (IVR), which had impressive awareness levels of 91%, but much lower usage rates at 55% and 45%, respectively. This suggests that while extension educators recognise the existence and potential of digital tools, various systemic challenges prevent widespread practical adoption. The findings align with prior research, notably Owolabi & Yekinni (2022), which noted that agricultural extension agents exhibit strong theoretical knowledge of ICTs but face constraints that limit their full implementation.

A closer examination of the barriers restricting digital tool adoption reveals affordability and technical constraints as dominant factors. While respondents acknowledge the effectiveness of digital tools such as short messaging services, mobile apps and video conferencing platforms, financial limitations and insufficient technical expertise appear to hinder their frequent usage. Mustapha et al. (2022) argue that the cost of acquiring digital tools, maintaining subscriptions and ensuring stable connectivity are among the primary concerns limiting agricultural extension personnel's ability to integrate ICTs into their work. Additionally, Phillip & Ndirpaya (2020) emphasise that limited training opportunities and a lack of digital proficiency create significant barriers, preventing educators from fully leveraging the available technological resources. The underutilisation of digital tools among extension educators in Kwara State reflects broader trends observed in other developing agricultural economies.

Table 4. Awareness and usage level of digital extension tools by the respondents

Items	Level of Awareness (%)		Level of Usage (%)	
	High	Low	High	Low
Short Messaging	85.5	14.3	13.9	88.1
Interactive Voice Response	90.5	9.5	44.7	45.3
Apps	85.5	14.3	45.3	54.7
USSD	90.5	9.5	54.8	45.3
Web	81.0	19.0	54.8	45.3
Video conferencing	78.6	21.4	57.2	42.8
News and discussion group	61.0	31.0	50.0	50.0
Farming Video	83.3	16.7	57.1	42.9

Source: Authors' computation, 2024.

In India, Singh et al. (2021) examined the widespread use of mobile advisory systems and found that while extension educators exhibit strong awareness of mobile-based platforms, sustained grassroots-level engagement and structured training programmes are necessary to ensure adoption. Similarly, in Kenya, Mwangi et al. (2022) highlighted the critical role of professional networks in fostering digital competence among extension personnel, emphasising that peer-driven capacity-building initiatives improve digital literacy and facilitate the practical application of ICT tools. These insights suggest that Nigeria could benefit from adapting similar frameworks, particularly by integrating structured digital training programmes within extension education curricula and fostering professional networks to encourage peer learning and digital tool adoption.

Solving these issues requires multi-pronged interventions that emphasise affordability, technical capacity-building and infrastructural support. To improve accessibility, stakeholders should reduce the costs associated with acquiring and maintaining digital tools by offering subsidies or financial grants to agricultural extension educators. This approach has proven effective in countries like India and Kenya, where government-led incentives significantly increased digital tool adoption among extension personnel (Kimani et al., 2023). Moreover, targeted training programmes are essential to equip extension educators with practical digital skills. Workshops, tutorials and online modules tailored to address specific digital literacy gaps can empower extension educators to fully engage with available technologies. Adebayo et al. (2023) advocate for hands-on digital training programmes, noting that skill acquisition directly influences the extent to which educators integrate ICT tools into their extension services. Beyond affordability and training, connectivity and infrastructure development remain key priorities. Many respondents cited unstable internet and unreliable power supply as significant limitations affecting digital tool usage. Ouma & Mwangi (2021) reported similar trends in African agricultural extension systems, where weak infrastructure hinders technology adoption in rural areas. To mitigate this, stakeholders must prioritise investments in broadband expansion, provision of off-grid power solutions and support for local ICT innovations that provide low-cost digital access for extension educators. This will bridge the gap between digital awareness and usage, ensuring that extension educators can effectively integrate digital tools into their work.

Constraints to the utilisation of digital extension tools

As shown in Table 5, the major constraints identified by respondents were poor orientation (92.8%), high internet connectivity costs (90.5%) and high equipment costs (90.6%). These challenges align with findings by Ibe et al. (2020) and Godson-Ibeji et al. (2018), who emphasised infrastructural deficits and affordability issues as significant barriers to e-extension adoption in Nigeria.

The study identified several major constraints to the utilisation of digital extension tools by agricultural extension agents, including poor orientation (92.8%), high internet connectivity costs (90.5%) and high equipment costs (90.6%). These issues highlight infrastructural deficits and affordability challenges that hinder the effective adoption of e-extension systems. This finding is consistent with observations by Ibe et al. (2020) and Godson-Ibeji et al. (2018), who noted that extension agents in Nigeria face significant barriers related to inadequate infrastructure and the prohibitive cost of digital tools. Other challenges revealed by the study include erratic power supply, limited internet coverage and unfavourable government policies, which further compound the difficulties

faced by extension personnel in utilising digital tools. These systemic issues require urgent attention, as they impede the accessibility and effectiveness of digital extension systems, particularly in underserved areas. Additionally, constraints such as high maintenance costs, poor technical know-how and the unavailability of modern gadgets reflect broader gaps in support and resource allocation, which limit the potential of extension agents to leverage digital innovations.

Table 5. Constraints to the utilisation of digital extension tools by the respondents

Constraints	Percentage	Grand Mean
Poor orientation	92.8	3.0
High cost of internet connectivity	90.5	2.9
High cost of equipment	90.6	2.9
Power instability	85.7	2.7
Poor ICT infrastructure	85.7	2.7
High cost of internet maintenance	83.4	2.7
Poor technical know-how	83.3	2.7
Unavailability of modern gadgets	83.3	2.6
Limited internet coverage	81.0	2.6
Unfavourable government policies	78.5	2.5
Poor enabling environment	78.5	2.5
High cost of tool maintenance	78.6	2.5

Source: Authors' computation, 2024.

Addressing these challenges requires a range of targeted policy-level interventions. First, infrastructure development must be prioritised by expanding internet coverage and ensuring a reliable power supply, both of which are essential for the effective use of digital tools. To reduce the financial burden associated with acquiring and maintaining ICT tools, policymakers should explore measures such as subsidies, grants and tax relief. These efforts would help extension institutions and personnel gain the necessary resources for effective e-extension service delivery. Singh et al. (2021) documented the success of mobile advisory systems in India, which were bolstered by structured training and grassroots engagement, while Mwangi et al. (2022) highlighted how professional networks in Kenya have enhanced digital knowledge among extension educators. Although developed nations like the United States benefit from robust ICT infrastructures and high digital literacy, developing regions continue to face challenges such as inconsistent connectivity and limited affordability. By adapting effective training models and collaborative frameworks from contexts like India and Kenya, Nigeria can better integrate digital tools into agricultural extension practices.

Relationship between Selected Socio-Economic Characteristics and Attitude Towards Digitising Agricultural Extension Services

The results of the correlation analysis showed that age ($r = 0.191$) and years of teaching ($r = 0.054$) had a positive and significant relationship with attitude towards digitising agricultural extension services at $P \leq 0.01$. The results further show that the number of years

spent in school (r = 0.152) and knowledge of digital extension services (r = 0.720) had a positive and significant relationship with attitude towards digitising agricultural extension services at P ≤ 0.05. The results indicated that younger individuals tend to be more receptive to innovation and technological advancements, which could facilitate their willingness to integrate digital tools into extension practices. Their academic qualifications, years of teaching and knowledge of digital extension tools are major determinants of their attitude towards practising digitising agricultural extension services. These three factors provide individuals with analytical skills, problem-solving capabilities and exposure to complex technological ecosystems, making them better equipped to integrate ICTs into agricultural extension services. This finding explicitly refutes the initial hypothesis stated earlier in the paper, which posited no significant relationship between educators' knowledge of digital tools and their attitude towards adopting digital extension services. The strong positive correlation (r = 0.720) clearly demonstrates that greater knowledge among extension educators is associated with a more favourable attitude, confirming that digital literacy plays a key role in shaping their openness to ICT-based agricultural innovation.

Table 6. Relationship between selected socio-economic characteristics and attitude towards digitising agricultural extension services

Variable	R-value
Age of respondents	0.191**
Number of years spent in school	0.152*
Household size	0.147
Years of teaching	0.054**
Knowledge of digital extension services	0.720*
Usage of digital extension tools	0.699
Challenges in accessing digital extension tools	0.529

** Significant at p ≤0.01; * Significant at p ≤0.05

Source: Authors' computation, 2024.

Conclusions and recommendations

The findings of this study reveal that while agricultural extension educators in Kwara State exhibit high levels of awareness and hold favourable attitudes towards digital tools, their actual usage remains moderate due to socio-economic and infrastructural constraints. Despite being well-informed and open to adopting digital extension services, financial limitations, unreliable internet connectivity and inadequate digital infrastructure impede full-scale integration and practical utilisation. This disconnect between awareness and application underscores the need for targeted interventions that bridge technological, financial and institutional gaps to ensure extension educators can fully leverage digital innovations. Furthermore, the empirical results presented in this study explicitly refute the initial hypothesis positing no significant relationship between extension educators' knowledge of digital tools and their attitude towards digitising extension services. The strong positive correlation observed confirms that greater knowledge is indeed linked to a more

favourable attitude, thereby reinforcing the importance of digital literacy as a key enabler of technology adoption in agricultural extension. However, the scope of this study was limited to extension educators within Kwara State, and the relatively small sample size may constrain the generalisability of the findings to broader populations or other geopolitical zones. Future studies should consider expanding the sample size and incorporating comparative analyses across multiple states or regions to strengthen the robustness and applicability of the conclusions.

To address these challenges, strengthening the digital capacities of extension educators should be a top priority. This requires structured training programmes, periodic retraining sessions and hands-on workshops incorporated into conferences organised by professional extension bodies. These initiatives must focus on technical proficiency, digital literacy and ICT troubleshooting, ensuring that educators are equipped with practical knowledge to navigate digital tools effectively. Investments in digital infrastructure by universities and government agencies should prioritise robust internet services, reliable power supply and the subsidisation of digital equipment at extension offices. Addressing these foundational constraints will significantly enhance digital tool accessibility, creating an enabling environment for the seamless adoption of e-extension models. Becerra-Encinales et al. (2024) and Ojo et al. (2024) emphasise that localised extension strategies and context-aware digital platforms are essential for overcoming infrastructural and institutional limitations in developing countries. These studies also highlight the importance of participatory design and multi-directional communication between extension agents, researchers and farmers to ensure relevance and sustainability. Further institutional and policy-level interventions are necessary to sustain digital transformation in agricultural extension services. Stakeholders should establish digital inclusion policies, ensuring that rural extension educators receive targeted subsidies, financial grants or public-private partnerships aimed at reducing digital tool acquisition costs. Lessons from international contexts, such as India's grassroots training models (Singh et al., 2021) and Kenya's peer-driven capacity-building initiatives (Mwangi et al., 2022), demonstrate that structured institutional backing, consistent funding and collaborative digital extension strategies are fundamental to overcoming adoption barriers. Additionally, Sen et al. (2025) advocate for interactive digital extension systems that incorporate feedback loops and localised content to improve engagement and effectiveness among smallholder farmers. By implementing contextualised best practices and fostering cross-sector collaborations, agricultural extension systems in Kwara State can transition towards a more inclusive, efficient and technology-driven framework. These interventions will empower educators, enhance knowledge dissemination and strengthen agricultural advisory services, contributing to the broader goals of food security, agricultural productivity and sustainable rural development.

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Sustainable Management of Challenges in the Agri-Food Supply Chain: the Case of Upcountry Vegetable Farmers in Nuwara Eliya District, Sri Lanka

Abstract. This study aimed to identify the challenges associated with the sustainable management of the agri-food supply chain, with a particular focus on the upcountry vegetable sector. Additionally, it sought to develop strategies to address these challenges and establish mechanisms to further enhance sustainable supply chain management. A sample of 300 vegetable farmers from the Nuwara Eliya district was selected using a simple random sampling method. Data collection was undertaken between July and October 2024 through a field survey and two focus group discussions. Descriptive statistics and Garrett's Ranking technique were applied to analyse the quantitative data obtained from the survey. The qualitative data from the focus group discussions were analysed using thematic analysis. The findings revealed several key social challenges to sustainable development in agri-food supply chains, including limited access to agricultural inputs, insufficient awareness about managing these supply chains and low adoption of modern technologies. Major economic challenges identified included high production costs, inadequate financial support, difficulties for small-scale farmers in competing in both domestic and international markets, and poor knowledge of using ICT for market information. As the environmental challenges included long-distance transportation of products, limited product diversification capabilities and threats to entering export markets through maintaining the product quality. Hence, the study suggests providing concessional financial support for purchasing agricultural inputs, conducting awareness programmes to improve knowledge and experience in managing supply chains, introducing modern technologies to encourage the adoption of best practices, implementing strategies to reduce production costs, developing market information systems with better ICT access and improving transportation and opportunities for producing diversified agri-food products.

Keywords: agri-food, challenges, sustainable development, Sri Lanka, supply chains

JEL Codes: Q13, Q56

Introduction

The agri-food industry is one of the major manufacturing sectors in both developed and developing countries. This sector often consumes significant natural resources during the manufacturing process of agri-foods. Consequently, constraints within agri-food supply chains (AFSCs) hinder sustainable development in many developing countries (Jayalath et al., 2021). While developed countries pay greater attention to the sustainable management of AFSCs for community development, developing countries face numerous socio-economic issues due to the mismanagement of agri-food supply chain activities (United Nations [UN], 2020). Moreover, the AFSC is central to ensuring food security and supporting sustainable agricultural practices globally (Rejeb et al., 2021). However, increasing challenges such as

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climate change, resource depletion, and the need for economic equity are intensifying the pressure on AFSCs to adopt more sustainable practices (Annappa et al., 2023). Sustainable AFSC management integrates environmental, economic and social dimensions to create more resilient and equitable supply chains (Wang et al., 2024). Thus, sustainable management of AFSCs has the potential to foster development in rural areas of developing countries (Nchanji and Lutomia, 2021).

Given that Sri Lanka is a developing country, it is crucial to explore how the management of agri-food supply chains can be effectively utilised to address and mitigate the current challenges faced by AFSCs in Sri Lanka. This study specifically focuses on the upcountry vegetable sector in the Nuwara Eliya district, examining how AFSC management can be applied to overcome the challenges faced by smallholder farmers in this region.

In particular, farming requires an adequate amount of resources and a wide variety of services to optimise productivity. Resource deficiencies lead to lower productivity and reduced efficiency in agri-food supply chains (Lezoche et al., 2020; Food and Agriculture Organisation [FAO], 2018). In the context of developing nations, key challenges within their AFSCs include resource scarcity for farming, poor post-harvest practices, global climate change, environmental degradation and increasing food demand (De Boni et al., 2022).

This research aims to investigate the existing agri-food supply chain practices among upcountry vegetable farmers in Nuwara Eliya and to identify opportunities for improving sustainability through targeted interventions in supply chain management. The study seeks to understand the key constraints faced by the farmers and propose sustainable strategies involving technology adoption, policy reform, collaboration among stakeholders and capacity-building initiatives.

By focusing on a context-specific case in Sri Lanka, this research contributes to the broader literature on sustainable AFSC management in developing countries. It fills a critical gap by offering localised insights and practical recommendations that can be applied in similar rural and resource-constrained environments. Furthermore, it underscores the importance of integrating sustainability into every stage of the supply chain to promote both environmental stewardship and rural economic development.

Literature review

What are agri-food supply chains?

Agri-food supply chains (AFSCs) involve the sequential processes of transforming agricultural inputs into distributed and marketed agri-foods through production and processing (Borsellino et al., 2020; Lezoche et al., 2020). AFSCs are characterised by strong linkages between farmers, food processors or traders and retailers (Djekic et al., 2021; Aday and Aday, 2020). A typical agri-food supply chain is illustrated in Figure 1.

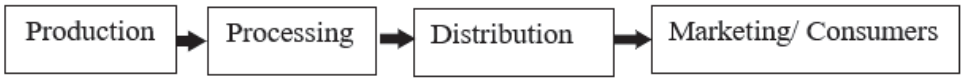

Fig. 1. Typical agri-food supply chain

Source: United States Department of Agriculture [USDA], 2022.

Moreover, during the processing stage, various processed products are created from farm products and are then delivered to consumers through transportation, storage and retailing (FAO, 2022; Vroegindewey and Hodbod, 2018).

Conceptualising Sustainable AFSC Management

Sustainable AFSC management encompasses various approaches, including resource optimisation, waste reduction, fair trade and ethical labour practices (Awais, 2024). According to Gyarmati (2024), the sustainability of AFSCs is typically evaluated through three pillars: environmental sustainability, economic sustainability and social sustainability. The environmental dimension involves reducing the carbon footprint, minimising waste and promoting biodiversity. Economic sustainability ensures profitability and long-term viability, while social sustainability focuses on labour rights, community welfare and equity in food distribution (Rosli et al., 2024). Pereira et al. (2020) highlight that sustainability in AFSCs requires a systemic approach, incorporating the entire supply chain from production to consumption. The adoption of circular economy principles, such as resource reuse and waste valorisation, has been emphasised in recent studies as a way to improve the sustainability performance of AFSCs (Bakker et al., 2023).

Importance of managing agri-food supply chains

AFSC management plays a significant role in enhancing sustainability in the agriculture sector, including reductions in labour requirements and costs (Hidayati et al., 2021). Managed AFSCs typically have lower labour requirements due to strong linkages between each step of the supply chain and a high degree of mechanisation. Consequently, labour needs are reduced, and expenses associated with labour wages are minimised within AFSCs (Bhat and Jõudu, 2019). Additionally, as the efficiency of AFSCs increases, the transparency of the production process improves, supporting better production practices in agribusinesses (FAO, 2022). Well-managed AFSCs also feature strong linkages between each component of the supply chain, which enhances communication throughout the process (Kim, 2018). Effective management of AFSCs involves the formulation and implementation of timely and significant legislation to enhance their efficiency and effectiveness (FAO, 2018; International Labor Organization [ILO], 2016). Sustainably managed AFSCs produce high-quality end products that meet consumer preferences, thereby enhancing competitive advantage (Barua and Rahman, 2021; Reklitis et al., 2021). Furthermore, properly managed AFSCs facilitate access to export markets by expanding global trade in agri-foods (Dissanayaka and Thibbotuwana, 2021). Overall, well-managed AFSCs contribute to the sustainability of the agricultural sector by minimising negative externalities and supporting sustainable development (Borsellino et al., 2020). However, consider the environmental sustainability, economic sustainability and social sustainability in AFSCs as follows:

Environmental Sustainability in AFSCs

Environmental sustainability is a primary concern in AFSCs. Sustainable sourcing and eco-efficient logistics are essential to reducing environmental impacts (Wang et al., 2024; Tasca et al., 2017). Innovations such as precision farming, organic farming and regenerative agriculture are becoming increasingly prominent (Konfo et al., 2024; Rempelos et al., 2023). Technologies such as sensor-based systems and drones allow farmers to optimise inputs like water and fertilisers, reducing environmental pollution (Ranjan et al., 2024). Additionally,

the use of renewable energy in processing and sustainable packaging is key to reducing the environmental footprint of AFSCs (Cossu et al., 2024).

Economic Sustainability and Resilience

Economic sustainability in AFSCs revolves around long-term profitability and the resilience of supply chains to external shocks, including geopolitical instability and climate change (Oriekhoe et al., 2024). Research highlights the importance of risk management, supply chain diversification and digital technologies for enhancing supply chain resilience (Olutimehin et al., 2024). Additionally, addressing food waste, particularly during storage, transport and retail, is essential for improving economic and environmental sustainability (Todd and Faour-Klingbeil, 2024).

Social Sustainability and Fair-Trade Practices

Social sustainability is concerned with labour rights, fair wages and food security (United Nations, 2020). Ethical supply chain practices, including fair trade certifications, have gained attention for improving the livelihoods of farmers in developing countries (El Din and Masengu, 2024). Furthermore, food access and equity remain significant challenges, as small-scale farmers often face barriers to market participation and large retailers dominate the food distribution system (Dhillon and Moncur, 2023).

Digitalisation and Technology in Sustainable AFSCs

Technological advancements such as IoT, artificial intelligence (AI) and big data analytics are transforming AFSCs (Konfo et al., 2023). These technologies are being applied to optimise resource use, reduce waste and improve decision-making (Misra et al., 2020). AI-driven predictive analytics helps farmers improve production schedules, while IoT devices monitor factors like soil health and weather patterns, enabling more efficient farming (Burak, 2024).

Sustainable management of the agri-food supply chain in Sri Lankan scenario

According to Wątróbski (2019), sustainable management can be defined as the formulation, implementation and evaluation of decisions and actions related to both environmental and socio-economic sustainability. Thus, sustainable management of the agri-food supply chain is increasingly recognised as essential for promoting environmental health, economic stability and social fairness. This is particularly true in regions that are both ecologically sensitive and economically dependent on agriculture (Çakmakçı et al., 2023). The Nuwara Eliya District in Sri Lanka, known for its upcountry vegetable cultivation, exemplifies the complexities involved in managing a sustainable agri-food supply chain, given its high altitude, diverse crops and reliance on small-scale farming (Aiome et al., 2022).

Sustainable management in this context involves a range of practices aimed at reducing environmental impact, optimising resource use and strengthening the resilience of farming systems (Çakmakçı et al., 2023). In Sri Lanka, proper management strategies for AFSCs have not yet been well formalised or implemented in the agricultural sector (Dissanayaka and Thibbotuwana, 2021). When AFSC activities are isolated, it leads to various issues within the agriculture sector. As a result, Sri Lanka loses approximately 270,000 metric tons of fruit and vegetable production due to inefficiencies in the supply chain (Dissanayaka and

Thibbotuwana, 2021). This situation underscores the importance of sustainably managing AFSCs within Sri Lanka's agri-food sector.

Recently, the management of AFSCs has received attention from researchers and practitioners. However, the literature suggests that the potential benefits of sustainability in AFSCs are not yet fully explored, especially regarding enhancing the sustainability of the agricultural sector and developing Sri Lanka's economy (Jayalath et al., 2021). In Nuwara Eliya, vegetable farmers face significant challenges such as resource management, market access and climate change impacts (Gunathilaka and Samarakoon, 2022).

Methodology

The concept of managing agri-food supply chains (AFSCs) is well established in Sri Lanka. Both developed and developing countries have increasingly embraced AFSC management as a crucial strategy to promote sustainability within the agricultural sector (Çakmakçı et al., 2023). Recently, AFSC management has been recognised as a vital approach for achieving sustainable development in many developing nations, including Sri Lanka (Bandara and Amarasekara, 2023). This study aimed to identify the challenges associated with sustainable AFSC management in Sri Lanka's upcountry vegetable sector and to propose strategies to address these issues. Furthermore, the study sought to develop mechanisms to enhance the overall sustainability of AFSC management. In the Nuwara Eliya District, approximately 66,148 vegetable farmers operate within this sector. Using Krejcie and Morgan's (1970) sample size determination table, a sample size of 300 farmers was selected as appropriate for this population. A simple random sampling method, utilising a random number generator, ensured that all participants had an equal chance of selection. This sample size is widely accepted as sufficient to provide reliable and accurate results while balancing practical constraints, particularly with a 95% confidence level. Data collection took place from July to October 2024, employing a pre-tested, self-administered questionnaire complemented by two focus group discussions, each involving ten participants. The questionnaire survey examined the current status of AFSC management and identified challenges to sustainable practices. The focus group discussions offered in-depth insights into the obstacles faced and helped formulate timely and practical strategies to overcome them. For data analysis, descriptive statistics profiled the socio-economic characteristics of respondents, while Garrett's Ranking technique was applied to prioritise the key challenges encountered in the sustainable management of AFSCs in Sri Lanka.

Results and Discussion

Socio-demographic profile of the respondents

Descriptive statistics were used to analyse the selected socio-demographic profile of the selected respondents. The results are presented in Table 1.

Table 1. Socio-demographic profile of the respondents

Factor	Category	Number	Percentage (%)
Age (Years)	20-39	60	20.0
	40-59	195	65.0
	60-79	45	15.0
Gender	Male	257	85.7
	Female	43	14.3
Marital status	Single	10	3.3
	Married	290	96.7
	Other	00	00.0
Educational level	No primary education	05	01.7
	Primary education	20	06.7
	Junior secondary education (O/L)	243	81.0
	Senior secondary education (A/L)	32	10.7
Monthly income (LKR)	Less than 20,000	27	09.0
	20,001 - 40,000	263	87.7
	40,001 - 60,000	10	3.3
Number of family members	less than 4	57	19.0
	4-5	223	74.3
	more than 5	20	6.7
Cultivated land size (Acres)	0.0-0.5	30	10.0
	0.5-1.0	63	21.0
	1.0-1.5	197	64.3
	1.5-2.0	10	3.3
Farming experience (Years)	0-5	55	18.3
	5-10	92	30.7
	10-15	133	44.3
	15-20	20	6.7

Source: Field survey July - October 2024.

According to the findings of Table 1, the majority of the respondents (65.0%) were in the age category of 40-59 years. Additionally, among the respondents, 85.7% were male and

only 14.3% were female. Furthermore, in this study, 96.7% of farmers were married, and the majority of them (81.0%) had studied up to junior secondary education (GCE Ordinary Level). However, only 10.7% of the respondents had senior secondary education. According to FAO (2018), if farmers have a considerable level of education, there is potential for access to the adoption of modern farming technologies, access to necessary credit facilities and also agricultural information needs and accessibility. Nevertheless, most of the respondents reported that they had 4-5 members in their families. Moreover, their average farm size was 0.84 acres, and the average level of farming experience was 13 years. While 87.7% of them received LKR 20,001–40,000 as their monthly income, 9.0% received only LKR 20,000 as their monthly income.

Measurement of constructs

The challenges associated with AFSCs can be broadly categorised into three main constructs: social, economic and environmental. 'Social challenges' refer to barriers related to awareness, access, institutional support and socio-cultural issues that hinder effective participation in the development of AFSCs. These include limited accessibility to agricultural inputs such as: fertilisers, seeds and agrochemicals; a lack of research and development supporting small-scale agri-food production; farmers' limited awareness of grassroots-level AFSC management; gender-based barriers to access; underutilisation of modern farming technologies; the absence of clear policies and regulations for AFSC governance at the farmer level; weak collaboration between public and private institutions.

'Economic challenges' encompass financial and market-related constraints affecting the sustainability of AFSCs. These challenges include high production costs, insufficient financial support for AFSC activities, limited agribusiness expansion based on the 3Rs (Reduce, Reuse, Recycle) concept, small-scale farmers' difficulty in competing in local and international markets, poor economic conditions among farmers and AFSC stakeholders and inadequate knowledge of ICT tools for accessing market information.

'Environmental challenges' highlight environmental and logistical difficulties influencing AFSC performance and competitiveness. These challenges include adverse climatic conditions causing significant yield losses, the burden of long-distance transportation of agricultural goods, concerns over maintaining product quality for export markets, limited capacity for product diversification and high levels of competition among AFSC participants. To assess these challenges, a survey instrument can be used where respondents indicate their level of agreement with each statement on a five-point Likert scale, ranging from 1 (Strongly Disagree) to 5 (Strongly Agree) in a quantitative manner.

Farmer characteristics reflecting two focus group discussions

The characteristics of the farmer, reflecting two focus group discussions, are presented in Table 2.

Table 2. Characteristics of the farmer reflecting two focus group discussions

Focus Group	Farmer ID	Type of Farmer	Age	Farming System	Key Focus Area	Theme(s)	Code(s)	Insights / Remarks
1	1	Carrot Farmer	45	Highland root crop farming	Limited input access	Social Challenge	Limited input access	Access to quality seeds and organic fertilisers is limited and costly.
	2	Leek Farmer	39	Small-scale vegetable farming	Market competitiveness challenge	Economic Challenge	Market competitiveness challenge	Struggles to compete with low-cost imports and local bulk producers.
	3	Cabbage Farmer	61	Mono-crop hill farming	Poor institutional coordination	Social Challenge	Poor institutional coordination	Weak support from agri-extension services hinders market connections.
	4	Bean Farmer	43	Intensive vegetable farming	Awareness gap in AFSC management	Social Challenge	Awareness gap in AFSC management	Limited understanding of supply chain efficiency and market linkages.
	5	Tomato Farmer	56	Mid-elevation vegetable belt	Underuse of modern farming tech	Social Challenge	Underuse of modern farming tech	Slow adoption of tech like poly tunnels or drip systems in hilly terrain.
	6	Potato Farmer	51	Highland monocropping	Financial constraints	Economic Challenge	Financial constraints	Needs capital for cold storage and market expansion.
	7	Bell Pepper Farmer	48	Greenhouse farming	Export quality compliance issues	Environmental Challenge	Export quality compliance issues	Post-harvest losses and lack of standardisation hinder exports.
	8	Cucumber Farmer	60	Tunnel farming	ICT illiteracy in market access	Economic Challenge	ICT illiteracy in market access	Limited ability to use digital tools for price discovery or buyer outreach.
	9	Lettuce Farmer	42	Organic leafy greens	Lack of product diversification	Environmental Challenge	Lack of product diversification	Focused only on fresh sales; no value-added processing or packaging.
	10	Radish Farmer	55	Upland seasonal farming	High agri-production cost	Economic Challenge	High agri-production cost	Rising costs of land prep, labour and transport strain profits.
2	1	Cauliflower Farmer	44	Cool-climate cultivation	Climate-related yield loss	Environmental Challenge	Climate-related yield loss	Irregular rainfall and frost damage affect yields.
	2	Broccoli Farmer	49	Export-oriented farming	Climate-related yield loss	Environmental Challenge	Climate-related yield loss	Export targets unmet due to unseasonal rains.
	3	Chilli Farmer	46	Mixed crop with spices	Low economic resilience	Economic Challenge	Low economic resilience	Fluctuating prices make income unstable.
	4	Female Carrot Farmer	41	Family-based diversified plot	Gender inequality in AFSC access	Social Challenge	Gender inequality in AFSC access	Faces barriers in accessing credit, inputs and training compared to male farmers.
	5	Small-Scale Eggplant Farmer	59	Off-season vegetable grower	Policy and regulatory vacuum	Social Challenge	Policy and regulatory vacuum	Lacks policy support to stabilise off-season production.
	6	Organic Herb Farmer	38	Mixed herb and vegetable farm	Weak adoption of sustainable practices	Economic Challenge	Weak adoption of sustainable practices	Limited composting, rainwater harvesting or residue reuse.
	7	Goat-integrated Tomato Farmer	47	Vegetable-livestock integrated	Logistical/transportation burden	Environmental Challenge	Logistical/transportation burden	Difficult terrain and poor roads increase transport costs and spoilage.
	8	Community Veg Farmer	36	Collective farming effort	Poor institutional coordination	Social Challenge	Poor institutional coordination	Group faces weak links with institutional buyers or cooperatives.
	9	Export-oriented Cabbage Farmer	52	Certified export production	Export quality compliance issues	Environmental Challenge	Export quality compliance issues	Certification adds cost but buyers still demand more quality assurance.
	10	Climbing Bean Farmer	50	GAP-certified system	Lack of product diversification	Environmental Challenge	Lack of product diversification	Focused only on fresh beans; lacks investment in dried/processed formats.

Source: Authors' research.

Primary codes assigned for the focus group discussion findings

Primary codes were assigned for the focus group discussion, and the findings are presented in Table 3.

Table 3. Primary codes assigned for the identified challenges

Item	Challenge	Primary Code
	Social Challenges	
1	Lower accessibility to agricultural inputs	Limited input access
2	Inadequate research & development for small-scale production	Lack of R&D support
3	Lack of awareness on managing AFSCs at the grassroots level	Awareness gap in AFSC management
4	Gender-based access barriers	Gender inequality in AFSC access
5	Low use of modern farming technologies	Underuse of modern farming tech
6	No policies/regulations for farmer-level AFSC management	Policy and regulatory vacuum
7	Weak public-private institutional collaboration	Poor institutional coordination
	Economic Challenges	
1	High production costs	High agri-production cost
2	Inadequate financial support for AFSC development	Financial constraints
3	Limited agribusiness expansion via the 3Rs	Weak adoption of sustainable practices
4	Small-scale farmers can't compete in markets	Market competitiveness challenge
5	Poor economic conditions of farmers and stakeholders	Low economic resilience
6	Poor ICT knowledge for market info sharing	ICT illiteracy in market access
	Environmental Challenges	
1	Yield losses from adverse climate	Climate-related yield loss
2	Long transport distances for agri-products	Logistical/transportation burden
3	Export market entry challenges due to quality standards	Export quality compliance issues
4	Limited capacity for product diversification	Lack of product diversification
5	High competition in AFSCs	Market saturation/competition pressure

Source: Authors' research.

As per the information in Table 3, each of these challenges identified from the focus group discussion is assigned a simplified primary code for easier identification and thematic analysis, providing a clear framework for understanding the multifaceted issues facing sustainable AFSC management in Sri Lanka.

Challenges encountered in sustainably managing agri-food supply chains

Management of agri-food supply chains (AFSCs) is not novel to Sri Lanka. However, its application remains at a considerably lower level (Vidanapathirana et al., 2018). Thus, the current status of AFSC management is timely and important for identifying the challenges of sustainably managing AFSCs in the country.

A field survey and focus group discussions were conducted to identify the key challenges in the sustainable management of AFSCs in Sri Lanka. These challenges were studied under three categories: social challenges, economic challenges and environmental challenges. The findings are presented in Table 4.

Table 4. Challenges of sustainably managing AFSCs in the study area

No	Challenges	SD	D	M	A	SA	Mean	SD	Decision
	Social challenges								
1	Lower accessibility to agricultural inputs such as fertiliser, seeds and agrochemicals.	07	17	19	21	56	3.85	3.56	Agree
2	Inadequate research & development activities for improving small-scale agri-food production activities.	06	13	24	43	34	3.72	3.37	Undecided
3	Lack of awareness regarding the way of managing AFSCs activities at grassroots level.	04	09	17	22	68	4.18	3.81	Agree
4	Poor accessibility to the AFSCs due to gender-oriented issues.	21	18	37	34	10	2.95	2.69	Undecided
5	A lower level of utilising modern farming technologies within the AFSCs.	03	05	16	19	77	4.35	3.95	Agree
6	Unavailability of policies and regulations to manage the AFSCs at the farmer level.	37	44	05	22	12	2.40	2.28	Disagree
7	Poor level of public and private institutional collaboration for the management of AFSCs-based activities.	02	17	28	34	39	3.76	3.40	Agree
	Economic challenges								
1	Higher production costs associated with agri-foods.	00	02	00	47	71	4.56	4.07	Agree
2	Unavailability of adequate financial facilities for the development of AFSCs based activities.	01	08	21	28	62	4.18	3.78	Agree
3	Expand agribusiness activities based on the 3Rs concept.	08	29	44	23	16	3.08	2.77	Disagree
4	Small-scale farmers are inability to compete with higher capturing shares of domestic markets and international markets.	00	12	38	21	49	3.89	3.52	Agree
5	The poor economic status of the farmers and other AFSC components.	33	18	32	28	11	2.77	2.56	Undecided
6	Poor knowledge regarding the utilisation of ICTs for sharing market information.	02	11	26	36	45	3.93	3.55	Agree
	Environmental challenges								
1	Yield losses due to adverse climatic conditions.	26	64	28	24	38	4.37	3.30	Agree
2	Long-distance transportation of agricultural products.	01	04	25	37	53	4.14	3.72	Agree
3	Threats to entering into export markets through maintaining the product quality.	00	21	24	28	47	3.84	3.49	Agree
4	Product diversification capability	02	04	19	41	54	4.18	3.76	Agree
5	A large number of competitors around the AFSCs.	19	24	22	38	17	3.08	2.85	Undecided

Note: 1.00-1.49 = strongly disagree, 1.50-2.49 = disagree, 2.50-3.49 = undecided, 3.50-4.49 = agree, 4.50-5.00 = strongly agree

Source: Field survey July-October 2024.

According to the findings of Table 4, social challenges that need to be overcome for sustainably managing AFSCs include lower accessibility to agricultural inputs such as fertiliser, seeds and agro-chemicals, a lack of awareness regarding the management of AFSC activities at the grassroots level, a low level of utilisation of modern farming technologies within the AFSCs and poor public and private institutional collaboration for the management of AFSC-based activities. However, respondents disagreed with the notion that there is an unavailability of policies and regulations to manage AFSCs at the farmer level. Even though policies are formulated and implemented to manage the AFSCs, their activation is considerably lower.

As for the economic challenges, higher production costs associated with agri-foods, unavailability of adequate financial facilities for the development of AFSC-based activities, small-scale farmers' inability to compete with higher capturing shares of domestic and international markets and poor knowledge regarding the utilisation of ICTs for sharing market information were identified. Additionally, respondents disagreed regarding the expansion of agribusiness activities based on the 3Rs concept. In this study, identified environmental challenges included yield losses due to adverse climatic conditions, long-distance transportation of agricultural products, threats to entering export markets while maintaining product quality and product diversification capability.

Challenges that are highly affecting the sustainable management of AFSCs

Challenges affecting the sustainable management of AFSCs were ranked from the most important factor to the least important factor according to the farmers' perspective. Garrett's Ranking technique was used to rank the challenges to identify the adverse impact on the sustainable management of AFSCs. According to Garrett's Ranking technique, the findings are presented in Table 5.

Table 5. Percept position and Garrett's value

No	Likert-scale grading	$\frac{100\ (Rij-0.5)}{Nj}$	Percept position	Garrett's value
1	SD	$\frac{100(1 - 0.5)}{5}$	10	75
2	D	$\frac{100(2 - 0.5)}{5}$	30	60
3	M	$\frac{100(3 - 0.5)}{5}$	50	50
4	A	$\frac{100(4 - 0.5)}{5}$	70	40
5	SA	$\frac{100(5 - 0.5)}{5}$	90	25

Source: Authors' research.

Validation of ranking results;

Null Hypothesis (H_0): There is no significant difference between the ranks of the responses.

Alternative Hypothesis (H_1): At least one response differs significantly from the others.

Calculate the Friedman Test Statistic for the validation process using the formula:

$$1560(\chi^2 F) = \frac{12}{(5 \cdot 5 \cdot (5+1)} + [5^2 + 10^2 + 15^2 + 20^2 + 25^2] - 3 \cdot 5 \cdot (5 + 1)$$

$$(\chi^2 F) = 1560$$

The calculated test statistic value (p-value) is greater than 0.05; there is no significant difference in the rankings across responses.

Hence, Garrett's Ranking technique was used to rank the challenges to identify the adverse impact on the sustainable management of AFSCs. Results are presented in Table 6.

Table 6. Challenges of sustainable management of AFSCs in the study area

	Challenges	SD	D	M	A	SA	Total	Avg	Score	Rank
	Social challenges									
1	Lower accessibility to agricultural inputs such as fertiliser, seeds, and agro-chemicals	525	1020	950	840	1400	4735	39.46	56	3
2	Inadequate research & development activities for improving small-scale agri-food production activities	450	780	1200	1720	850	5000	41.67	54	5
3	Lack of awareness regarding the way of managing AFSCs activities at the grassroots level	300	540	850	880	1700	4270	35.58	58	2
4	Poor accessibility to the AFSCs due to gender oriented issues	1575	1080	1850	1360	250	6115	50.96	50	6
5	Lower level of utilising modern farming technologies within the AFSCs	225	300	800	760	1925	4010	33.42	59	1
6	Unavailability of policies and regulations to manage the AFSCs at the farmers' level	2775	2640	250	880	300	6845	57.04	47	7
7	Poor level of public and private institutional collaboration for the management of AFSC-based activities	150	1020	1400	1360	975	4905	40.88	55	4
	Economic challenges									
1	Higher production costs associated with agri-foods	0	120	0	1880	1775	3775	31.46	60	1
2	Unavailability of adequate financial facilities for the development of AFSC based activities	75	480	1050	1120	1550	4275	35.63	58	2
3	Expand agribusiness activities based on the 3Rs concept.	600	1740	2200	920	400	5860	48.83	51	5
4	Small-scale farmers are unable to compete with higher capturing shares of domestic markets and international markets	0	720	1900	840	1225	4685	39.04	57	3
5	Poor economic status of the farmers and other AFSC components	2475	1080	1600	1120	275	6550	54.58	48	6
6	Poor knowledge regarding the utilisation of ICTs for sharing market information	150	660	1300	1440	1125	4675	38.96	56	4
	Environmental challenges									
1	Yield losses due to adverse climatic conditions	1950	3840	1400	960	950	9100	75.83	37	5
2	Long-distance transportation of agricultural products	75	240	1250	1480	1325	4370	36.42	57	1
3	Threats to entering into export markets through maintaining the product quality	0	1260	1200	1120	1175	4755	39.63	55	3
4	Product diversification capability	150	240	950	1640	1350	4330	36.08	56	2
5	A large number of competitors around the AFSCs	1425	1440	1100	1520	425	5910	49.25	50	4

Source: Authors' research.

As per the results of Table 4 and Table 6, the main social challenges for the sustainable management of AFSCs are a lower level of utilisation of modern farming technologies within the AFSCs, a lack of awareness regarding the management of AFSC activities at the grassroots level and lower accessibility to agricultural inputs such as fertiliser, seeds and agro-chemicals. According to the findings from the focus group discussions, the social

challenges faced by upcountry vegetable farmers in Sri Lanka include a lower utilisation of modern farming technologies. Tomato farmers (FG1, ID 5) report that difficult terrain and a lack of technical support hinder the adoption of innovations like poly tunnels and drip irrigation, aligning with the quantitative findings of low technology use. Organic herb farmers (FG2, ID 6) similarly reveal weak uptake of sustainable practices such as composting and rainwater harvesting, indicating gaps in awareness and practical training. ICT illiteracy among cucumber farmers (FG1, ID 8) further limits the adoption of digital tools, constraining market access and farm management efficiency. Additionally, a lack of awareness regarding AFSC management is evident, with bean farmers (FG1, ID 4) expressing limited understanding of supply chain dynamics and market linkages, signalling a need for grassroots capacity building. Community vegetable farmers (FG2, ID 8) also face poor institutional coordination, weakening their connections to cooperatives and institutional buyers, reflecting systemic weaknesses in AFSC management. Accessibility to agricultural inputs is another key issue; carrot farmers (FG1, ID 1) struggle with costly and scarce quality seeds and fertilisers, while female carrot farmers (FG2, ID 4) confront gender-based barriers to credit and input access, exacerbating inequalities.

In addition to that, the economic challenges for sustainable management of the AFSCs are higher production costs associated with agri-foods, the unavailability of adequate financial facilities for the development of AFSC-based activities and the inability of small-scale farmers to compete with larger shares of domestic and international markets. Based on the focus group discussion findings, economic challenges are highlighted by rising production costs reported by radish farmers (FG1, ID 10), including expenses for land preparation, labour and transport that erode profitability, as well as capital shortages faced by potato farmers (FG1, ID 6) for essential infrastructure such as cold storage, which hinders scaling operations. The unavailability of adequate financial facilities limits farmers' capacity to buffer income fluctuations or compete effectively; leek farmers (FG1, ID 2) and chilli farmers (FG2, ID 3) point to this gap, as do goat-integrated tomato farmers (FG2, ID 7), who are unable to invest in better logistics. Small-scale farmers, such as leek growers, face scale disadvantages in competing with imports and bulk producers, while export-oriented cabbage farmers (FG2, ID 9) bear high certification costs yet still encounter stringent buyer quality demands, highlighting a cost-reward imbalance that threatens market competitiveness.

Moreover, identified environmental challenges for the sustainable management of AFSCs are the long-distance transportation of agricultural products, product diversification capability and threats to entering export markets while maintaining product quality. The focus group discussion findings revealed that the environmental challenges include long-distance transportation difficulties, with goat-integrated tomato farmers (FG2, ID 7) citing poor roads and rugged terrain that increase transport time and spoilage, an issue also shared by potato and cabbage farmers in remote highland areas. Product diversification remains limited, as lettuce (FG1, ID 9) and climbing bean farmers (FG2, ID 10) rely heavily on fresh produce sales without value addition, making them vulnerable to market price fluctuations and wastage. Furthermore, bell pepper farmers (FG1, ID 7) and export-oriented cabbage growers (FG2, ID 9) face significant post-harvest losses, lack of standardisation and stringent export quality requirements, exemplifying environmental challenges in maintaining export competitiveness amid infrastructural and resource constraints.

This integrated interpretation demonstrates how statistical trends manifest as complex, lived realities for farmers, underscoring the urgent need for targeted interventions including technology transfer, gender-sensitive input support, financial inclusion and infrastructural

improvements to foster more sustainable and resilient agri-food supply chains in Sri Lanka's upcountry vegetable sector.

Strategies to overcome the challenges associated with managing agri-food supply chains in Sri Lanka

Based on the findings of this study, the following strategies can be highlighted:

- Empowering farmers by facilitating financial facilities at concessionary rates to purchase required agricultural inputs such as fertiliser, seeds and agro-chemicals.
- Encouraging research and development activities for improving small-scale agri-food production activities.
- Conducting awareness programmes to disseminate knowledge and improve experiences for the AFSCs at the grassroots level.
- Organising extension programmes to enhance farmers' adoption of sustainable development of AFSCs.
- Facilitating foreign training opportunities to gain the latest information about sustainably developed AFSCs, as well as outsourcing foreign experts to provide timely, updated information from other countries.
- Introducing mechanised farming practices to overcome the labour shortage issues arising from labour-intensive activities in farming.
- Introducing modern technologies to enhance farmers' adoption of AFSCs-based practices.
- Policies and strategies need to be updated promptly for managing the AFSCs at the farmer level.
- Enhancing collaboration among relevant public institutions to formulate and implement the management of AFSCs-based practices within AFSCs.
- Formulating and implementing timely strategies for reducing the high production costs associated with agri-foods.
- Developing market information systems by increasing the availability of ICTs to access market information.
- Encouraging small-scale farmers to capture considerably higher market shares in domestic and international markets.
- Persuading farmers to cultivate resilient agri-food crop varieties in adverse climatic conditions.
- Expanding facilities for storing agri-food products and enhancing the accessibility of proper transportation.
- Persuading farmers to use Good Agricultural Practices (GAP) while performing their farming activities to maintain the final agri-food quality.
- Facilitating more opportunities to produce diversified agri-food products.

Scope of managing agri-food supply chains for sustainable agriculture in Sri Lanka

Correct application of the AFSC approach facilitates sustainable development in the agriculture sector in Sri Lanka. According to the literature review, proper management of AFSCs ensures the achievement of six Sustainable Development Goals (SDGs) out of the 17 SDGs set by the UN for developing countries (Pietrzyck et al., 2021; Djekic et al., 2021).

Over the past decades, the concept of managing AFSCs has received considerable attention as a solution to mitigate social, environmental and economic challenges in the agri-food industry (Naik and Suresh, 2018). Thus, agri-food supply chain management plays a

significant role in supporting sustainable development in the agriculture sector in Sri Lanka (Dissanayaka and Thibbotuwana, 2021).

Hence, correct management of AFSCs supports the reduction of hunger within the nations of the globe by increasing the accessibility of food for them (UN, 2020). Moreover, proper management of AFSCs helps enhance the economy within the farming community as well as the other components of the AFSCs. Thus, this leads to enhanced economic growth within the nations (Lezoche et al., 2020; FAO, 2018). In addition, sustainably managed AFSCs lead to optimised responsible consumption and production of agri-foods (Kumar et al., 2022; Pietrzyck et al., 2021). Considering the farmers' perspective, well-managed AFSCs can help protect life on land when practising their farming activities: GAP certification (Bamunuarachchi et al., 2019; Naik and Suresh, 2018). Hence, farmers perform necessary climate actions to minimise hazards to the surrounding environment, leading to reduced environmental pollution (Djekic et al., 2021). Additionally, public and private collaboration builds strong partnerships to achieve the goals for sustainable management of AFSCs (Trang et al., 2022; Pancino et al., 2019)

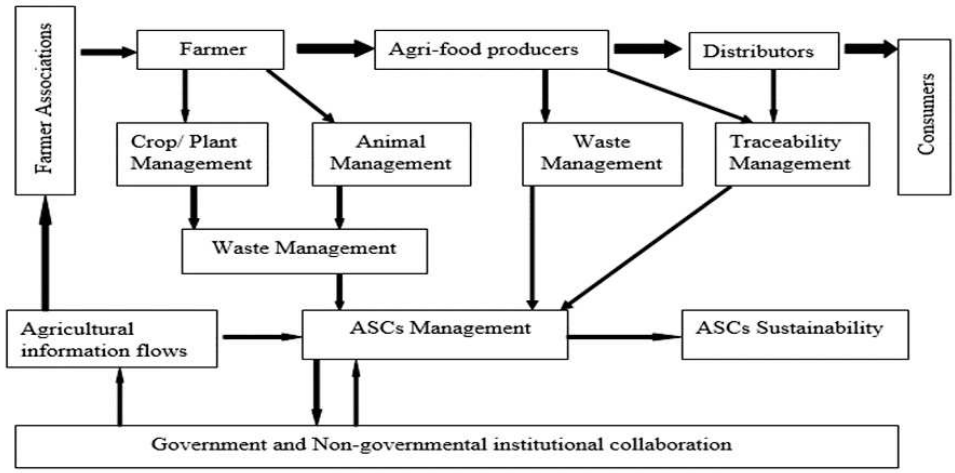

Fig. 2. Sustainable management of AFSCs in Sri Lanka

Source: Adapted from Rejeb et al., 2021; Florea et al., 2019.

Sustainable management of agri-food supply chains for the future

Nowadays, AFSCs require major transformations aimed at promoting sustainability by reducing and recycling waste for the reuse of AFSC activities (Agnusdei and Coluccia, 2022). Hence, Figure 2 illustrates the importance of crop/plant management, animal management, waste management and traceability management for the sustainable management of AFSCs to enhance their collaborative demand (Rejeb et al., 2021; Florea et al., 2019).

Figure 2 shows the adapted form of Rejeb et al. (2021) and Florea et al. (2019). The study of Rejeb et al. (2021), summarising the framework of the potentials of big data for AFSC sustainability, describes that crop/plant management, animal management, waste management and traceability management lead to sustainable AFSC management. Moreover, the general representation of an agri-food supply chain elaborates on the farmer associations,

farmers, food industries, distributors and consumers (Florea et al., 2019). According to Figure 2, agri-food supply chain components are interconnected with all the representatives: farmers, agri-food producers, distributors and consumers. The literature review indicates that sustainable AFSC management consists of crop/plant management, animal management, waste management and traceability management. Thus, farmers engage in crop/plant and animal management or integrated farming systems management through the management of waste/residuals to build sustainable AFSCs. In addition, governmental and non-governmental institutional collaboration supports the dissemination of agricultural information to farmers' associations as well as individual farmers. Regarding agri-food producers, they transform agricultural production into agri-foods while managing their waste materials based on the 3R approach. Moreover, agri-food producers and distributors maintain traceability management practices by planning, organising and coordinating all tasks interconnected with traceability.

Conclusions

As per the findings of the study, the majority of the farmers are middle-aged, married and have studied up to junior secondary education. The challenges encountered in the sustainable management of AFSCs fall into three categories: social, economic and environmental. The key social challenges include lower accessibility to agricultural inputs, limited awareness regarding the management of AFSCs and a lower level of utilisation of modern technologies within AFSCs. The main economic challenges are higher production costs associated with agri-foods, inadequate financial facilities, small-scale farmers' inability to compete with larger shares of domestic and international markets and poor knowledge regarding the use of ICTs for sharing market information. Furthermore, the primary environmental challenges for the sustainable management of AFSCs are the long-distance transportation of agricultural products and limited product diversification capability. Therefore, to address these challenges, the following strategies are recommended: providing financial facilities at concessionary rates for purchasing necessary agricultural inputs; conducting awareness programmes to disseminate knowledge and improve farmers' experiences with AFSCs; introducing modern technologies to increase farmers' adoption of AFSCs-based practices; formulating and implementing timely strategies to reduce high production costs associated with agri-food; developing market information systems by increasing ICT availability; enhancing transportation accessibility; facilitating more opportunities to produce diversified agri-food products. These strategies are identified as essential for the sustainable management of AFSCs in the upcountry vegetable sector in Sri Lanka. Hence, sustainable management of AFSCs is enhanced through collaboration with local agricultural extension services to address the specific challenges faced by farmers in the upcountry vegetable sector, offering government incentives or subsidies for farmers using modern technology, implementing credit access for small-scale farmers, promoting product branding and marketing strategies to help farmers compete in both domestic and international markets, introducing user-friendly mobile apps to share market information with farmers, and encouraging the use of refrigerated vehicles for transporting perishable goods.

Implications

Policy-makers' perspective: According to the findings, focusing on improving infrastructure, reducing post-harvest losses and ensuring fair market access for upcountry farmers leads to the development of policies that enhance the resilience of the vegetable supply chain in Sri Lanka. However, sustainable practices and government support in technology adoption, farmer training and market linkages could be crucial for enhancing the sustainable development of AFSCs.

Non-government organisations' perspective: They support leveraging the research to design targeted interventions that address specific challenges faced by farmers in the region, such as improving farming techniques, supporting organic farming and facilitating market connections. They also promote environmental sustainability and food security initiatives within the AFSCs.

Farmers' perspective: The study can offer insights into best practices for sustainable farming, help reduce dependency on harmful chemicals and suggest ways to adapt to climate change. Moreover, the findings elaborate on the strategies for better marketing, reducing costs, increasing income and improving the overall efficiency of the vegetable supply chain.

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