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Priorities for Research on Sustainable Agriculture: The Case of Poland

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Abstract: The need for sustainable agricultural sector is growing rapidly due to climate changes. As there are still knowledge gaps and the need for innovations that support farmers in the sustainability transition, there is a need for determining priority research areas that are vital for the sustainable development of agriculture. The aim of our study was to derive a long-term vision of the desirable agricultural sector in Poland and prioritize research areas required to make Polish agriculture sustainable. We applied the living lab approach and, by conducting a backcasting exercise with the lab members, we identified a desirable vision of agriculture in Poland and the research areas needed to realize this vision. Using Analytic Hierarchy Process (AHP) and Cumulative Voting (CV), we prioritized these research areas. Our results show that adaptation to climate changes is the most important area of research, having 38.6% of the total possible number of points using AHP and 29.7% in the case of CV. The analysis of the Polish strategic documents related to agriculture and agricultural research shows that, to some extent, these key research areas are already part of the national policy, but there is not sufficient funding and coordination to tackle all aspects of sustainability in agriculture.

Keywords: sustainable agriculture; research agenda; action research; backcasting; prioritization; living lab

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1. Introduction

The need for sustainable agricultural sector is growing rapidly in line with news regarding the state of the environment and the pace of climate change. As the natural resources have been depleted, circular economy and bioeconomy solutions and practices need to be introduced. Yet, the transition of agriculture requires conducting it in such a way that food security is not endangered. It should also encompass factors other than the environmental components of sustainability. Moreover, even the most ambitious strategies for reducing the negative impact of agriculture on the environment, such as the European Union's (EU) farm-to-fork strategy, cannot be implemented if there is no public consensus and if there are doubts about the feasibility of meeting the proposed targets without putting food security at risk, and about increasing sustainability [1].

New models of food systems are needed to enable a green transition that is fully sustainable and just. The new models require multi-actor governance [2,3] and engagement of research to propose innovative solutions and to verify their green credentials.

The green transition currently shapes public policies and priorities in the public research agenda at the level of the European Union (EU) [4]. The EU based its policies for the coming years and decades on the challenges related to climate changes and the condition of nature (such as the legislative package Fit for 55). Therefore, the European Commission proposed the European Green Deal strategy and created detailed strategies and policies that should make the EU a circular [5] and sustainable economy having zero emissions and providing effective protection of biodiversity [6].

In Poland, the progress in the green transition has been slow due to low public pressure, lack of political will, and insufficient funding. Poland is the only EU member that did not commit itself to the zero emissions target in 2019 [7]. The Polish Next Generation recovery plan also does not envisage significant funds for the green transition. This also applies to the greening of the common agricultural policy (CAP), which is strongly opposed, and the draft of the Polish CAP strategic plan is a simple continuation of the current CAP approach, which does not contribute significantly to biodiversity protection and sustainable agriculture [8]. Nonetheless, the CAP reform has not yet been finalized at the EU level and there are no secondary regulations detailing its implementation rules. Furthermore, its potential contribution to the Green Deal is still not certain [9] and depends on the member state's strategic plans.

The future vision plays an important role in the process of the green transition as it helps identify the challenges, and the potential risks and solutions. It can also help in identifying research areas that can support finding green solutions in different parts of the socio-ecological system. The participatory "bottom-up" future long-term vision has been proven to be an essential part of research and innovation agenda setting [10].

As the funds for agricultural research are scarce and the time pressure to identify methods and technologies that enable the green transition, and which do not jeopardize food security, is growing, the priority research areas must be chosen carefully and thoughtfully to maximize value for money and efficiently use the available time. Therefore, a process of research priority setting must be conducted. There is no one-size-fits-all method to conduct this process and the methods applied must fit the specificity of the problems that are subject to prioritization [11].

The aim of the article is to present the results of a study of the long-term vision of the desirable agricultural sector in Poland, and the prioritization of the research agenda that is required to make the Polish agriculture sustainable and resilient. The study also assessed the extent to which the current agricultural research agenda and agricultural policy fit into the identified needs. To the best of our knowledge, this is the first participatory priority research agenda setting for agriculture conducted in Poland.

We based our research on a living lab approach to identifying needs related to sustainable development of Polish agriculture. For the vision of desirable agriculture and the needed research, we applied backcasting, whereas for the prioritization of the research areas we used two methods: Analytic Hierarchy Process (AHP) and Cumulative Voting (CV).

The process included the selection of experts, conceptualization of sustainable agriculture vision, and selection of research areas critical for sustainable agriculture implementation and its hierarchization. Finally, the results of the study were confronted with flagship national programs devoted to agriculture and rural development. The discussion results highlight the necessity for stronger integration of research policies in the process of sustainable agriculture policy planning.

The article is divided into three main parts. The first part presents the materials gathered and methods applied in the study, in each of its three key phases conducted during consecutive meetings of the living lab created for the purpose of this study. The results are presented in the second part of the paper for each of the study phases. The third part of the paper is devoted to the discussion of the results.

2. Materials and Methods

The materials for the study presented in this article were collected during three meetings. The first of these was conducted in October 2019 when the participants and the research team met in person. The second meeting was conducted in May 2021 and was an online event. The third meeting took place in October 2021 and was also an online event. Participants represented three groups of stakeholders—researchers, practitioners (farmers, agri-food entrepreneurs, beekeepers, agricultural advisors, and residents of rural areas) and NGO representatives.

The group was established and organized according to the principles of living labs. Living labs are a widely used tool in social sciences [12] to solve societal challenges [13]. In order to ensure openness in sharing opinions with other participants, the group meetings operated under Chatham House rules, which means that the citation of the opinions presented during the meetings cannot include the name of the person who presented a given statement. To ensure the effectiveness of the debate and prevent a lack of transdisciplinary collaboration [14], four guiding principles were applied:

- flexible programming;
- co-constructing policy recommendations;
- multi-level interactions;
- impartiality and transparency [15].

The structure of the platform members was skewed towards overrepresentation of the research sector. The experts were asked to present themselves by stating their links to agriculture. A vast majority of the participants—19 of the 21—presented more than one reason they could be named as agriculture stakeholders (Table 1).

Table 1. Presentation of the experts.

Person	Assigned Role	Own Presentation
1	Research	Researcher—geographer, member of an NGO specializing in rural development
2	Research	Researcher—agricultural policy, beekeeper, farmland holder
3	Research	Farm accountancy, farmland owner, member of an NGO specializing in rural development
4	Research	Researcher—geographer, member of an NGO specializing in rural development
5	Research	Researcher—environmental issues, watering adviser, resident of rural areas
6	Research	Researcher—agricultural finance, farmland owner, resident of rural areas
7	Research	Research in agricultural policy and food industry; member of an NGO specializing in rural development
8	Research	Researcher—geographer, resident of rural areas
9	Research	Researcher—farming efficiency, former farmer, former agricultural adviser
10	Research	Researcher—farm accountancy, former agricultural adviser
11	Practice	Farmer—specialization in potatoes, owner of a company purchasing cereals, PhD in agricultural sciences, president of an associating of Polish potatoes growers, resident of rural areas
12	Practice	Farmer—milk production, agri-tourism, researcher—economic analysis of beef and milk farms
13	NGO	cheese producer, owner of a horse-riding school
14	NGO	Member of an NGO specializing in rural development, researcher—innovations in agriculture, rural development, resident of rural areas, owner of an orchard—1.5 ha
15	NGO	President of an NGO specializing in rural development, researcher—rural development, rural entrepreneurship, member of a LAG

Table 1. *Cont.*

Person	Assigned Role	Own Presentation
16	NGO	Member of a LAG
17	NGO	Eco-activist, coordinator of a consumer purchasing group buying products directly from local farmers, psycho-dietician, sociologist
18	Practice	Member of a LAG
19	Practice	Owner of a honey and honey products producing company, beekeeper, researcher—risk management in agriculture, president of an NGO specializing in agricultural issues
20	Practice	Manager at a company buying and selling meat and meat products, former employee of the Polish ministry for agriculture and rural development, agricultural activist—FB page on Polish agriculture, author of a book on the needed transformation of the Polish agriculture
21	Practice	Agricultural adviser, resident of rural areas, former farmer, extension services adviser, resident of rural areas

Source: Living lab experts' presentation.

We used a mixed-method design for our study. The methodology of research applied in the study was based on the participatory action research philosophy often applied in social sciences [16–18]. The term "action research" was first used in 1944 by Kurt Lewin. Action research "aims at both taking and creating knowledge or theory relating to that action" [18]. It is a reflexive process, where the next step is conducted after a critical analysis of both the results and the process leading to these results. This methodology also helps bridge the gap between theory and practice [19]. As the participants of the conducted study represented different academic backgrounds, the study was not only a participatory action research, but also a transdisciplinary one.

Moreover, as our study was not only aimed at developing knowledge but also sought practical recommendations for policymakers, it can be argued that we did not apply action research, but a design science research methodology. However, it can be argued that both methodologies are similar [20].

The process of sustainable agriculture research priority setting included (a) selection of experts; (b) proposal of critical research areas for sustainable agriculture; (c) selection of prioritization criteria; (d) hierarchization of critical research areas; and (e) assessment of the extent to which current strategic plans include the priority research areas (Figure 1).

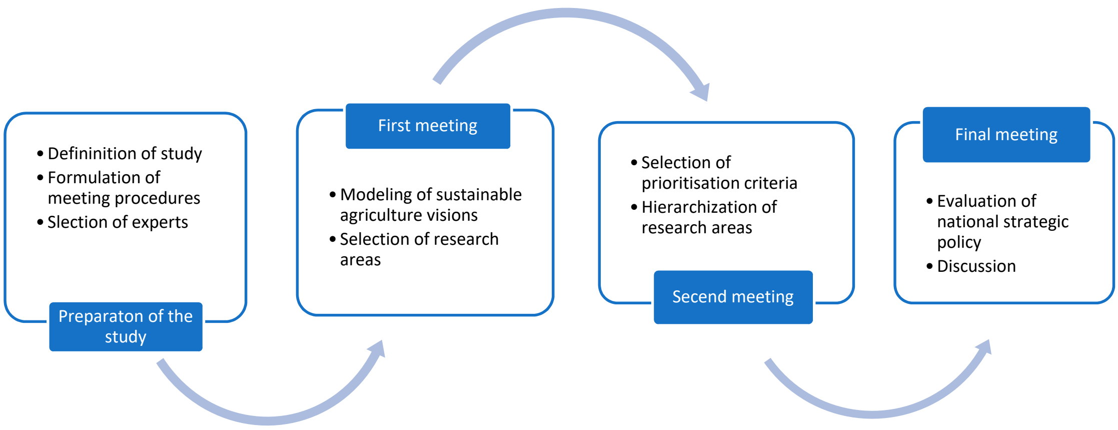

Figure 1. Process of sustainable agriculture research priority setting. Source: Own elaboration.

During the first meeting the experts were divided into three groups. The division was performed during the preparation of the meeting and was aimed at creating groups with representatives of different types of stakeholders. The meeting focused on discussing two main issues: the desirable state of the Polish agriculture in 2100 and the research areas that must become priorities to make possible the transition from the current state of agriculture to the discussed desirable one.

For the task of envisioning desirable agriculture, backcasting was used. This method, especially participatory backcasting, is a popular approach in studies examining the future and is in constant development [21]. It is used for visioning and strategic planning [22] where there are no data and/or the continuation of the current trends is not desirable [23]. It was proposed first in the 1970s as an "analysis looking back" by Lovins, A.B. [24], whereas the name "backcasting" was first used by Robinson, J. in 1982 [25]. Backcasting has been applied to future visioning of complex and difficult problems such as climate change [26], energy transition [27,28], energy use [29], transportation [30,31], health [32], food waste [33], consumption-based GHG emissions [34], urban planning [35], landscapes [36], land use planning [37], demand for ecosystem services [38], food production [39], sustainability in universities [40], sustainable municipalities and regions [41], sustainable food systems [42] or sustainable consumption [43]. Backcasting has even been used in strategic planning for COVID-19 mitigation [44].

This method is used for creating long-term policy based on an ideal future, i.e., a desired state [45] at a given future point of time. It uses a reverse direction of thinking about the future compared with forecasting. First, we create a desirable future scenario and, then, we sequentially return to the present time while building pathways that can ensure that we reach this desirable future. In backcasting, we concentrate on the issue of "how desirable futures can be attained" [46]. The idea of this "desirable" future, which can be seen as utopian, proves useful as it provides an additional perspective to planning [47].

As our aim was to identify priority research areas for sustainable agriculture, we limited the backcasting exercise of identifying the pathway to the desirable agriculture, to determining only its starting point; that is, the tools needed on this pathway, namely, research areas that can generate solutions to enable embarking on this pathway.

The second meeting focused on prioritization of the research areas identified during the first meeting. We applied two methods to minimize the problem of the lack of autonomy of the key research areas identified to support development of sustainable agriculture in Poland. This need stemmed from the fact that the identified priority research areas overlapped, resulting in difficulties in rating in a paired and multi-object comparison. The Analytic Hierarchy Process method is based on pair comparisons with the use of scales to reflect the relative strength of the preferences of options [48]. AHP has a widely proven relevance in decision support methods [49]. It has been proven to be efficient in supporting both multinational [50] and local level policy-related decisions [51]. The AHP method, among others, is considered to give priority to the decision maker's preference and can help to solve multidimensional decision problems [52]. AHP is considered to be a low scalability method [53]; however, it is relatively easy to apply and allows for verification of the results' consistency and revision of problematic elements [54,55].

A questionnaire matrix of the paired comparison was elaborated in line with the results of the first step of the research, which indicated four critical research areas (Table 2)

Table 2. Questionnaire matrix for research area prioritization. Source:Own elaboration based on Satty [48].

		Research Areas			
		A	B	C	D
Research areas	A	$X_{A,A} = 1$	$X_{A,B}$	$X_{A,C}$	$X_{A,D}$
	B	$1/X_{A,B}$	$X_{B,B} = 1$	$X_{B,C}$	$X_{B,D}$
	C	$1/X_{A,C}$	$1/X_{B,C}$	$X_{C,C} = 1$	$X_{C,D}$
	D	$1/X_{A,D}$	$1/X_{B,D}$	$1/X_{C,D}$	$X_{D,D} = 1$

The provided instruction highlighted the necessity to value the supremacy of the research area selected as critical to achieve a vision of sustainable agriculture by 2100. A questionnaire matrix consistent with the AHP method was prepared and distributed among the experts. Experts were asked to use a point scale, as presented in Table 3, for the assessments of the degree of preference of one research area over another in direct comparison in the function of achieving the overarching objective, i.e., research areas' impact on the achievement of the vision of sustainable agriculture by 2100. Experts were asked to submit a completed questionnaire before the meeting and were informed about judgment consistency tests. In the case of significant non-compliance, experts were asked to revise the matrix. The commonly used fundamental scale was applied, ranging from 1 to 9, where 1 corresponds to equal importance of the compared research areas, and 9 depicts extreme supremacy of one research area over another.

Table 3. The scale of the scoring of the preferences of one research area in direct comparison with another. Source: Own elaboration based on Satty [48].

Score	Description
1	The areas compared contribute equally to the overarching goal
3	Experience and judgment slightly favor the first area taken into account in comparison to the second
5	Experience and judgment strongly favor the first area taken into account compared to the second
7	The first area taken into account in comparison is definitely privileged and its dominance has been demonstrated in practice
9	Confirmed supremacy of the first area taken into account compared to the second one
2, 4, 6, 8	Used in the need for a compromise between the above-mentioned assessments

Each expert provided their own elaborated questionnaire matrix indicating the relevant importance of each research area in comparison with the others. The accumulated questionnaire matrix results provided hierarchy of the critical research areas to be further discussed.

As in the case of AHP, the second method applied in the study—the Cumulative Voting (CV) approach—has proven its efficiency in policy prioritizing [56]. This method is based on the distribution of a given number of points to proposed options by participating experts. A simplified version of Cumulative Voting was applied assuming equal importance of criteria and expert opinions [57]. Therefore, the more points accumulated by a given research area, the more important it was classified in hierarchy. Although the use of equal treatment of voting participants is questionable [58], it was assumed in the study that the prevailing number of researchers and involvement of experts was relevant in the research policy assessment.

AHP and CV were chosen over the brainstorm approach and other methods based on direct discussion as they enable the comparison of each expert hierarchy with the accumulated results of the group. This helps to stimulate discussion aiming at an explanation of possible divergences in expert opinions, while allowing easy identification of the differences.

During the meeting, participating experts were introduced to the CV hierarchization table (Table 4) and procedures of voting. Namely, a brief explanation of the chosen criteria for hierarchization of research areas was presented:

- Criterion I—The need to finance research area using public funds, non-commercial research. This criterion was chosen in line with the concept of maximizing public resources efficiency. It assumes that research areas that are attractive for the commercial research sector are likely to be conducted without public support. Therefore, public resources should be directed to other research areas.

- Criterion II—Public access to research results. In the case of research areas with results that are likely to be licensed, limited possibilities of common application can be expected. Therefore, it is justified to finance these research areas from public money and provide free access to research results. Unlimited access is recognized here as being critical for broad implementation of research results in practice.
- Criterion III—The expected time of generating research results. This criterion was proposed to increase preference for research areas that need less time relative to others to generate results. This criterion considers the urgent need for sustainable solutions.
- Experts were instructed to distribute 10 points between research for each criterion. Research areas that should be favored according to expert opinion, taking into account the given criterion, should receive more points.

Table 4. Expert research areas' valuation table according to given criteria with a 10-point scale. Source: Own elaboration.

		Criteria		
		I	II	III
Research areas	A	X_{iIA}	Y_{iIIA}	Z_{iIIIA}
	B	X_{iIB}	Y_{iIIB}	Z_{iIIIB}
	C	X_{iIC}	Y_{iIIC}	Z_{iIIIC}
	D	X_{iID}	Y_{iIID}	Z_{iIIID}
$\sum$		$X_{iIA} + \ldots + X_{iID} = \leq 10$	$Y_{iIIA} + \ldots + Y_{iIID} = \leq 10$	$Z_{iIIIA} + \ldots + Z_{iIIID} = \leq 10$

Experts' votes during the meeting were collected with the use of Microsoft® Forms to directly provide results for the following discussion.

The third meeting of the living lab was devoted to the assessment of the current Polish policy in relation to sustainable agriculture. To access the extent to which the agricultural policy takes into account the research priority areas, the second draft of the Polish Strategic Plan for CAP 2023–2027 (later referred to as the Polish CAP Strategic Plan) and the draft of the Polish Recovery Plan were analyzed. The choice of these documents was dictated by the fact that there is no strategic document stipulating agricultural research priorities in Poland. Therefore, agricultural priorities are considered to be a proxy for the research priorities, especially if the policy measures directly or indirectly mention research, knowledge, or Agricultural Research and Innovation System (AKIS). Moreover, the analyzed strategic plans show the development direction chosen for Polish agriculture, and living lab members could verify the extent to which it is in line with the desirable future of Polish agriculture identified during the first meeting. The research team familiarized the members of the living lab with their findings. Then, the experts were asked to discuss the presented findings.

3. Results

3.1. Polish Agriculture in 2100

The first meeting focused on two exercises. The first was a backcasting exercise where all three groups into which the participants were divided discussed the desirable shape of Polish agriculture in the year 2100. Such a long-term perspective was chosen to let the experts think "outside of the box", without the burden of the dependency paths and policy or technology limitations. An alternative base year 2050 was rejected as all the participating experts were familiar with the extent of the transition of Polish agriculture in the past 30 years and there was a risk that this could limit their thinking.

At the beginning of this exercise, the concept of backcasting and the task were clearly explained to the participants. The concept of backcasting was already known to some participants. All three groups were overwhelmed at first by the scope of this exercise. They thought it was too hard to imagine what could happen within 80 years. However, they also saw the positive side of the exercise, i.e., the lack of limitations other than environmental ones. All the groups discussed ideas presented by each of their members and later presented their joint results to the other groups.

In the first group, the discussion concentrated on the possible changes in the environment. In this group's opinion, there will be no monocultures, and the Earth will be by 4 degrees Celsius warmer compared to the Paris agreement reference point. One of the members of this group stated that agriculture should be "colorful". This can be achieved by protecting biodiversity. The debate within the first group led to the derivation of a model of the food system with three types of providers of food raw material:

- Highly efficient, smart, economically and environmentally efficient, and automated farms;
- Socio-cultural (local) food providers combining agriculture and small-scale food processing where social ties among suppliers and buyers are very important;
- "Food pills" providers—manufacturers of synthetic food using nanotechnologies where no land is needed (other than to build a factory producing these pills).

The second group did not propose a set of different food providers, but concentrated on a set of distinguishing features that, in their vision, will characterize Polish agriculture in 2100. These relate to both production technologies and its structure:

- Sustainable production and stronger direct contact with consumers/clients;
- 100% organic;
- Extensive production regarding input use and land productivity;
- Application of advanced technology;
- Local production making use of the specificity of local natural resources;
- Cooperatives or similar forms of cooperation;
- Blockchain—food tracking;
- Flow of know-how;
- Conscious production and consumption choices.

This group also stated that animal production will shrink and amount to approx. 20% of its current level. This source of proteins will be replaced by meat produced in the laboratories, insects, soya, and alfalfa.

The third group discussed several different issues related to the whole food system, in addition to specific problems of agriculture. According to this group, Polish agriculture in 2100 will be very polarized with both highly specialized, large farms and family operated farms with diversified production. Both supply and demand will be characterized by a dualism—cheaper and lower quality products vs. more expensive products of high quality. The group underlined the importance of making agricultural employment an attractive choice of a professional career. Agriculture also should be supported by advisory services that offer a wide range of support, including advice on integrating with other farmers in different projects and activities. Precision farming will be a dominating form of farming. Agriculture must be profitable and the status of ownership of the land must be clearly regulated. The key issue is minimizing harmful impacts of agriculture on the environment.

The second exercise of the backcasting was coming back to the present time and discussing the research areas that can provide the solutions needed to enable agriculture as envisioned in the first exercise, because there are still technologies that need to be developed to ensure sustainable agriculture can be a reality in 2100.

In the first phase of the second exercise, the experts were asked to think about the list of research areas and topics that are vital for the implementation of the vision discussed in the previous part of the meeting. The group members presented their proposals and justification for a named research area. The similar research areas were clustered together and then presented to the other two groups as during the first exercise.

The first group named several environmental and economic topics:

- Research on adaptation of local communities to economic and environmental changes and introducing innovations (models of behavior, propensity to diversify economic activity);
- Sustainable intensification of farming using agro-ecological methods (issue of increasing productivity of agriculture while achieving environmental goals of sustainability);
- Short food supply chains (efficiency, what can be supplied?);
- Water management (how to save water? Water use optimization);
- Research on efficiency and risk in highly-efficient farming (environmental and economic risks);
- Photosynthesis 2.0 (research on increasing plant productivity);
- Risks related to biodiversity loss.

The second group also identified diverse research areas that play a crucial role in enabling the implementation of the vision of sustainable agriculture. These include all dimensions of sustainability. In the case of the environmental issues, preventing biodiversity loss and developing biological methods of plant protection were named. Some of the research areas proposed by this group can be seen as part of both environmental and economic dimensions of sustainability. These research areas include water management, climate change adaptation, and soil fertility. The other research areas proposed by this group were related to social and economic aspects of sustainability in agriculture. Among these, the second group listed circular economy solutions and methods for better use of local resources that may enable increasing the scale of direct sales or small processing of agricultural products, and thus increase added value and farm incomes.

The third group named only four topics. These represented different research areas. The first related to new food, including replacing animal products with other sources of proteins. The second topic concentrated on social issues such as cooperation, social innovations, social aspects of implementing innovations, and education. The third research area covered precision farming. The fourth issue related to biodiversity and the problem of preferred animal and plant species for agricultural production.

Finally, based on the research areas presented by the groups, a set of common critical topics for sustainable agriculture research areas was established in the course of a discussion among all the experts:

1. Ecosystem services;
2. Climate change adaptation;
3. Technological innovations;
4. Research on the state and possibility of improvements in social capital.

3.2. Prioritization of Research Areas

The expert method of prioritization was based on three formerly defined assessment criteria. The CV method conducted during the meeting delivered the following results: Criterion I—The need to finance research area from public funds—favored the research area of adaptation to climate changes (32.8% of the total points). Ecosystem services accumulated 29.0% of the total number of points. Living lab members pointed to technological innovation research areas as the least important regarding financing from public funds (16.4% of the total points). Research on the state and possibility of improvements in social capital gathered almost 22% of the total points. The voting results in respect to Criterion II—public access to research results—highlighted the adaptation to climate changes research area, having 30.0% of the total points, as the most preferred by experts to guarantee open access to research results. Research areas such as ecosystem and technological innovation scored about 25% of the total points, whereas research on the state and possibility of improvements in social capital gathered only 18.4% of the total points. This means that the last research area is considered to potentially be the least subject to limited access to research results. Regarding Criterion III—expected time of generating research results—the majority of experts chose the technological innovations research area as the relatively fastest in delivering results. Second place was granted to the adaptation to climate changes research area (26.3% of the total points). The research areas of ecosystem services and research on the state and possibility of improvements in social capital were almost equally assessed; each accumulated about 21% of the total points (Figure 2).

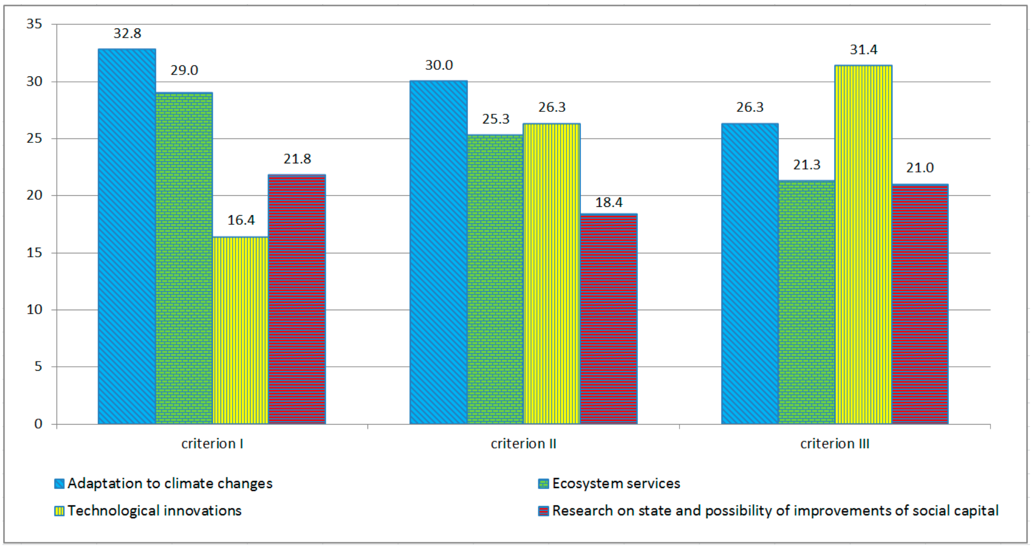

Figure 2. Expert CV prioritization on research areas depending on the criterion (% of total number of points). Source: Study results.

Finally, the results of the Cumulative Voting method were combined to provide a synthetic overview of hierarchization. Cumulative Voting resulted in choosing adaptation to climate changes as the top priority, having 29.7% of the total points. Technological innovation was given 24.7% of the points, whereas ecosystem services received 25.2% and research on the state and possibility of improvement in social capital only received 20.4% (Figure 3).

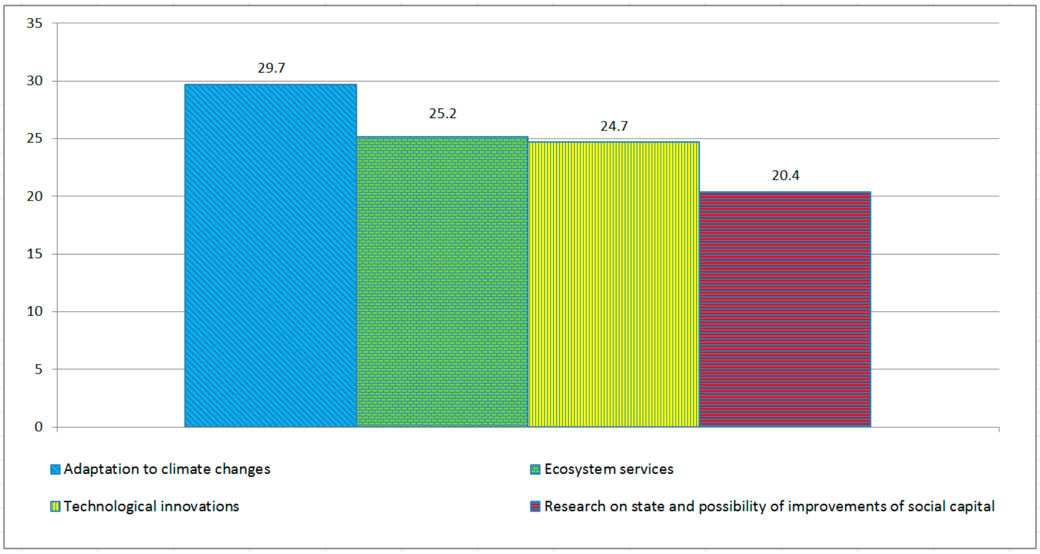

Figure 3. Aggregated results of expert opinions on research areas hierarchy based on CV. Source: Study results.

The alternative AHP method achieved similar results. As the most important research area, the experts assessed adaptation to the climate changes, having 38.6% of the total number of points. The second on the priority list was research concerning ecosystem services, having 29.7%. Technological innovations were listed third, having 22.8% of the points, whereas research on the state and possibility of improvements in social capital gathered only 8.9% of the points (Figure 4). However, in the AHP method, diversions between the most important research area—adaptation to climate changes—and the least important research area—the state and possibility of improvements in social capital—were amplified. The pair comparison dramatically diminished the importance of social capital related research areas, while augmenting the importance of the adaptation to climate changes research area.

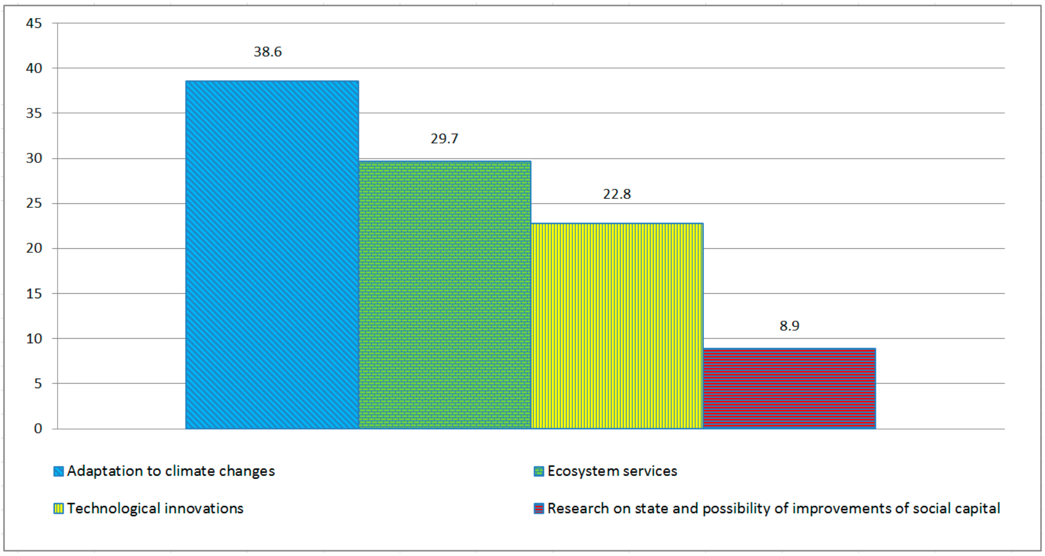

Figure 4. Hierarchy of research areas based on AHP method (% of total number of points). Source: Study results.

3.3. Priority Research Areas Versus Polish Strategic Programmes for Support of Agriculture

The results of the examination of the Polish CAP Strategic Plan show that knowledge and innovation transfer and dissemination were named as one of the key strategic needs, and three elements of this need are directly listed in the document:

- Improvement of the knowledge and innovation system;
- Improvement of knowledge and skills of farmers and other rural inhabitants;
- Comprehensive advisory support for farmers.

The research and innovation are also elements of two of the ten objectives named for the CAP 2023–2027:

1. Objective 2. Increase market orientation and farm competitiveness, both in the short and long term, including greater focus on research, technology, and digitization.
2. Objective 10 (cross-cutting). Modernize the sector by supporting and sharing knowledge, innovation, and digitization in agriculture and rural areas, and encourage farmers to benefit from them through better access to research, innovation, knowledge exchange, and school.

Among the detailed needs presented in the Polish CAP Strategic Plan, also exist those related to research and innovation:

- Increasing innovation application in the agri-food sector and in rural areas through the creation and widespread use of innovative solutions.
- Improving knowledge about the rational use of natural resources—water, soil, and air.
- Enhancing the qualifications and skills of staff involved in the exchange of knowledge and innovations and ensuring the availability of professional advisory and training services.
- Strengthening cooperation between AKIS partners.

- Improving methods and ways of cooperation and improving the efficiency of AKIS operation in Poland, especially in terms of access to knowledge and dissemination of innovative solutions (including digital ones), in addition to the development of conditions for their creation and use in farms.

In the Polish CAP Strategic Plan, it is stated that grants will be provided for the preparation and implementation of innovative solutions in the agri-food sector entities that include R & D elements (grants will be provided to R & D entities, including, among others, institutes, schools, and universities in the scope of conducting research on reduction in emissions in agriculture, rational management of resources, and agriculture 4.0) and investments by agricultural administration in digitalization of management, monitoring, and evaluation processes. Support will also be granted for investments in digital solutions providing access to knowledge bases, enabling more efficient knowledge transfer, and sharing of knowledge and skills.

Support for research is directly foreseen as being part of support measures for two sectors of agricultural production—beekeeping and fruit and vegetables. In the case of the beekeeping sector, the intervention will enable financing implementations of research results, applied research, and other studies that will have a positive impact on beekeeping management and quality of bee products. The results of these analyses will be available to all beekeepers, which should translate into better economic decisions and contribute to improving the general conditions of beekeeping management. This support is addressed to scientific and research units dealing with beekeeping. One of the requirements for beneficiaries of the support will be publication on the implementation of the project and the achieved results.

In the case of the fruit and vegetable sector, the intervention aims to involve fruit and vegetable producer organizations in the implementation of innovative operations:

- Promoting sustainable production methods;
- Responding to market demand;
- Optimizing production and improving competitiveness, focused on research, technology, and digitization.

A vital part of the support for innovation and knowledge transfer is improving the vocational qualifications of farmers and agricultural advisors. In the case of farmers, the intervention concerns training for farmers, covering issues related to the objectives of the CAP and the implementation of the objectives of the European Green Deal in agricultural activity and the use of farm resources. The intervention will ensure the transfer of knowledge and information in the field of farm development. Support for farmers also includes comprehensive agricultural advice. This intervention provides advisory support to agricultural holdings through both individual advisory programs and group training. There is also support for upskilling agricultural advisors.

In order to improve dissemination of innovations, the Polish CAP Strategic Plan also envisages support for demonstration farms. The intervention will ensure the transfer of knowledge through visits to demonstration farms.

After the presentation, a MS Teams survey was conducted on the compatibility of the approach of the Polish CAP Strategic Plan towards research, its dissemination, and innovation with the key research areas identified by the living lab's experts. The participants were asked to give a score from 1 to 10, where 1 was not compatible at all and 10 was fully compatible. The highest score was achieved by the compatibility of the Polish Strategic Plan and the research area related to technological innovations—score: 7.3. For the adaptation to climate change, the score was 6.4, for ecosystem services—5.6, and for research on the state and possibility of improvements in social capital—6.5 (Figure 5).

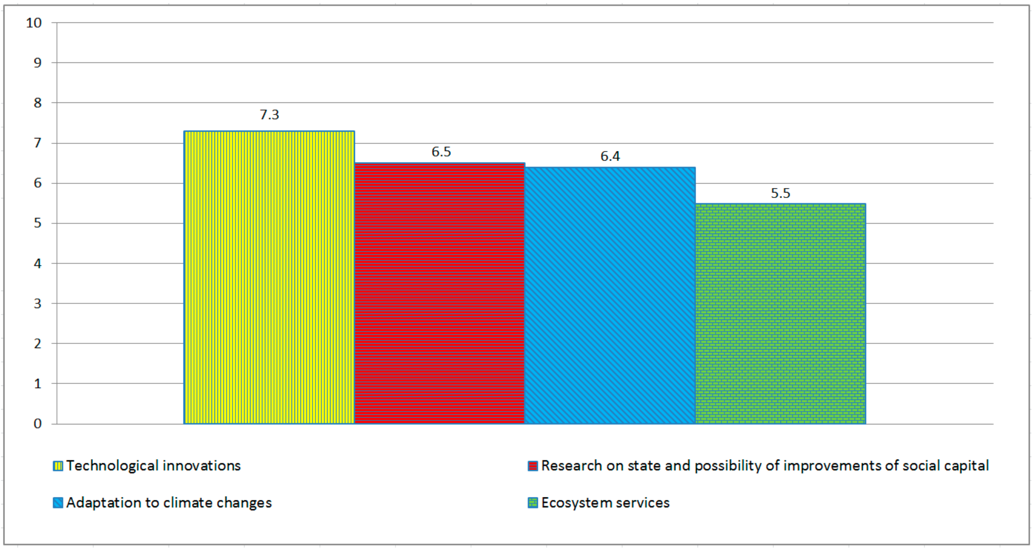

Figure 5. Compatibility of the approach of the Polish CAP Strategic Plan to research and innovation with key research areas identified by the living lab. Source: Study results.

The other strategic document examined was the draft of the Polish Recovery Plan. In relation to the agricultural sector, it foresees investments leading to shorter product supply chains, especially:

- Inclusion of agri-food processing SMEs in a circular economy;
- Support for investment in agri-food processing facilities that improve environmental and climate standards;
- Support for investment in the use of non-genetically modified protein raw materials for feed production.

The Plan also envisages investment in the development of research potential related to the agricultural sector:

1. Modernization or establishment of specialized laboratories to support the preservation of high-quality food and feed and genetic resources;
2. Investments in ensuring adequate food safety standards to protect the interests of food consumers;
3. Investments in the development of precision agriculture and renewable energy sources in companies with State Treasury shares, acting as demonstration and training facilities and pilot projects.

Support for the development of modern education is also part of the Polish Recovery Plan, in particular:

- Establishment of sectoral skills centers of vocational excellence including the dissemination of innovation;
- Development of a system for coordination and monitoring of regional activities for vocational education, higher education, including adult education.

Also closely related to the issues of sustainable agriculture is the planned support for sustainable water and wastewater management in rural areas:

- Construction, extension or modernization of water supply or sewage systems in rural areas;
- Investments related to the promotion of rational water and sewage management;
- Co-financing of infrastructure using digital solutions and creation of tele-informatic systems for water and sewage management.

As the COVID-19 pandemic vividly showed, providing access to a high-speed Internet connection is crucial for agriculture and rural areas. The intervention will support projects for the construction of broadband networks, ensuring access to fast Internet in areas that are currently digitally excluded.

The support for development of e-public services is also vital for agricultural policy and agriculture itself. Therefore, the Plan envisages:

1. Implementation of geolocation solutions and satellite monitoring in agriculture;
2. Implementation of an agricultural land verification system;
3. Strengthening the veterinary supervision system.

After the presentation, the participants were asked to assess the compatibility of the Polish Recovery Plan with the key research areas for sustainable agriculture. As in the previous survey, 1 was totally incompatible and 10 was totally compatible. The results were similar to those in relation to the Polish CAP Strategic Plan. The highest score—7.2—was given to innovative technologies. The second was adaptation to climate change—6.5. For research on the state and possibility of improvements in social capital, the score was 6.3, and for ecosystem services it was 5.0 (Figure 6).

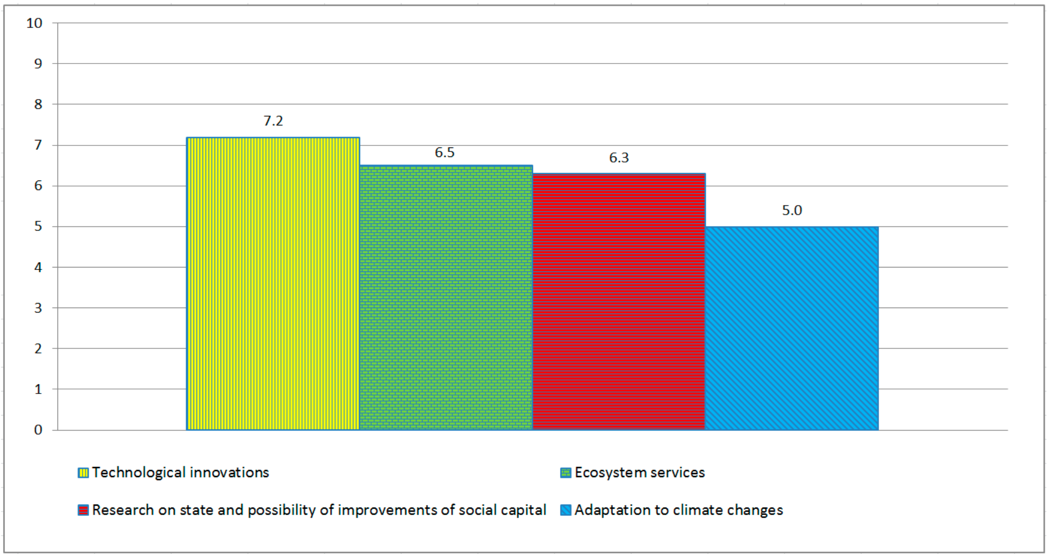

Figure 6. Compatibility of the Polish Recovery Plan with the key research areas identified. Source: Study results.

4. Discussion

Research agenda setting is an increasingly important issue due to growth in the complexity of socio-ecological systems and because sustainability is crucial for the survival of humanity. The COVID-19 pandemic showed the importance of prioritizing the areas of research, with several countries and private companies allocating substantial resources to developing a vaccine that could help overcome the disease. Involving practitioners in research agenda setting can improve the impact of research programs [59].

Setting a research agenda can be seen as the first step leading to implementing the findings of the backcasting exercise for establishing a desirable future. This first step must be followed by several other steps. The key among them is translating the research findings into the policy agenda. This is a difficult task as it "occurs in a complex, fluid system which includes multiple 'research clouds', 'policy spheres' and other networks" [60]. However, the next step is also a challenging task because it requires popularizing and implementing research findings at the farm level. The diffusion of evidence-based knowledge is even more demanding because the farming sector is diverse, and the applicability of certain solutions can require some fine tuning, or additional research or insight. Therefore, efficient and active AKIS is a crucial stakeholder in building a sustainable and resilient agriculture.

The backcasting exercise conducted in the study showed that even with a heated debate on the future of the common agricultural policy, climate change and its impact on agriculture, and the problems in the functioning of the current food system, such as growing societal obesity, unbalanced power of different stakeholders in the food chain, and omnipresent food waste, imagining a desirable model of agriculture is difficult because path dependency is seen as a barrier for revolutionary transition.

This resulted in a vision of the Polish agriculture that is "different but yet the same". The visions discussed by the participants can be traced back to the trends being observed or foreseen for the coming decades. Because backcasting is a qualitative method, the structure of Polish agriculture in 2100 was not quantified; neither was there a debate on the regional specializations or characteristics. However, the results showed the basic importance of the influence of environmental and economic limitations on the future of Polish agriculture, and offer a direct recommendation for research and policy regarding their future directions when designing both research and policy agenda.

The research areas proposed by the living lab's experts cover a wide range of issues related not only to sustainable agriculture, but also to the sustainability of the whole food system. The proposed research areas are a reminder that sustainability has different dimensions [61]. All these dimensions need to be present at a sector and farm level to ensure genuine sustainability. Balancing environmental and socio-economic issues was mentioned as the key problem, which is not only a research problem, but also a problem of a societal consensus where the long- and short-term perspectives are difficult to reconcile.

It must be stated that the research areas proposed by the participants of the study are in line with the headings proposed by the European Commission for the Horizon Europe program in agriculture and forestry. The EC chose the following research areas:

1. Increasing production efficiency and coping with climate change, while ensuring sustainability and resilience;
2. Providing ecosystem services and public goods;
3. Empowerment of rural areas, support to policies and rural innovation;
4. Sustainable forestry [62].

The prioritization of research areas is an important topic given the huge number of knowledge gaps, and the need to support the sustainability and resilience of the agricultural sector. The prioritization exercise conducted during one of the meetings of our living lab showed that this issue is a problem when the research areas are not fully separated from one another. This is also difficult to achieve in real life, when the research in one area can influence more than one aspect of agricultural activity and the whole food system.

The criteria used for prioritization also influence the outcomes of the prioritization process. Technological innovation seems to be the quickest to achieve and the most able to engage private funds. An important component of technological innovations in times of depleting natural resources is the aspect of efficient use of energy and water. Thus, such innovations support the sustainability of agriculture, at least in its economic and environmental dimensions.

Moreover, solutions adapting agriculture to climate changes can be of interest to the private sector and can raise private funding, but only in some aspects of this research area. Therefore, this research area is more in need of public funding. The area most in need of public funds is research on ecosystem services. This is still an area of significant knowledge gaps in terms of the generation, valorization, and relationship between agricultural production and ecosystem services. When looking from the food system perspective, the research on the state and possibility of improvements in social capital and the willingness of all stakeholders to support the sustainability transition in their strategic and daily life choices is a vital part of the knowledge that is needed to enable the transition.

During the debate on the compatibility of the Polish strategic documents with the discussed sustainable development of Polish agriculture and the priority research areas, the experts stated that both strategic documents presented are a step in the right direction, both in terms of the research that they directly and indirectly support, and the measures proposed for supporting sustainable agriculture. However, the capacity of these plans is limited given the scale of resources planned for these measures.

The discussion on the Polish CAP Strategic Plan started with the problem of creating innovations in Poland. It was stated that neither Polish science nor Polish private enterprises can provide innovative solutions, and these can only be offered by big international companies. Agriculture 4.0 is a domain of super enterprises in which the roles of their science and R & D divisions are strong. Agricultural advisory services should be more specialized because the knowledge required in modern agricultural activities is highly specialized. Currently, this expertise knowledge is only offered in Poland by commercial companies supplying modern equipment and technologies of production.

The next question in the debate concerned the problem of the structure of the Polish farming sector—a large number of small farms and a small number of big farms—and the degree in which this is taken into account in the Polish Strategic Plan and the functioning of the Polish public advisory system. The vocational training for farmers is generally targeted at smaller farms because bigger farms, in their search to boost competitiveness and keep costs as low as possible, turn to new technologies offered by commercial companies, together with training and consultations about how to apply them most effectively in their specific setting [63]. This shows a high level of division continues to exist in the models of knowledge transfer in Polish agriculture.

Another issue discussed was the question of demonstration farms as a model of diffusion of sustainable agriculture research achievements. One of the participants noted that, 100 years ago, in the period between World Wars I and II, whole demonstration villages were established in Poland, which farmers from other parts of Poland visited to see modern agricultural practices and equipment. This raised the question of whether this means of knowledge transfer and diffusion of innovations can also be used at the present time. The answer may be that the rapid development of new technologies is overwhelming for many people, not only in the farming sector, and demonstrations of the applications of modern equipment or agricultural practices can be easier to comprehend and thus more effective in the transition of the farming sector. Moreover, farmers in demonstration farms can act as innovation brokers and promotors of sustainable agriculture. Farmers should pay an active role in the innovation process and report their needs to the other stakeholder groups that take part in this process. It was also underlined that more attention should be paid to the issues related to GHG emissions and zoonotic diseases by farmers and science in Poland.

It was also stated that, for more innovative farms, the Polish CAP Strategic Plan, such as via the current Rural Development Programme, offers a "Cooperation" measure in which farmers and researchers try to identify innovative solutions to the needs reported by farmers. However, this measure is not popular and there is a small number of projects being implemented within it.

The representative of the farming advisory stated that they have to familiarize farmers with new technologies, and this is the direction of development of the advisory services. However, the employees of these services are flooded with different tasks and there is no system of specialization. Therefore, they find it hard to offer services tailored to the specific needs of a given farm, and farmers predominantly seek the advice of the advisory service regarding their struggles with filling in different documents required in relation to CAP support. The CAP reform will increase the administrative burden placed on farmers and, thus, the administrative burden advisers have to deal with. This means that farming services currently specialize in supporting farmers in rent seeking and not in improving the sustainability of their farms [64].

Despite their growing involvement in administrative support, the advisors expressed great satisfaction in bringing innovations related to agriculture 4.0 closer to farmers. The representative of advisory services stated that its regional advisory center is already very active in demonstration activities showing farmers environmentally friendly and productive new solutions in relation to water management, which are in line with eco-schemes in the new CAP. In his opinion, advisors cannot be creators of innovations and can only act as a bridge between science and industry on one side and farmers on the other side.

One of the representatives of research stated that Polish science has a role to play in the innovation process, but its limited innovation potential calls for redefining its role in the process of creating innovations. In his opinion, the Polish Strategic Plan does not fully represent the role played in the innovation process by private companies. Moreover, given the EU Green Deal, the widespread implementation of precision farming solutions is inevitable. However, precision farming technologies are currently very expensive and only the biggest farms and groups of farmers can afford to apply them. Nonetheless, it should not be forgotten that innovations not only comprise high-tech machines and equipment, but also involve climatic adjustment in the production type and structure, and social solutions such as the organization of production.

Agricultural advisors can also be creators of innovations related to management skills. They can disseminate good practices and help select the right technologies. However, this requires improvement in the public advisory system in Poland to enable high specialization of agricultural advisers. It should not be expected that an adviser knows everything regarding every aspect of the functioning of a farm.

Supporting small farms in the transition to green technologies and solutions is an important issue. The biggest farms receive solutions directly from commercial companies, whereas small farms are left behind as they are not seen as prospective clients. Therefore, public advisory services are required to familiarize small farm holders with the potential benefits of solutions that are already commercially available. Small farms can also improve their position by introducing social innovations. Therefore, social sciences are key to offering such innovations and supporting their successful implementation.

The digitalization of rural areas is a complicated issue. This not only requires high-speed and reliable Internet connections, but also the transfer of knowledge to citizens, including farmers, to show what can be done and how to use the Internet for one's professional activities. Currently, the technological skills of rural citizens, and the ways in which they use technology, are generally still underdeveloped, although this has changed rapidly. Five or six years ago the Internet was used passively, i.e., to obtain information, whereas it is now used actively to interact with the market, i.e., to create information about the products.

Building competence is a challenge for agricultural advisory services because different agricultural farms have different needs. Generally, there is a need for more advisors specializing in modern technologies. Access to the Internet for rural communities is more of a task for the EU cohesion policy, and competence development may be achieved in stages. There is also the issue of who owns and who can make use of the data gathered by devices used by farmers. The right solutions are being sought to help in the sustainability transition, which seems to be undervalued in the process of prioritization of research areas. This requires social and technological solutions. A large amount of information has already been gathered, and simple algorithms can be applied by public institutions and used by public advisory services. This can be supported by digitalization of the public administration's monitoring of the CAP.

The absorption of research outcomes can be supported by better cooperation among public agricultural advisory centers, public administration, and science. The relevant institutions should cooperate in disseminating their case studies, best practices, and research findings to stimulate diffusion and transfer of knowledge, because there may be good practices that have a regional character but can be verified in other regions. It is also important to know that the most advanced solutions are not necessary the best ones in a given socio-economic, cultural, and institutional context, and that the solutions being implemented must take these factors into account. This opinion is supported by the scientific literature on innovation systems, which states that there is a need for structural coupling between different parts of the innovation system [65].

It was highly appreciated by the living lab members that the Polish Recovery Plan acknowledges the importance of short supply chains, and that it gives an opportunity to develop and popularize this approach. To ensure the success of short supply chains, it is crucial to build trust between producers and consumer. Moreover, local energy management chains are needed. Ultimately, however, the market is the basis for the sustainability and resilience of agriculture.

Because the study involved participatory knowledge co-creation, the process of conducting the study must also be discussed. In debates among various stakeholders who are supposed to reach a common understanding or a consensus, the dynamics of the discussions is vital. Therefore, the facilitators of the group or plenary discussions played an active role in ensuring that all the participants had equal opportunities for expressing their opinions. To help the participants better understand one another's positions, the meetings started with a brief introduction of each of the participants, focusing on the link between sustainable agriculture and their professional experiences. This proved to be a very efficient means to establish relations among participants and build a trusting environment.

All the methods applied at different stages of the study proved to be adequate. In the case of the key part of our study—prioritization—we used two methods, about which we knew their strengths and limitations (presented in the Materials and Methods section). The similar results achieved by the application of AHP and CV shows that AHP could be used in our study. This was the case because the living lab experts had an extensive knowledge of different aspects of farming, and could fully assess the role and importance of the research areas in the prioritization process. Without this knowledge of the experts, only CV would have been able to be used because it is applicable for groups with different backgrounds [56].

The weak point of the study was the limited number of stakeholder groups involved, as there were no representatives of the retail food processing sector. The numbers of farmers and policy makers involved was also insufficient. Moreover, the study did not directly relate to the regional specificity of Polish agriculture, which is important in shaping the development potential of the farms.

Further studies should include field experiment exercises in which participants are asked to divide a certain amount of funds among the research areas. The interesting question here is whether the outcomes of the prioritization exercise would be similar or different if, rather than using abstract points, the participants were required to provide an actual budgetary allocation of the funds spent in Poland on agricultural research. Other areas for further studies include strategic foresight and scenario planning.

Navigating the socio-technological transition of the food system is crucial for both humanity and the planet. It involves solving numerous problems relating to a wide range of science disciplines. The identification of knowledge gaps and priority research areas is vital to plan policies that support the sustainability transition.

The study identified the key research areas that can support the sustainability transition of Polish agriculture. Although Polish strategic documents indicate the need for supporting these research areas, the actual progress in research and innovation required to stimulate the transition will be limited and fragmentary due to budgetary constraints. There is a need both for more funding and the coordination of research activities and policy to tackle all the aspects of sustainability in agriculture and the food system.

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