**Author(s):** Kristine Valujeva, Elizabeth K. Freed, Aleksejs Nipers, Jyrki Jauhiainen & Rogier P.O. Schulte

**Title:** Pathways for governance opportunities: Social network analysis to create targeted and effective policies for agricultural and environmental development

**Year:** 2023

**Version:** Published version



**Please cite the original version:**

Valujeva K., Freed E.K., Nipers A., Jauhiainen J., Schulte R.P.O. (2023). Pathways for governance opportunities: Social network analysis to create targeted and effective policies for agricultural and environmental development. Journal of Environmental Management 325, Part B, 116563. https://doi.org/10.1016/j.jenvman.2022.116563.

Journal of Environmental Management 325 (2023) 116563

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

# Pathways for governance opportunities: Social network analysis to create targeted and effective policies for agricultural and environmental development

Kristine Valujeva[a,b,c,*], Elizabeth K. Freed[a], Aleksejs Nipers[c], Jyrki Jauhiainen[d], Rogier P.O. Schulte[a]

[a] *Farming Systems Ecology Group, Wageningen University and Research, the Netherlands*
[b] *Scientific Laboratory of Forest and Water Resources, Latvia University of Life Sciences and Technologies, Latvia*
[c] *Institute of Economics and Regional Development, Latvia University of Life Sciences and Technologies, Latvia*
[d] *Natural Resources Institute Finland (Luke), Helsinki, Finland*

ARTICLE INFO

*Keywords:*
Functional Land Management
agri-environmental governance
soil functions
Agricultural Knowledge Innovation System

ABSTRACT

Participatory techniques are widely recognized as essential in addressing the challenges of agri-environmental policy and decision-making. Furthermore, it is well known that stakeholder analysis and social network analysis are useful methods in the identification of actors that are involved in a system and the connections between them. To identify key stakeholders and improve the transfer of information from national-to farm-level, we compared a stakeholder analysis with farmer-centric networks for primary productivity, carbon regulation and biodiversity through the case study of Latvia. Farmer-centric networks show a higher number of stakeholders communicating on the topic of primary productivity network comparing to other topics. We found three pathways for improving knowledge transfer in agri-environmental governance: horizontal strengthening of farming community, horizontal strengthening of policy departments, and vertical strengthening between policy departments and farmers. The first step is to ensure that policy-makers have a common understanding of the results that should be achieved. The second step is the transfer of know-how between farmers to develop new solutions. The third step is the training of advisers in the land multifunctionality and the strengthening of communication and knowledge transfer between policy departments and farmers in order to jointly achieve the desired direction at that national level. Long-term cooperation between many stakeholders, including knowledge transfer, the development and implementation of solutions, and monitoring are essential in order to adequately address global societal challenges. The application of our mixed methods approach to elucidate pathways for improved governance of knowledge and information is of direct relevance to other jurisdictions seeking to transition towards multifunctional and sustainable land management.

## 1. Introduction

The interaction between farmers, society, and the natural world is influenced by the increasing demand for resources, a growing population, increasing environmental pressures, the effects of climate change as well as shifting societal demands, and new technologies. Farming is not just for providing soil-originated resources, but also a means for providing income; as such, farmers expect their land to be both productive and healthy.

The sustainable land management principles become increasingly important and researchers seek knowledge and comprehension on processes to implement them. Soil is the most important resource for sustainable land management, since it provides food, feed, fiber, water purification and regulation, nutrient cycling, carbon sequestration and regulation, and a habitat for biodiversity (Calzolari et al., 2016; Haygarth and Ritz, 2009; Schulte et al., 2014). Functional and societal demands for these soil functions can be defined at the local, national, and international scales, while the supply depends on the soil biophysical properties and land-use. The Functional Land Management conceptual framework is used to look for trade-offs between the soil biophysical

* Corresponding author. Farming Systems Ecology Group, Wageningen University and Research, the Netherlands.
*E-mail address:* kristine.valujeva@wur.nl (K. Valujeva).

https://doi.org/10.1016/j.jenvman.2022.116563
Received 2 June 2022; Received in revised form 12 October 2022; Accepted 16 October 2022
Available online 26 October 2022

capacity to deliver these soil-based ecosystem services and societal demand for them (Schulte et al., 2014). Societal demands and the capacity of soils to meet the demand for soil functions have spatial variations that are influenced by the regional distribution of the population, agricultural intensity, geo-environmental conditions and landscape structure (Schulte et al., 2019). In order to find trade-offs between various policy targets and the ability of soils to deliver on these targets, we can apply additional management practices and land-use changes to guide a policy-making process adapted to local conditions (Valujeva et al., 2020, 2022). Investigating the effect of management practices and land-use change requires close cooperation between scientists, policy-makers and the farmers that will implement these changes on their land.

The Agricultural Knowledge Innovation System (AKIS) approach is being included by the European Commission in the post-2020 Common Agricultural Policy (CAP) as a strategy to contribute to farming-system resilience and support rural development through widespread dissemination of agriculture-related knowledge and innovation technologies (EC, 2018). The current AKIS 1.0 emphasizes the diverse agricultural-related groups of stakeholders who seek information and innovation exchanges, illustrating the necessity to improve collaboration between these groups. AKIS 1.0 does not take into consideration that farmers are not only the end-users of these innovations, but they also play a significant role in knowledge creation and dissemination (EC, 2018).

As a result, the updated AKIS 2.0 will be based on a knowledge exchange that is adapted to the needs of farmers, introducing peer-to-peer learning, and improving the interaction between research and practice, leading to jointly developed solutions that farmers are motivated to implement and from which they will benefit (EC, 2018). It requires the EU Member States to include a description of the organizational structure of the AKIS in the CAP Strategic Plans, the organizations involved in using and generating knowledge in agriculture and related fields, and the related knowledge flows. Another requirement is to show the outline of cooperation of advisory services, research and CAP networks within AKIS to provide advisory services and innovation (EU SCAR AKIS, 2019). For some Member States (e.g. Austria, Denmark, Ireland), AKIS already is very well established and integrated with a strong impact to support farmers. However, in other Member States (e.g. Latvia, Italy, Spain) AKIS is fragmented, with many public and private actors that operate from local to national levels (EU SCAR AKIS, 2019). Without a coordinating structure, the large number of involved actors leads to an overabundance of diverse information and knowledge, which is not aligned with national policies. Not all organizations that are involved in AKIS are active in communication with and knowledge transfer to farmers, so it is crucial to understand which key organizations are most valued by farmers.

Stakeholder analysis and social network analysis are well-known methods combined in various studies to identify stakeholders and establish their influence and interest, as well as their connections with each other (Ahmadi et al., 2019; Lienert et al., 2013; Prell et al., 2009; Wu et al., 2020). Both methods have complementary roles in highlighting the complexity of agri-environmental management systems, and allow for better decision-making and analysis. Hauck et al. (2016) found that social network analysis is a valuable tool not only to identify key stakeholders, but also gain an understanding of the various views that influence or are influenced by biodiversity governance. A study on the role of farmers' social networks in implementing no-till farming practices shows that farmers believe they have a higher level of knowledge due to practical experience compared to researchers and other organizations (Skaalsveen et al., 2020). This study also identified that knowledge is not equally available to all farmers due to geographic location, and formal consultations are unable to provide diverse, complex and highly specialized knowledge. Although farmers have accumulated experimental knowledge over the years, there is still a need for cooperation between farmers, consultants and researchers to critically evaluate and interpret the available information, and to ensure the dissemination of information. Farmers' perceptions and management practices are important factors in setting up the structure of the advisory network, and it is therefore necessary to raise farmers' awareness of their contribution to climate regulation and to encourage more involvement in the networks (Albizua et al., 2021).

Since the introduction of the CAP, farmers have access to both free and paid consultations, but not in all EU countries do farmers trust the information provided by consultants. Most often, farmers value each other as the best source of information. A number of studies highlight that advisors can play a key role in providing sound and scientific evidence to farmers (Micha et al., 2020; Mills et al., 2020, Mills et al., 2021; Schwilch et al., 2012; Šūmane et al., 2018), however the role of advisors in addressing environmental issues has received little attention. There is also a lack of information about other organizations providing information to farmers. Farmer decisions are not made in isolation and by understanding how farmers receive information on different topics especially related to environmental issues, we can better addressing the challenges of agri-environmental policy (O'Sullivan et al., 2022). Therefore, the aim of this study is to identify key actors in farmer-centric networks and potential pathways for improving information channels for primary productivity, carbon regulation and biodiversity. To do this, we appraise and combine four methodologies commonly used in social sciences. We use the AKIS of Latvia, part of the Baltic and Nordic regions of the EU, as our case study to evaluate how the gap between policy formation and farmer practices for sustainable land management can be bridged through improved governance of knowledge and information.

## 2. Materials and methods

### 2.1. Data sources and data collection

This study had four main steps, as shown in Fig. 1, and was focused on three soil functions: primary productivity (PP), carbon regulation (CR), and biodiversity (BD). The first step was to compile a list of stakeholders based on a review of organizations' websites and online resources. The second step was the evaluation (by experts) of stakeholders' interest and influence of land-use issues that were related to PP, CR, and BD. This step categorized each stakeholder based on their level of interest and level of influence. The third step was to identify stakeholders through farmer interviews. The fourth step was to conduct a social network analysis, where we investigated the relationships between farmers and different organizations for each soil function. Finally, the results obtained over the studied steps were compared for key recommendations.

#### 2.1.1. Selection of stakeholders

In this study, the first selection of agri-environmental governance stakeholders in Latvia were identified through websites. Selection was started with the government ministry websites, followed by subordinate institutions, which are included in the stakeholder list. Next, we looked for other partners and organizations that were mentioned in the websites of the subordinate institutions. The search was ended when the organisation founded did not meet the criteria: interest in land management issues. To the stakeholder list we also added five clusters of Latvian agricultural farms defined by the EVIDEnT project (http://www.vpp-evident.lv/index.php/en/), where: (1) Cluster 1 represents intensive mixed specialization farms that keep animals in housing with a farm size greater than 400 ha; (2) Cluster 2 represents intensive cereal farms with a farm size greater than 200 ha; (3) Cluster 3 represents medium-sized mixed specialization farms with livestock grazing and a farm size greater than 400 ha; (4) Cluster 4 represents organic farms; (5) Cluster 5 represents backyard farms with a farm size less than 10 ha (Eory et al., 2018; Kreišmane et al., 2018). Backyard farms in Law on Land Reform in Rural Areas of the Republic of Latvia are defined as agricultural farms whose land user (owner) owns a residential house or buildings necessary for the work of a craftsman, and these farms have

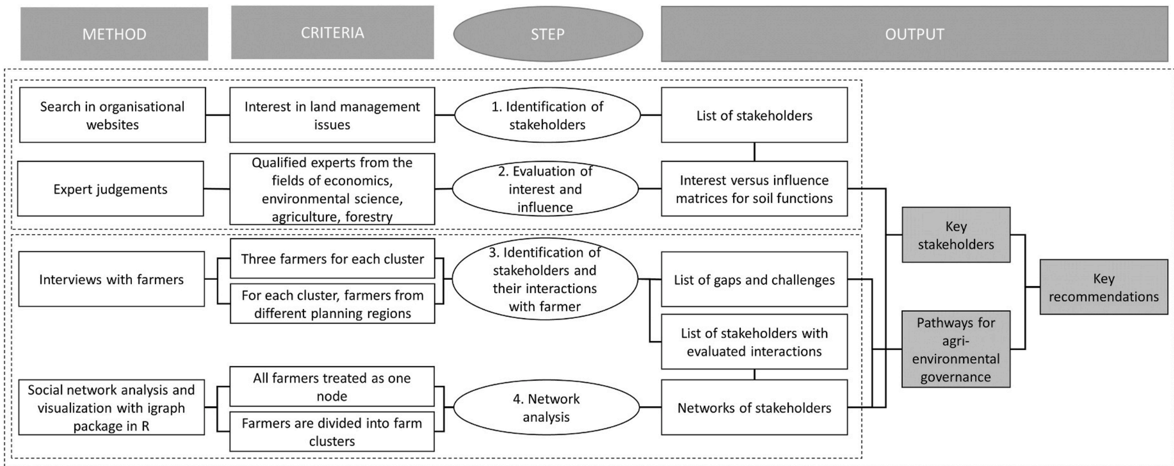


**Fig. 1.** Schematic representation of key methodological steps.

the character of an auxiliary farm (LR, 1990).

The list of stakeholders was sent to eight experts in the fields of economics, environmental science, agriculture, and forestry for the evaluation of interest and influence. All experts were representatives of their respective fields who have qualified for the status of experts of the Latvian Council of Science (https://sciencelatvia.lv/#/pub/eksperti/list). We asked them to evaluate the interest and influence of previously selected stakeholders in range from 1 to 10, where 1 is low and 10 is high. This is a frequently used method to understand the engagement of stakeholders in a given issue or decision-making process (Ahmadi et al., 2019; Prell et al., 2009; Reed et al., 2009; Reed and Curzon, 2015). We created three evaluation matrices where we asked: How much stakeholders are interested and how much they can influence the increase in (1) primary productivity, (2) carbon regulation, and (3) biodiversity. Also, experts were invited to add additional stakeholders if deemed necessary. We calculated average interest and influence for all stakeholders and developed an interest versus influence matrix for each soil function. We were particularly interested in stakeholders that have high interest and high influence or low interest but high influence. Those stakeholders were classified as “key players” and “context setters”. “Key players” are the most important stakeholders to work with because of the high interest in and influence over land management issues. Stakeholders classified as “context setters” do not have high interest, but they can inadvertently influence important processes related to land management. “Subjects” have high interest, but low influence, and are therefore supportive stakeholders and may become influential by forming alliances with others. Stakeholders with low interest and low influence form the “crowd” and there is little need to engage with them in decision-making processes. Based on review of organizations’ websites, online resources and assessment of experts, 52 stakeholders were selected in total for stakeholder analysis.

### 2.1.2. *Semi-structured interviews*

This study used semi-structured interviews to gain an understanding of who the powerful stakeholders are (in relation to the farmer perspective) to exchange information about PP, CR, and BD. The following two criteria were applied in selecting the targeted farmers for interviews: (1) we were looking for three farmers for each cluster, and (2) for each cluster, we chose farmers from different planning regions in Latvia in order to exclude specific regional impact. Interviews were done both face-to-face and online (11 and 4, respectively) during the period of June to November in 2021 (n = 15). After the first interview, we decided to ask about communication with farmers in general in the remaining interviews, without asking each interviewed farmer to which cluster the farmers they communicate with belong. This decision was made, firstly, to reduce the time of interview, because the interviews were conducted during the period when the farmers were busy with harvesting, and secondly, the farmers have their own perception how to cluster farmers based on type of farming, area and output, which does not always correspond to the results of the previous studies. The interviews consisted of an introduction, in which the objective of the study, general information (age, farm size, land use, soil type, number of animals, priorities of farm), and information flows on PP, CR, and BD were stated. Interviewees were asked to characterize stakeholders from whom they have received or to whom they have sent information about PP, CR, and BD. Before asking about soil functions, we asked prompting questions:

1. Would you like to produce more products on your farm?
2. Who has made you think that it is possible to produce more?
3. Have you heard from anyone about farming practices that would increase production?
4. Do you think about increasing the carbon content in soil?
5. Are you aware of the benefits of increasing the carbon content in soil?
6. Do you know how you can increase carbon in soil?
7. How would you describe the landscape where your farm is located?
8. Do you think about conserving and maintaining biodiversity in your farm?
9. Have you called on others to take care of biodiversity in Latvia?

Additionally, we asked each stakeholder to rate the frequency of received/sent information (daily = 5, weekly = 4, monthly = 3, yearly = 2, annually = 1) and the evaluation of received/sent information (high potential = 4, medium-high potential = 3, medium-low potential = 2, low potential = 1).

During the interviews, we filled in tables regarding the stakeholders from which farmers receive information and with whom they share information on each soil function. All interviews were recorded in audio format and then the statements that were associated with farmer views, perceptions, and knowledge relating to soil functions were transcribed.

## 2.2. *Data analysis: farmer-centric social network analysis*

The main elements of a social network are: nodes, which represent different stakeholders; edges, which represent the links/relationships/ties between nodes; and edge weights, which indicate the frequency and impact potential of received/sent information. We systematized the data from interviews by creating a node catalogue with the names of all actors and their node attributes for each soil function. Further, we created an edge list defining all connections between farmers and other stakeholders, including edge attributes. We created networks from nodes, edges and edge weights by using the igraph package in R 4.0.5

(https://igraph.org/) (Nepusz, 2022). Duplicate edges were merged into single edges and edge weights were summed. The networks were aggregated for each soil function in two ways: (1) where all farmers were treated as one node and (2) where farmers were divided into farm clusters. Then, in-depth links for the farm cluster networks were analysed using degree centrality. The following equation indicates that the degree centrality $C_D$ is the number of connections $A$ of given node (Lizardo and Jilbert, 2022):

$$C_D(j) = \sum_{j=1}^{n} A_{ij} \tag{1}$$

In the graphical representation, node size and color intensity represent the degree centrality of a stakeholder. The edge weights demonstrate the 'frequency x potential' of communication, while the color shows the direction of communication.

## 3. Results and discussion

This section presents the main gaps in reaching an improved understanding of primary productivity, carbon regulation and biodiversity, key actors in farmer-centric networks, and potential pathways for improving information channels. To identify key stakeholders and improve the transfer of information from the national to the farm level, we compared the stakeholder analysis with the farmer-centric networks for each soil function. It is vital to understand not only the tools needed to implement changes, but also the main gaps and needs of farmers, in order to establish result-based agri-environmental policies.

### 3.1. Primary productivity

Traditionally, profit and productivity have been the highest priority for farmers as shown by the PP farmer-centric networks, in which the information exchange and the largest number of organizations are concentrated (Fig. 2a). An increase in production was mentioned as a priority by 12 out of 15 farmers: "*Productive land must produce, while non-productive land must be used for other purposes*". For agriculture, like any other business, production and sale of products is a priority. Another farmer also mentioned: "*It is important to give the information to the consumer on what we produce and why the consumer should use it and leave for the consumer to decide for himself whether he needs it*". Almost all farmers indicated in the interviews that they communicate with other farmers on a daily basis, share farm events related to production, harvesting, sowing, latest technologies used in their farms, and provide each other with both technical support and knowledge. The social network analysis shows that the structures and communication channels for primary productivity are well established. The most important stakeholders with whom farmers have two-way communication about primary productivity are other farmers, the Latvian Rural Advisory and Training Centre (LLKC), the Farmers' Parliament (ZS) and the media.

### 3.2. Carbon regulation

Fig. 2b denotes far fewer connections, which means that farmers lack knowledge about on-farm carbon regulation and its relation to different farming practices that are already implemented on-farm. During the interviews, seven of 15 farmers said that they were not aware of carbon regulation issues; they indicated that while such information may be disseminated, they are not paying attention to it due to the lack of both time and interest. Only one farmer indicated increasing the carbon content of the soil as a priority on his farm, as this farm manages soils with insufficient organic matter content and the farmer believes that it is not possible to obtain a competitive yield without additional measures for improving the organic matter in soil. At the same time, 3.8% of managed land among the interviewed farmers is on organic soils. Agricultural production on organic soils results in net GHG emissions and causes a loss of soil carbon (Buschmann et al., 2020; Purola and Lehtonen, 2022; Qiu et al., 2021; Stainforth and Bowyer, 2020), yet there is a lack of knowledge about organic soils in the farming community. One farmer stated: "*There is a lack of knowledge surrounding what in Latvia constitutes as organic soil according to the current soil classification*", while another said: "*It is difficult to grow anything on drained organic soils, because organic soils are unable to maintain the moisture that the plant needs (…) in hot summers it becomes dusty, but when organic soil is wet, it attracts frost in the spring*". Often farmers choose pathways that are most beneficial for their farms (Mattila et al., 2022), and sometimes that happens to be in line with climate change mitigation: "*We have abandoned ploughing because we realized that it is not suitable for the farm's heavy soils, because the amount of organic matter in the soil is reduced, we are telling other farmers about the minimum tillage on the farm, but not with the aim to sequester carbon, it is like a bonus that you do not realize and that comes with it*".

Soil physical, chemical, and biological properties are mainly affected by soil organic matter and directly relate to soil organic carbon content, because soil organic carbon is often used to measure soil organic matter (Ontl and Schulte, 2012), but this knowledge is either not disseminated in the farmer community or the link between 'organic matter' and 'carbon' is not established: "*The importance of carbon in the soil is more background information*", and "*(…) I did not connect that carbon is organic matter that leads to fertile soil and yield*". Confusion and misalignment in terminology were also highlighted in interviews: "*I do not know how*

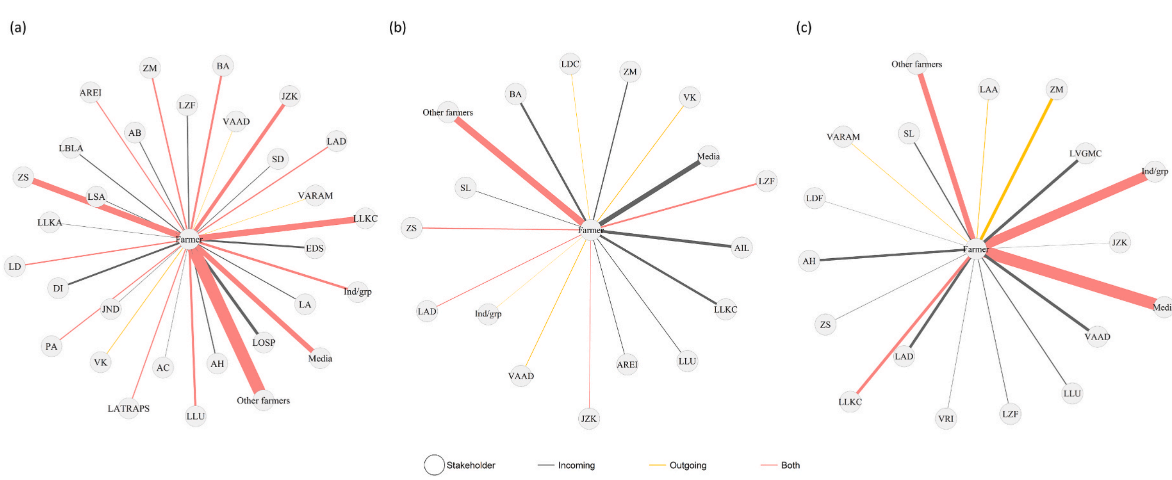


**Fig. 2.** Farmer-centric networks for (a) primary productivity (b) carbon regulation and (c) biodiversity. The thickness of the lines represents the weight of edge. Acronyms are explained in Supplementary Material Table S1 and overview of the networks is given in Table S2.

*much we need to think about carbon sequestration on the farm; we think more about liming and increasing organic matter, but we have not thought about increasing carbon in soil*", and another farmer also mentioned at the beginning of the interview that increasing the carbon content of the soils is a priority, but during the further interview admitted that: "*(…) it is relevant to us, we grow legumes, clover, alfalfa, which fix nitrogen (…) What is carbon? (…) then I mixed*".

### 3.3. Biodiversity

Fig. 2c shows the same number of connections as Fig. 2b, but with stronger links in both directions. In the last decade, biodiversity at the farm-scale has been garnering increased attention (Herzog et al., 2017; Maleksaeidi and Keshavarz, 2019), but still there is no clear opinion in the farming community regarding what constitutes on-farm biodiversity: "*There is a lack of qualitative and targeted information on ensuring biodiversity. What biodiversity is, is not defined and where it is naturally, where it could be artificially created and where it is clear that it will not be*". Five farmers mentioned that an increase in biodiversity is the least important attribute for their farms. Farmers can improve biodiversity on their farms (Stoeckli et al., 2017), and some see the necessity for close cooperation with scientists: "*There is a need for a scientific basis regarding what would improve [on the farm] and be necessary for the maintenance and enhancement of biodiversity*".

Because of the lack of knowledge in what constitutes biodiversity, farmers do not recognise themselves as an important stakeholder in its maintenance: "*We hear about biodiversity all the time, but we are not the ones to whom it should be told, we understand that for ourselves (…) those who farm normally are already taking care of surroundings and protect it*". The knowledge about biodiversity at the farm-level is affected by farmers' perception that environmental gains are considered to be losses in profitability (Dominati et al., 2019): "*We believe that productive land must produce, we must create the value of products, but in those land areas that are not suitable for production, we create biodiversity. We have a lot of old boreal forests on the farm, where there is a variety of insects, animals, birds, plants*", "*I will not leave one third or one fifth of agricultural land to nature, just to save the world*", and "*We should look at what already is, for example, the place of old houses, existing large trees, buffer strips*".

### 3.4. Stakeholder analysis

Fig. 2 is a very farmer-centric view, but in reality, there is an entire ecosystem of stakeholders; farmers do not work in isolation, as they are a part of the AKIS. The experts ranked selected stakeholders from organizational websites, and those with the surrounding lines are also mentioned by the farmers themselves (Fig. 3). We see the following discrepancies: (1) for PP, farmer interest and influence of are closely correlated; (2) but when for CR and BD, the interest of farmer clusters

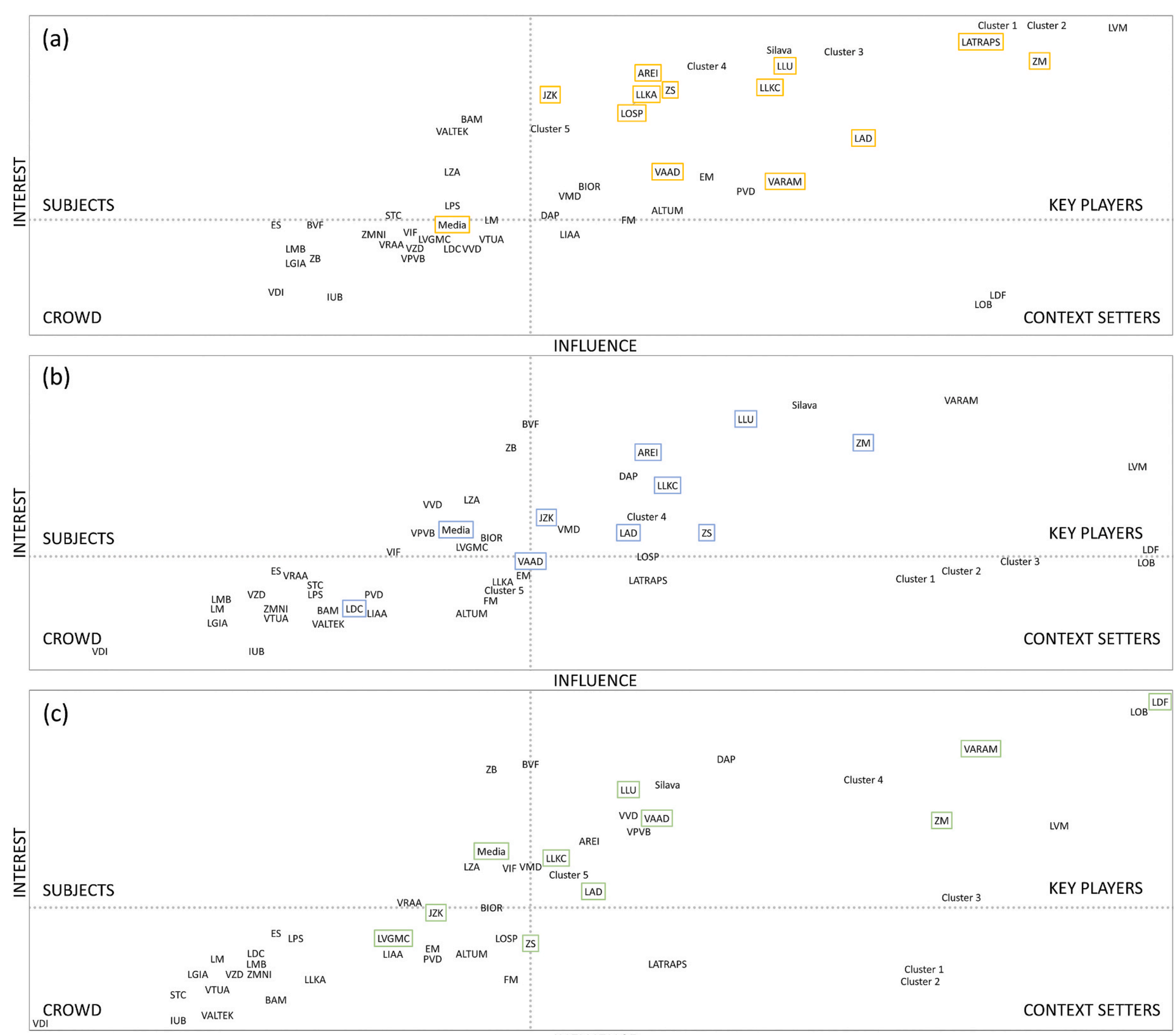


**Fig. 3.** Interest versus influence matrices on (a) primary productivity, (b) carbon regulation, (c) biodiversity. Organizations with frames are stakeholders mentioned by farmers in interviews. Acronyms are explained in Supplementary Material Table S1.

fall well below their influence.

### 3.5. Diversity of farmers

The farming community is not homogenous. The farmer-centric networks include a wide variety of different public administrations and scientific organizations, NGOs, private companies and the media, and there are also differences within the farming community. Farm clusters differ in how they communicate with different stakeholders, which is most likely related to both the specialization of the farm and the farmer's own willingness, interest and ability to engage in activities that do not directly impact on their on-farm activities. From Fig. 4a, we can see that all clusters are quite active in communication about production except for Cluster 5, which represents small backyard farms (see also overview in Supplementary Material Table S3). Backyard farmers often combine the income generated from their jobs with both backyard gardening and touristic activities. Farm size sets the economic ability to adopt technologies and mechanization of farm processes (Foster and Rosenzweig, 2017), which consequently enrich the information exchange about production. The stakeholder analysis shows that large farm clusters (Cluster 1 and Cluster 2) are more interested (and influential) in production issues comparing to other clusters (Fig. 4a).

Assessing the network in Fig. 4b, the leader in communication regarding carbon regulation is Cluster 1, which represents large mixed specialization farms, which have the time and resources to be actively involved in the information exchange. Interestingly, Cluster 2 (representing large cereal farms) receives information on carbon regulation from only one organisation and does not disseminate this information further—and although these farms are also among those that have both the time and the resources to engage in various activities, these specific interviewed farms do not see the issue of carbon regulation as binding (see also overview in Supplementary Material Table S4). However, from the stakeholder analysis we can see that Cluster 1, Cluster 2 and Cluster 3 do not have a high interest, but experts rank them as having a large influence over carbon regulation issues (Fig. 3b). While we have contradictory findings between large farmers' clusters, Koirala et al. (2022) found that adaptation responses to climate change are much higher for small-sized farmers, but the study of Peltonen-Sainio et al. (2021) found that organic farmers, female farmers and farmers with a farm size larger than 50 ha are most concerned about organic content in their fields.

From Fig. 4c, we can see that Cluster 3 communicates actively about biodiversity. This cluster represents medium, mixed specialization farms in which farmers themselves also do most of the work on the farm, which means that the time for off-farm activities is very limited. The second most active communicator is the cluster of organic farms (Cluster 4) (see also overview in Supplementary Material Table S5). Experts evaluate both clusters as "key players" in biodiversity (Fig. 3c). The farm size is one of the factors that determines farm processes and management practices (Stringer et al., 2020), which in turn affects the ecosystem structure and biodiversity; therefore small-scale agricultural areas are extremely important for the abundance of birds, butterflies and bumblebees (Belfrage et al., 2005).

### 3.6. Influential stakeholders in clustered farmer-centric networks

Key stakeholders differ between soil functions and farm clusters. Only 21 stakeholders out of 52 selected stakeholders in the stakeholder analysis are mentioned by farmers in interviews; and farmers mentioned an additional 20 organizations, which do not appear in the stakeholder analysis. In other words, the experts consulted for the stakeholder analysis failed to identify more than 25% of the actors that farmers interact with and found important enough to mention. This could be explained by the small-world phenomenon often found in SNA (e.g. O'Sullivan et al. (2022)), as experts and farmers may create their own small-worlds, where actors interact intensively with each other within small-world, but very little with other small-worlds. In order to transfer

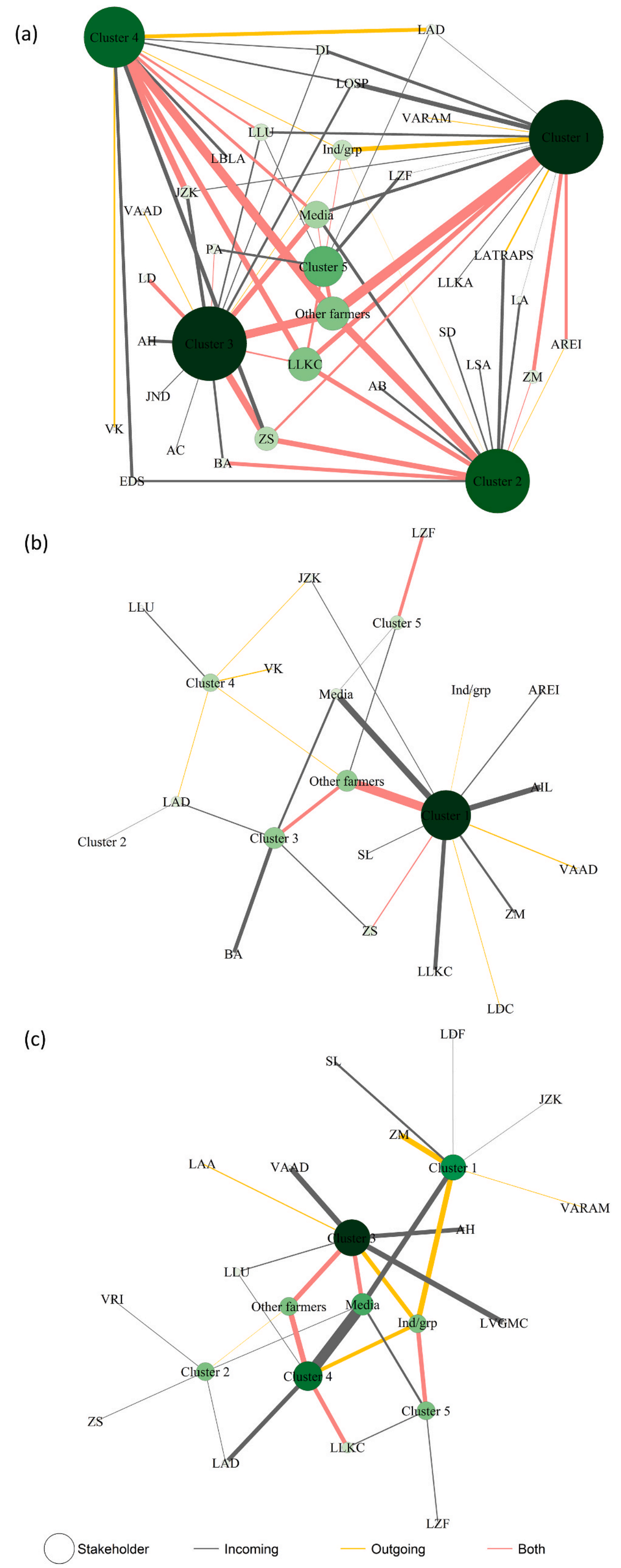


**Fig. 4.** Farmer-centric networks based on farm clusters for (a) primary productivity (b) carbon regulation and (c) biodiversity. The thickness of the lines represents the weight of edge, but the size and color intensity of node represents degree centrality. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

the knowledge and experience of one small-world to another small-world, a bridging actor or bridging organisation is needed, which accumulates knowledge and transfers it on when necessary.

In order to identify the most influential stakeholders in PP-, CR-, and BD-clustered farmer-centric networks, we used the degree centrality of each node in network, in which degree centrality is the number of edges incident upon a node (Fig. 4).

### 3.6.1. Primary production

In the PP-clustered farmer-centric network, other farmers appear to be the most valued source of information. This was found in other studies as well: it is recognized that peer-to-peer learning amongst farmers is often the most trusted source of information.(Franz et al., 2010; Thomas et al., 2020). During the interviews, several farmers indicated that they both inspire farmers in their neighborhood to try a new technology, and also adopt technologies from other farmers, without delving into the pros and cons of the technology, but trusting that it is a trend and "*if my neighbor does it, then I will too*". The LLKC is valued as an important player by both farmers and experts, but the media is recognized as an important player only by farmers. The LLKC was established to train farmers to increase yields and competitiveness. Both objectives are still valued by farmers, especially in regard to the demonstration farms where various technical solutions have been shown in practice in animal husbandry, crop production, diversification of the rural economy and promotion of cooperation. This, organized by the LLKC, serves as a means to transfer technology and knowledge from farmer to farmer.

Two high-valued, non-governmental organizations that are related to agricultural production were mentioned by at least three clusters: the Farmers' Parliament (ZS) and the Latvian Young Farmers' Club (JZK). Both are also valued by experts as influential stakeholders. Conversations with individuals and groups play an important role in farmers' communication with others, as some farmers are open to receive guests and to talk about their production technologies and experience. Educational and scientific institutions (LLU, DI, AREI) are not highly valued in the exchange of information in the PP-clustered farmer-centric network, despite the fact that these institutions study different technologies and measures to improve the efficiency of production technologies and resources (Bankina et al., 2021; Gravite et al., 2021; Jansone et al., 2021; Lepse et al., 2021; Valujeva et al., 2020, 2022). This could be related to the type of information and communication-style that is produced by these institutes, because scientific reports and seminars may not be interpretable by a general farmer audience. In this sense, many other organizations may have high importance on translating available scientific evidence into lay-speech. However, LLU and AREI are recognized as influential stakeholders by experts (Fig. 3a).

### 3.6.2. Carbon regulation

Other farmers and media are also influential actors in communication regarding carbon regulation. Rural Support Service (LAD) which is responsible for implementing unified state and the EU support policy for agriculture, forestry, fisheries and rural development, is recognized as an important player in the information exchange about carbon regulation by both farmers and experts. The role of LLKC in CR-clustered farmer-centric network is insignificant, which does not coincide with the experts' assessment. The ZS and Latvian Young Farmers' Club (JZK) are recognized non-governmental organizations by both farmers and experts.

### 3.6.3. Biodiversity

Although other farmers play an important role in the BD-clustered farmer-centric network, communication amongst the media, individuals, and groups is more important for farmers (Fig. 4), which shows that there is a great public interest in biodiversity issues; this is fueled by various non-governmental media campaigns that aim to protect natural areas and decrease the negative effects of agriculture to biodiversity (for instance, #RestoreNature and "Save Bees and Farmers!"). Experts also recognise the important role of non-governmental organizations in biodiversity issues. The Latvian Ornithological Society (LOB) is one of the well-known non-governmental organizations that draws the attention of the public and of scientists towards biodiversity, but there is no interaction between farmers and LOB. The role of LLKC in the clustered farmer-centric network is also insignificant. Similar to CR-clustered farmer-centric network, the LAD is also mentioned as an important source, which is most likely because of the responsibilities of LAD for granting or refusing support payments, so it also indirectly provides information on biodiversity issues.

## 3.7. Transmission of information

Over the last decade, a variety of information is being circulated daily about agricultural issues in the news media and scientific arenas, which also directs the public opinion about agriculture (Akhter et al., 2021). Very often, the same information is republished by several sources/organizations. Farmers also emphasized in interviews that newsletters from various organizations are received by email every week, often duplicating messages. The way of presenting information has to be in accordance to the capabilities on the information receiver to process it; for instance, farmers do not have enough time to read each newsletter every week. A farmer (especially the owner of small and medium size farms) is an all-around worker who must be able to perform soil cultivation, harvesting, allocation of work and supervision, planning of fields where to sow, planning of fertilization, financial planning, and purchasing of materials. For each of the daily activities, many different organizations provide the latest information every week, often duplicating it. This results in information converging at the farm-level, and the farmer needs to distill it into practical actions and management plans (O'Sullivan et al., 2022). Different actors often have competing interests and desires, which influences on-farm sustainability (Bernard et al., 2014). Frequent changes in policy regulations and poor communication between farmers and the government undermine farmers' trust, leading to misinformation, a lack of information, and a widening gap between the farmer and the general public. Farmers and the general public rank their priorities differently (Valbuena et al., 2010). Farmers focus more on functional demands to the land in order to ensure productivity, while societal demands on land also include: protecting biodiversity, mitigating climate change, reducing flood risks, and improving water quality (Schulte et al., 2019).

In order to come up with solutions that satisfy all stakeholders, one of the stakeholders from the network has to act as a bridge between policy-makers, scientists and farmers. For instance, science-based understanding is not always in line with farmers' experiences and observations in growing conditions, productions risks and needed future measures to cope with the weather-related changes (Peltonen-Sainio et al., 2020). For the translation of science into practical farm advice, the advisory centres already take this role of a bridging organisation, providing consultations in agriculture, forestry, environment and climate, innovation and technology, as well as economic aspects and social legislation. The education, experience, and ability of advisors to work with each individual case-study are the most important factors that farmers will assess during the consultation. In our case, although the LLKC is the main state company for agricultural and rural advice, its role in environmental and climate networks were found to be low. Advisory centres have been recognized by farmers, but there is a strong opinion that the main focus of public authorities is to restrict activities, rather than to provide information on how to farm better. Strengthening the advisory centres and promoting the availability of advice in farming communities are also highlighted in the CAP for the period from 2021 to 2027 (ZM, 2022). However, advisers' environmental and climatic understanding needs to be improved in order to address the contemporary knowledge gaps for farmers. Also, the translation of policies and scientific evidence on the environment and climatic topics need to have practical interpretations in order to be convincingly communicated with the farmers. Advisers are in a unique position to influence on-farm decisions and to help achieve national and international objectives on sustainability and climate change.

### 3.8. Networking as a sustainability measure

Collaboration between farmers and other stakeholders has been identified as a crucial method for achieving long-term agricultural sustainability. Farmers' voices are paramount when policy changes are being introduced, especially if these changes can affect their financial stability (in which case, the changes needs to be coupled with financial incentivisation mechanisms). It is extremely difficult for farmers to find and implement solutions alone, and creating acceptable solutions to all parties is a collaborative effort. We recommend the horizontal strengthening of the network within policy departments in order to increase the understanding and awareness of desired directions and outcomes. This could be achieved, for instance, by strengthening the cooperation, information exchange and achieving a common understanding of environmental protection and production between the Ministry of Environmental Protection and Regional Development of the Republic of Latvia (VARAM), which is responsible for implementing policy in environmental protection and regional development, and LLKC, which is recognized as a key player in the farmer-centric networks of primary productivity and biodiversity.

Because farmers value mostly information exchange with other farmers, strengthen horizontal networking among farmers can further enhance the dissemination of information on multifunctional land management practices. Farmers are interested in discussing new emerging ideas, especially if it accrues economic benefits, but actors new to the farming community find it challenging initiate engagement with these farmer-peer groups. Therefore, one of the ways to facilitate the transfer of know-how between farmers is to leverage the existing practical trainings and demonstration events of good practices on farms, and to communicate the impact of practices not only on primary production, but also on other ecosystem services and national policy objectives.

Future climate action requires equal and close cooperation between farmers and other stakeholders from the beginning to avoid misunderstandings and confusion (Sorvali et al., 2021). Farmers are the most experienced experts in land use, so close cooperation between farmers and other stakeholders is a necessity. During the COVID-19 pandemic, the Ministry of Agriculture of the Republic of Latvia (ZM) introduced an information exchange between a small groups of experts and the ministry in an online platform to discuss a variety of issues. This novel communication model can prove useful to encourage greater involvement of farmers in solving future challenges as well, because online platforms can be accessed from anywhere with proper internet connection and does not negates the need for travel time to meetings. The fragmentation of the AKIS in Latvia highlights the importance of strengthening closer cooperation between all parties involved (ZM, 2022). Training advisers in the multifunctionality of land would strengthen the vertical knowledge transfer between policy departments and farmers. Farmers do not necessarily connect their farms and applied management practices to terminology surrounding carbon sequestration/carbon stock/organic matter decomposition/biodiversity. Communication can be improved if some of the organizations use more practical terms and compare 'scientific/policy' terms with 'practical' examples to demonstrate how soil organic carbon contents are increased or decreased, and how farm management affects biodiversity. For the longevity of a collaboration and its accomplishments, it is not the absolute network density that matters, but rather the increase in network density over time (Velten et al., 2021). Long-term cooperation between many stakeholders, including knowledge transfer, the development and implementation of solutions, and monitoring are essential to adequately address global societal challenges.

This is how far we can bring our recommendations towards inclusive policy based on the small set of farmers that we interviewed. Each of these horizontal, vertical, horizontal tools requires further research in order to come to very concrete instruments would be most applicable.

## 4. Conclusions

Participatory techniques in addressing the challenges of agri-environmental policy and decision-making are essential to bridging the gap between the formulation of policy goals, and the actual implementation of land management practices. The methods used in this study provide entry points into gaining better insight into local contexts associated with the adoption of stakeholder participation in policy development on sustainable land use. Despite the small sample sizes of this study, the social network analysis clearly identified local players and influential stakeholders and allowed for the analysis of their relationships with the aim to streamline the dissemination and exchange of information and knowledge on sustainable land management. This study highlights the need for policies that further utilize existing knowledge and relationships between different stakeholders in order to achieve a common understanding of desired directions. The development of a shared understanding of intended directions, outcomes and knowledge requirements requires both horizontal and vertical strengthening of the national AKIS. Horizontal strengthening refers to the networks and information exchange between policy departments and between farmers' communities. Vertical transfer of information and knowledge between policy-makers and farmers can be strengthened by a bridging organisation, which in the Latvian case is the advisory centres. This requires the training of existing advisers on multifunctional land management.

## Author statement

Kristine Valujeva: Conceptualization, Methodology, Software, Writing – original draft, Visualization. Elizabeth K. Freed: Writing – review & editing. Aleksejs Nipers: Conceptualization, Resources, Supervision, Writing – review & editing. Jyrki Jauhiainen: Validation, Writing – review & editing. Rogier P.O. Schulte: Conceptualization, Methodology, Supervision, Writing – review & editing.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

Data will be made available on request.

## Acknowledgments

The research is conducted within the framework of the project "Demonstration of climate change mitigation potential of nutrients rich organic soils in Baltic States and Finland" (LIFE OrgBalt, LIFE18 CCM/LV/001158). We would also like to thank all of the experts and interviewees for their time and contribution in the creation of this work.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvman.2022.116563.

## References


Ahmadi, A., Kerachian, R., Rahimi, R., Emami Skardi, M.J., 2019. Comparing and combining social network analysis and stakeholder analysis for natural resource governance. Environ. Dev. 32, 100451 https://doi.org/10.1016/j.envdev.2019.07.001.

Akhter, P., Hussain, T., Ahsan, H.B., 2021. Mass media as a source of agricultural information: an overview of literature. Glob. Reg. Rev. VI 58–63. https://doi.org/10.31703/grr.2021(vi-ii).08.

Albizua, A., Bennett, E.M., Larocque, G., Krause, R.W., Pascual, U., 2021. Social networks influence farming practices and agrarian sustainability. PLoS One 16, 1–18. https://doi.org/10.1371/journal.pone.0244619.

Bankina, B., Bimsteine, G., Arhipova, I., Kaneps, J., Darguza, M., 2021. Impact of crop rotation and soil tillage on the severity of winter wheat leaf blotches. Rural Sustain. Res. 45, 21–27. https://doi.org/10.2478/plua-2021-0004.

Belfrage, K., Björklund, J., Salomonsson, L., 2005. The effects of farm size and organic farming on diversity of birds, pollinators, and plants in a Swedish landscape. Ambio 34, 582–588. https://doi.org/10.1579/0044-7447-34.8.582.

Bernard, F., van Noordwijk, M., Luedeling, E., Villamor, G.B., Sileshi, G.W., Namirembe, S., 2014. Social actors and unsustainability of agriculture. Curr. Opin. Environ. Sustain. 6, 155–161. https://doi.org/10.1016/J.COSUST.2014.01.002.

Buschmann, C., Röder, N., Berglund, K., Berglund, Ö., Lærke, P.E., Maddison, M., Mander, Ü., Myllys, M., Osterburg, B., van den Akker, J.J.H., 2020. Perspectives on agriculturally used drained peat soils: comparison of the socioeconomic and ecological business environments of six European regions. Land Use Pol. 90, 104181 https://doi.org/10.1016/j.landusepol.2019.104181.

Calzolari, C., Ungaro, F., Filippi, N., Guermandi, M., Malucelli, F., Marchi, N., Staffilani, F., Tarocco, P., 2016. A methodological framework to assess the multiple contributions of soils to ecosystem services delivery at regional scale. Geoderma 261, 190–203. https://doi.org/10.1016/J.GEODERMA.2015.07.013.

Dominati, E.J., Maseyk, F.J.F., Mackay, A.D., Rendel, J.M., 2019. Farming in a changing environment: increasing biodiversity on farm for the supply of multiple ecosystem services. Sci. Total Environ. 662, 703–713. https://doi.org/10.1016/J.SCITOTENV.2019.01.268.

EC, 2018. Agricultural Knowledge and Innovation Systems, Stimulating Creativity and Learning. European Commission [WWW Document]. EIP-AGRI Serv. Point Publ. Broch. URL. https://ec.europa.eu/eip/agriculture/en/news/brochure-akis-stimulating-creativity-and-learning.

Eory, V., Pellerin, S., Carmona Garcia, G., Lehtonen, H., Licite, I., Mattila, H., Lund-Sørensen, T., Muldowney, J., Popluga, D., Strandmark, L., Schulte, R., 2018. Marginal abatement cost curves for agricultural climate policy: state-of-the art, lessons learnt and future potential. J. Clean. Prod. 182, 705–716. https://doi.org/10.1016/J.JCLEPRO.2018.01.252.

EU SCAR AKIS, 2019. Preparing for Future AKIS in Europe. European Commission, Brussels (Brussels).

Foster, A., Rosenzweig, M., 2017. Are there too many farms in the world? Labor-market transaction costs, machine capacities and optimal farm size. National Bureau of Economic Research Working Paper Series 23909. http://www.nber.org/papers/w23909.

Franz, N., Piercy, F., Donaldson, J., Richard, R., Westbrook, J., 2010. How farmers learn: implications for agricultural educations. J. Rural Soc. Sci. 25, 37.

Gravite, I., Dekena, D., Kaufmane, E., Ikase, L., 2021. Intensive type plum plantations in Latvia. Acta Hortic. 1322, 221–227. https://doi.org/10.17660/ActaHortic.2021.1322.32.

Hauck, J., Schmidt, J., Werner, A., 2016. Using social network analysis to identify key stakeholders in agricultural biodiversity governance and related land-use decisions at regional and local level. Ecol. Soc. 21 https://doi.org/10.5751/ES-08596-210249.

Haygarth, P.M., Ritz, K., 2009. The future of soils and land use in the UK: soil systems for the provision of land-based ecosystem services. Land Use Pol. 26, S187–S197. https://doi.org/10.1016/j.landusepol.2009.09.016.

Herzog, F., Lüscher, G., Arndorfer, M., Bogers, M., Balázs, K., Bunce, R.G.H., Dennis, P., Falusi, E., Friedel, J.K., Geijzendorffer, I.R., Gomiero, T., Jeanneret, P., Moreno, G., Oschatz, M.L., Paoletti, M.G., Sarthou, J.P., Stoyanova, S., Szerencsits, E., Wolfrum, S., Fjellstad, W., Bailey, D., 2017. European farm scale habitat descriptors for the evaluation of biodiversity. Ecol. Indicat. 77, 205–217. https://doi.org/10.1016/J.ECOLIND.2017.01.010.

Jansone, I., Sterna, V., Stramkale, V., Stramkalis, A., Justs, A., Zute, S., 2021. Impact of cultivation technologies on soybean production and quality. Vide. Tehnol. Resur. - Environ. Technol. Resour. 1, 101–107. https://doi.org/10.17770/etr2021vol1.6605.

Koirala, P., Kotani, K., Managi, S., 2022. How do farm size and perceptions matter for farmers' adaptation responses to climate change in a developing country? Evidence from Nepal. Econ. Anal. Pol. https://doi.org/10.1016/J.EAP.2022.01.014.

Kreišmane, D., Lēnerts, A., Naglis-Liepa, K., Popluga, D., Rivža, P., 2018. Siltumnīcas efektu izraisošo gāzu emisiju robežsamazinājuma izmaksu līknes (MACC) tipiskajiem Latvijas lauku saimniecību klasteriem. In: Rivža, P., Popluga, D., Lazdiņš, A., Sudārs, R., Bērziņa, L., Kreišmane, D., Naglis-Liepa, K. (Eds.), Siltumnīcefekta Gāzu Emisiju Samazināšanas Iespējas Ar Klimatam Draudzīgu Lauksaimniecību Un Mežsaimniecību Latvijā. Latvijas Lauksaimniecības universitāte, Jelgava, pp. 158–203.

Lepse, L., Zeipiņa, S., Missa, I., Osvalde, A., 2021. The effect of cultivation technology on the plant development of organically grown garlic 19, 1823–1829.

Lienert, J., Schnetzer, F., Ingold, K., 2013. Stakeholder analysis combined with social network analysis provides fine-grained insights into water infrastructure planning processes. J. Environ. Manag. 125, 134–148. https://doi.org/10.1016/J.JENVMAN.2013.03.052.

Lizardo, O., Jilbert, I., 2022. Social Networks: An Introduction [WWW Document]. URL. https://bookdown.org/omarlizardo/_main/.

LR, 1990. Likums "Par zemes reformu Latvijas Republikas lauku apvidos". Latvijas Republikas Augstākās Padomes un Valdības Ziņotājs 49, 06.12.1990 (in Latvian) [WWW Document]. URL. https://likumi.lv/ta/id/72849.

Maleksaeidi, H., Keshavarz, M., 2019. What influences farmers' intentions to conserve on-farm biodiversity? An application of the theory of planned behavior in fars province, Iran. Glob. Ecol. Conserv. 20, e00698 https://doi.org/10.1016/J.GECCO.2019.E00698.

Mattila, T.J., Hagelberg, E., Söderlund, S., Joona, J., 2022. How farmers approach soil carbon sequestration? Lessons learned from 105 carbon-farming plans. Soil Tillage Res. 215, 105204 https://doi.org/10.1016/J.STILL.2021.105204.

Micha, E., Fenton, O., Daly, K., Kakonyi, G., Ezzati, G., Moloney, T., Thornton, S., 2020. The complex pathway towards farm-level sustainable intensification: an exploratory network analysis of stakeholders' knowledge and perception. Sustain. Times 12. https://doi.org/10.3390/su12072578.

Mills, K.E., Koralesky, K.E., von Keyserlingk, M.A.G., Weary, D.M., 2021. Social referents for dairy farmers: who dairy farmers consult when making management decisions. Animal 15, 100361. https://doi.org/10.1016/J.ANIMAL.2021.100361.

Mills, K.E., Koralesky, K.E., Weary, D.M., von Keyserlingk, M.A.G., 2020. Dairy farmer advising in relation to the development of standard operating procedures. J. Dairy Sci. 103, 11524–11534. https://doi.org/10.3168/JDS.2020-18487.

Nepusz, T., 2022. Package 'igraph' [WWW Document]. URL, version 1.2.11. https://cran.r-project.org/web/packages/igraph/igraph.pdf.

O'Sullivan, L., Leeuwis, C., de Vries, L., Wall, D.P., Heidkroß, T., Madena, K., Schulte, R.P.O., 2022. Trust versus content in multi-functional land management: assessing soil function messaging in agricultural networks. Environ. Manag. 69, 1167–1185. https://doi.org/10.1007/S00267-022-01647-2.

Ontl, T.A., Schulte, L.A., 2012. Soil carbon storage [WWW document]. Nat. Educ. Knowl. 3 (10), 35. URL. https://www.nature.com/scitable/knowledge/library/soil-carbon-storage-84223790/.

Peltonen-Sainio, P., Sorvali, J., Kaseva, J., 2021. Finnish farmers' views towards fluctuating and changing precipitation patterns pave the way for the future. Agric. Water Manag. 255, 107011 https://doi.org/10.1016/J.AGWAT.2021.107011.

Peltonen-Sainio, P., Sorvali, J., Kaseva, J., 2020. Winds of change for farmers: matches and mismatches between experiences, views and the intention to act. Clim. Risk Manag. 27, 100205 https://doi.org/10.1016/J.CRM.2019.100205.

Prell, C., Hubacek, K., Reed, M., 2009. Stakeholder analysis and social network analysis in natural resource management. Soc. Nat. Resour. 22, 501–518. https://doi.org/10.1080/08941920802199202.

Purola, T., Lehtonen, H., 2022. Farm-level effects of emissions tax and adjustable drainage on peatlands. Environ. Manag. 69, 154–168. https://doi.org/10.1007/S00267-021-01543-1/TABLES/7.

Qiu, C., Ciais, P., Zhu, D., Guenet, B., Peng, S., Petrescu, A.M.R., Lauerwald, R., Makowski, D., Gallego-Sala, A.V., Charman, D.J., Brewer, S.C., 2021. Large historical carbon emissions from cultivated northern peatlands. Sci. Adv. 7 https://doi.org/10.1126/SCIADV.ABF1332/SUPPL_FILE/ABF1332_SM.PDF.

Reed, M.S., Curzon, R., 2015. Stakeholder mapping for the governance of biosecurity: a literature review. J. Integr. Environ. Sci. 12, 15–38. https://doi.org/10.1080/1943815X.2014.975723.

Reed, M.S., Graves, A., Dandy, N., Posthumus, H., Hubacek, K., Morris, J., Prell, C., Quinn, C.H., Stringer, L.C., 2009. Who's in and why? A typology of stakeholder analysis methods for natural resource management. J. Environ. Manag. 90, 1933–1949. https://doi.org/10.1016/j.jenvman.2009.01.001.

Schulte, R.P.O., Creamer, R.E., Donnellan, T., Farrelly, N., Fealy, R., O'Donoghue, C., O'hUallachain, D., 2014. Functional land management: a framework for managing soil-based ecosystem services for the sustainable intensification of agriculture. Environ. Sci. Pol. 38, 45–58. https://doi.org/10.1016/J.ENVSCI.2013.10.002.

Schulte, R.P.O., O'Sullivan, L., Vrebos, D., Bampa, F., Jones, A., Staes, J., 2019. Demands on land: mapping competing societal expectations for the functionality of agricultural soils in Europe. Environ. Sci. Pol. 100, 113–125. https://doi.org/10.1016/J.ENVSCI.2019.06.011.

Schwilch, G., Bachmann, F., Valente, S., Coelho, C., Moreira, J., Laouina, A., Chaker, M., Aderghal, M., Santos, P., Reed, M.S., 2012. A structured multi-stakeholder learning process for Sustainable Land Management. J. Environ. Manag. 107, 52–63. https://doi.org/10.1016/j.jenvman.2012.04.023.

Skaalsveen, K., Ingram, J., Urquhart, J., 2020. The role of farmers' social networks in the implementation of no-till farming practices. Agric. Syst. 181, 102824 https://doi.org/10.1016/J.AGSY.2020.102824.

Sorvali, J., Kaseva, J., Peltonen-Sainio, P., 2021. Farmer views on climate change—a longitudinal study of threats, opportunities and action. Clim. Change 164, 1–19. https://doi.org/10.1007/S10584-021-03020-4/FIGURES/4.

Stainforth, T., Bowyer, C., 2020. Climate and Soil Policy Brief: Better Integrating Soil into EU Climate Policy. Interactive Soil Quality Assessment, Institute for European Environmental Policy.

Stoeckli, S., Birrer, S., Zellweger-Fischer, J., Balmer, O., Jenny, M., Pfiffner, L., 2017. Quantifying the extent to which farmers can influence biodiversity on their farms. Agric. Ecosyst. Environ. 237, 224–233. https://doi.org/10.1016/J.AGEE.2016.12.029.

Stringer, L.C., Fraser, E.D.G., Harris, D., Lyon, C., Pereira, L., Ward, C.F.M., Simelton, E., 2020. Adaptation and development pathways for different types of farmers. Environ. Sci. Pol. 104, 174–189. https://doi.org/10.1016/J.ENVSCI.2019.10.007.

Šūmane, S., Kunda, I., Knickel, K., Strauss, A., Tisenkopfs, T., Rios, I. des I., Rivera, M., Chebach, T., Ashkenazy, A., 2018. Local and farmers' knowledge matters! How integrating informal and formal knowledge enhances sustainable and resilient agriculture. J. Rural Stud. 59, 232–241. https://doi.org/10.1016/J.JRURSTUD.2017.01.020.

Thomas, E., Riley, M., Spees, J., 2020. Knowledge flows: farmers' social relations and knowledge sharing practices in 'Catchment Sensitive Farming. Land Use Pol. 90, 104254 https://doi.org/10.1016/J.LANDUSEPOL.2019.104254.

Valbuena, D., Bregt, A.K., McAlpine, C., Verburg, P.H., Seabrook, L., 2010. An agent-based approach to explore the effect of voluntary mechanisms on land use change: a case in rural Queensland, Australia. J. Environ. Manag. 91, 2615–2625. https://doi.org/10.1016/J.JENVMAN.2010.07.041.

Valujeva, K., Debernardini, M., Freed, E.K., Nipers, A., Schulte, R.P.O., 2022. Abandoned farmland: past failures or future opportunities for Europe's Green Deal? A Baltic case-study. Environ. Sci. Pol. 128, 175–184. https://doi.org/10.1016/J.ENVSCI.2021.11.014.

Valujeva, K., Nipers, A., Lupikis, A., Schulte, R.P.O., 2020. Assessment of soil functions: an example of meeting competing national and international obligations by harnessing regional differences. Front. Environ. Sci. 8 https://doi.org/10.3389/fenvs.2020.591695.

Velten, S., Jager, N.W., Newig, J., 2021. Success of collaboration for sustainable agriculture: a case study meta-analysis. Environ. Dev. Sustain. 23, 14619–14641. https://doi.org/10.1007/S10668-021-01261-Y/FIGURES/2.

Wu, W., He, F., Zhuang, T., Yi, Y., 2020. Stakeholder analysis and social network analysis in the decision-making of industrial land redevelopment in China: the case of shanghai. Int. J. Environ. Res. Publ. Health 17. https://doi.org/10.3390/ijerph17249206.

ZM, 2022. Latvijas KLP Stratēģiskā Plāna 2023.-2027.Gadam Projekts, Latvijas Republikas Zemkopības Ministrija (in Latvian).