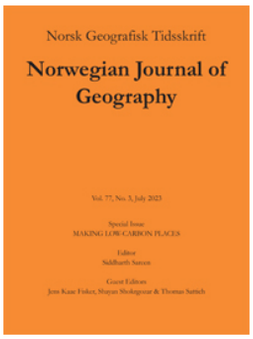

Routledge
Taylor & Francis Group

Norsk Geografisk Tidsskrift - Norwegian Journal of Geography

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/sgeo20

Norwegian low-intensity ovine and bovine farming systems—a resilience perspective

Kerstin Potthoff & Birgit Kopainsky

To cite this article: Kerstin Potthoff & Birgit Kopainsky (16 Oct 2023): Norwegian low-intensity ovine and bovine farming systems—a resilience perspective, Norsk Geografisk Tidsskrift - Norwegian Journal of Geography, DOI: 10.1080/00291951.2023.2258145

To link to this article: https://doi.org/10.1080/00291951.2023.2258145

© 2023 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group

Published online: 16 Oct 2023.

Submit your article to this journal

View related articles

View Crossmark data

Full Terms & Conditions of access and use can be found at
https://www.tandfonline.com/action/journalInformation?journalCode=sgeo20

Norsk Geografisk Tidsskrift–Norwegian Journal of Geography
https://doi.org/10.1080/00291951.2023.2258145

Routledge
Taylor & Francis Group

OPEN ACCESS Check for updates

Norwegian low-intensity ovine and bovine farming systems—a resilience perspective

Kerstin Potthoff [1] & Birgit Kopainsky [2]

[1]School of Landscape Architecture, Norwegian University of Life Sciences, Ås, Norway; [2]System Dynamics Group, University of Bergen, Bergen, Norway

ABSTRACT

The concept of socio-ecological resilience can be used to understand and measure to what degree farming systems are able to handle and adapt to disturbances. The article is based on the application of a framework for resilience assessment in European farming systems to the Norwegian low-intensity ovine and bovine farming systems. The aim is to identify the characteristics of farming systems and important trends in them. Interviews held at county and municipality level, and statistical data revealed that farming systems appeared quite robust, and resource-strong in terms of adhering and adjusting to current and coming environmental and animal welfare regulations, although some coming regulations may put farms under pressure and result in farm exit. Assessing the consequences of development trends envisioned by two scenarios underlines that the provision of goods and services by farming systems may be challenged in the future and that resilience needs to be enhanced. The authors conclude that the current war in Ukraine and its impacts on the food market, as well as the increased electricity prices in Norway, are examples of contextual changes that may challenge agricultural production. In this context, the article can serve as a baseline to reassess the resilience of farming systems.

ARTICLE HISTORY
Received 11 April 2023
Accepted 8 September 2023

EDITOR
Arne Isaksen

KEYWORDS
farming systems, Norway, robustness, social-ecological resilience

Potthoff, K. & Kopainsky, B. 2023. Norwegian low-intensity ovine and bovine farming systems—a resilience perspective. *Norsk Geografisk Tidsskrift–Norwegian Journal of Geography* Vol. 00, 00–00. ISSN 0029-1951.

Introduction

Food systems are expected to address the triple challenge of providing food security and nutrition, providing livelihoods, and substantially reducing the effects of food systems on the environment and climate (OECD 2021). The COVID-19 pandemic and the continuing high number of armed conflicts have exacerbated the difficulties in responding to these challenges and revealed the vulnerability of agricultural and food systems to crises and shocks (Klassen & Murphy 2020; Webb et al. 2021). Climate change is expected to challenge food production worldwide yet further and it requires developed and more resource-strong countries to adapt (Ford & Berrang-Ford 2011; FAO 2018). For agricultural production in the Nordic countries, it can be assumed that, despite potential benefits of climate change, challenges will arise (Kvalvik et al. 2011; Uleberg et al. 2014; Wiréhn 2018; Neset et al. 2019; Beitnes et al. 2022).

The concept of resilience can be used to understand and measure how and to what extent social-ecological systems such as farming systems react and adapt to contextual changes and disturbances without changing their function (Folke et al. 2010). Resilient farming systems are not only important for securing food production in an increasingly uncertain environment, but also for facilitating flexible responses to unanticipated changes, disturbances, and shocks (Darnhofer 2014).

Darnhofer et al. (2016) differentiate between three types of approaches to operationalizing resilience: (1) approaches focusing on biophysical structures of farms, (2) approaches focusing on social actors, and (3) relational approaches that view farming as emerging from relations. The EU Horizon 2020 SURE-Farm project (Towards SUstainable REsilient EU FARMing Systems) framework for resilience assessment (European Commission 2022) was developed to analyze the

CONTACT Kerstin Potthoff kerstin.potthoff@nmbu.no

© 2023 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group
This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. The terms on which this article has been published allow the posting of the Accepted Manuscript in a repository by the author(s) or with their consent.

resilience and sustainability of farms and farming systems in the European Union (EU) and combines the first two approaches. The framework has been applied to assess resilience in case studies in 11 EU countries covering very different farming systems such as large-scale corporate arable farming, small-scale faming (e.g., perennial crops), and extensive beef and sheep farming systems (Meuwissen et al. 2019; 2021).

According to SURE-Farm resilience assessments, stakeholders perceived many farming systems to be close to critical thresholds regarding their functions (e.g., supply of food, provision of quality of life, maintenance of natural resources), while attributes required to enhance resilience were perceived as only weakly or moderately present (e.g., diversity of policies, profitability) (Reidsma et al. 2020). Stakeholders perceived robustness of the farming systems as higher than the capacity to adapt and transform (Meuwissen et al. 2020; Reidsma et al. 2020; Paas et al. 2021). Adaptive processes at farm level were mainly geared towards robustness and adaptability (Nicholas-Davies et al. 2020; Manevska-Tasevska et al. 2021). To assess future resilience of farming systems, the SURE-Farm project developed different scenarios (EU-Agri-SSP 1 (Sustainability), 2 (Middle of the road), 3 (Regional rivalry), 4 (Inequality) and 5 (Fossil-fueled development)) (Mathijs et al. 2018). Most farming systems are moderately compatible with the scenario EU-Agri-SSP1 but hardly compatible with scenarios EU-Agri-SSP3, 4, and 5 (Accatino et al. 2020).[1]

In our study, we applied the SURE-Farm framework for resilience assessment (Meuwissen et al. 2020) to the Norwegian low-intensity ovine and bovine farming systems. Although these systems are going through processes of upscaling, especially the bovine production system (Rønningen et al. 2021), they can still be considered low-intensive, as they have an average of ca. 63 head of cattle and ca. 65 sheep per farm (Statistics Norway n.d.,f) and depend on outfield fodder resources. Thus, we investigate farming systems in a non-EU country with a strongly politically influenced agricultural sector (Kvalvik et al. 2011; Bjørkhaug & Rønningen 2014). Low-intensity ovine and bovine farming systems are the backbone of Norwegian agriculture, measured in area use, production value, and importance for both farmers' livelihoods and regional rural settlements (Jervell & Borgen 2000). Additionally, the two systems are the most widespread agricultural activity, as the cold climate and the relatively short growing season make the land primarily utilized and economically appropriate for forage-based animal production (Arnoldussen et al. 2014).

To cover larger geographical areas, which the very comprehensive and multifaceted analysis of the farming systems in the SURE-Farm cases only to a restricted degree allows for, we addressed farming systems at the municipality level and took contextual information from the county level into consideration. Departing from two fundamentally different SURE-Farm scenarios, SSP1 (Sustainability), and SSP5 (Fossil-fueled development) (see Materials and Methods for selection of scenarios), we ask: What characterizes farming systems in the selected municipalities? What are important trends within farming? To what degree can the farming systems be considered resilient both in a current perspective and when taking the environmental, economic, and social developments described in the scenarios into account?

The SURE-Farm resilience framework

The SURE-Farm framework for resilience builds on five steps (Meuwissen et al. 2019) (Fig. 1). The first step is the characterization of the farming system with the farms at the core, as well as farm and non-farm actors (resilience of what). The second step focuses on the identification of key challenges (resilience to what). EU agriculture has experienced and is experiencing well-known economic, environmental, social, and institutional challenges, such as extreme weather events, price drops for outputs and price spikes for inputs, sudden changes to on-farm social capital (e.g., illness, divorce), and sudden changes in access to markets (e.g., due to Brexit) (Meuwissen et al. 2019). Although farmers are used to tackling changing environmental conditions, more recent extreme weather events such as the drought in 2018 put agricultural production under pressure. Norwegian farmers experience similar challenges to those faced by EU farmers, both in terms of long-term stresses and short-term climatic shocks (Bjørkhaug & Rønningen 2014; Beitnes et al. 2022).

The third step in the SURE-Farm framework for resilience frames the essential functions of the farming system, comprising private goods such as production of food and public goods, providing livelihoods for farmers, and providing attractive places for living (resilience for what purpose) (Meuwissen et al. 2019). Step four addresses the resilience capacities of the farming system. While robustness requires a strong ability to tackle stresses and shocks, adaptability requires an ability to adjust production to, for example, changes in the regulatory framework without changing the structures of the system. Transformability requires the capacity to change

[1]SSP stands for Shared Socioeconomic Pathways.

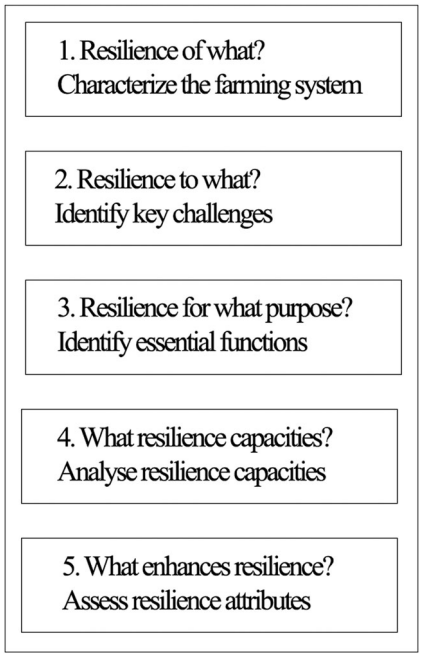

Fig. 1. The SURE-Farm framework for resilience assessment

the whole farming system significantly, but without changing its main functions. The fifth step in the framework assesses attributes that enhance resilience (what enhances resilience). Meuwissen et al. (2018) categorize resilience attributes into "learning," "production," "networks," "governance," "diversity," and "resources." Within each of these categories the attributes indicate which resilience capacity they enhance. For example, within the category "learning," incremental innovation enhances robustness, radical innovation adaptability, and major realignment transformability.

It can be argued that the degree to which different resilience capacities (robustness, adaptability, and transformability) are present in a farming system does not allow for any direct conclusions to be drawn about the resilience of the farming system. Depending on the context in which farms are operating, different resilience capacities may be required. One way to assess the resilience of farming systems and what would be needed to enhance that resilience it is to evaluate to what degree farming systems are able to fulfill their essential functions within the current situation and in the future.

Material and methods

Selection of municipalities

To investigate resilience within Norwegian ovine and bovine farming systems, we selected the four counties with the highest number of farms keeping livestock in 2016: Rogaland, Oppland,[2] Hordaland, and Sogn og Fjordane (Statistics Norway n.d.,a). To identify the municipalities with the largest number of farms using outfield resources, we used data relating to applications submitted for outfield grazing support in 2016; the data were downloaded from NIBIO's website. We assumed that most farmers applied for this type of support. We calculated the grazing pressure on the available grazing land and selected, as a first step, the five municipalities with the highest grazing pressure in each county. As a second step we considered whether farmers in the municipalities had received mountain summer farming support in 2008, since only data for 2008 were available for download from NIBIO's website at the time. In all selected municipalities except those in Rogaland, at least one farmer had received support. For Rogaland, we included the only municipality with registered applications for summer farming support and the four municipalities with the highest grazing pressure. Two of the four were excluded, since one municipality did not want to participate in our study and one municipality only had a very small outfield area included in the support scheme for outfield grazing. The two municipalities with the fifth and sixth highest grazing pressure were chosen instead.

Interviews and statistical data

We carried out interviews with the persons in charge of the agricultural sector at county and municipality level. Questions at county level dealt with structural changes in the agricultural sector (e.g., reasons for farm exit), changes in production (e.g., reasons for changes in organic production), and the future for livestock farming (e.g., potential consequences of changes in consumer preferences). Questions at municipality level addressed the following topics: (1) types of production, types of farmers and farm exit (e.g., types of production combined at farm level), (2) technological development, fodder production, and cooperation (e.g., important technological innovations), (3) possibilities for increased production and investments (e.g., types of investments carried out), (4) local food production (e.g., sales of local products), (5) and regulations for environmentally friendly production and animal welfare (e.g., challenges to changing to organic production). The 24 interviews were carried out via "GoTo Meeting" (software for online meetings), recorded and transcribed afterwards. Due to technical problems, two interviews were recorded using a dictation machine.

[2]In 2020, Oppland became part of Innlandet County, and Hordaland and Sogn og Fjordane were merged to become Vestland County.

In accordance with the request of one interviewee, responses were written down. The interviews were conducted between April and June 2018 and lasted between ca. 30 minutes and 2 hours. The interview transcripts were coded in NVivo version 12 with respect to the five steps in the resilience assessment framework and with special emphasis on resilience attributes. The interviews were complemented with data covering a wide range of topics, such as number of farms, number of organic farms, and types of production. These data were either downloaded from Statistics Norway's web pages or, in the case of data relating to organic farms, provided to us by Statistics Norway.

Interviews and statistical data were designed and accessed to obtain information about characteristics of the farming systems (resilience of what), such as types of farm products, full-time versus part-time farmers, and use of fodder resources. To address current challenges faced by the farming systems (resilience to what), we considered the main trends, drivers, and consequences within the farming systems. The time frames addressed in the interviews were 10 and 5 years. We asked representatives of the municipalities about the importance of agriculture for their municipality (resilience for what purpose). The characteristics of the farming systems and the long-term and short-term trends allowed us to identify resilience capacities. Finally, we addressed a selection of resilience attributes representing the categories "production" and "networks" (see Meuwissen et al. 2018 for an overview of the different categories and resilience attributes) by asking questions about, for example, collaboration, innovations, and resources to implement sustainable production. We decided to focus on the two categories because we found them most relevant to address at municipality level. Topics such as farm heterogeneity, collaboration, and innovation address either production or cooperation among farms and factors that directly impact agricultural production. Other categories would require a stronger focus on farm level (category "learning"), and regional or even national level (e.g., category governance).

While our methodological approach allowed us to cover issues of resilience at the municipality level, and to some extent we considered the regional level, such a focus may disregard cross-scale interactions that are important for socio-ecological systems. Interviews with persons in charge of the agricultural sector are appropriate for providing an overview of a given situation within a municipality; however, the entire diversity in terms of farming practices cannot be covered. We were interested in, for example, knowing whether the use of concentrated feed differed among municipalities, but since the use varied among farms within a municipality and from year to year, the question remained unanswered.

The SURE-Farm scenarios

To gain insights into potential future developments, we selected the SURE-Farm scenarios SSP1 (Sustainability) and SSP5 (Fossil-fueled development) (Mathijs et al. 2018). SSP1 departs from an increased environmental awareness that has resulted in, among other changes, higher costs for transport, changed consumer preferences, and a stricter environmental legislation (see Appendix 1 for more details about the scenarios). Assessing the resilience attributes required to achieve sustainable farming systems as envisioned in SSP1 is relevant because sustainable agriculture is an important topic on the Norwegian political agenda (Meld. St. 11 2016–2017). Compared to SSP1, SSP 5 has a stronger focus on local environmental problems, while many of the current trends continue or are even reinforced, such as technological developments in production, as well as imports of food and concentrated feed. Thereby, SSP5 provides the framework for discussing the potential development trends and needs for enhancing the resilience of farming systems of a strongly fossil-fuel dependent nation such as Norway.

The scenarios were adjusted to consider some elements of Norwegian farming that differ from the situation in the EU. For example, assumed changes in spatial production patterns in the EU in SSP1 were not taken into account. For SSP1, we considered the following Norwegian environmental regulations: regulation on manure *(Forskrift om gjødselvarer mv. av organisk opphav*) (Helse- og omsorgsdepartementet et al. 2003), regulation on production support and farm relief (*Forskrift om produksjonstilskudd og avløsertilskudd i jordbruket*) (Landbruks- og matdepartement 2015), regulation on organic production and labeling of organic products (*Forskrift om økologisk produksjon og merking av økologiske landbruksprodukter, akvakulturprodukter, næringsmidler og fôr*) (Nærings- og fiskeridepartement & Landbruks- og matdepartement 2017), and the regulation on large livestock farming (*Forskrift om hold av storfe*) (Landbruks- og matdepartement 2004a). For the latter regulation we considered that changes will occur. From 2024, cattle kept in cowsheds will have to be able to move freely, and from 2034 cattle will have to be given access to outdoor areas throughout the entire year.

To learn how farming could be impacted by the situations described in the scenarios, we added interview

questions that would help us to assess potential consequences. For example, we asked about the degree to which the environmental requirements of the current legislations posed challenges for farmers. This helped us to understand what consequences stricter regulations would have. We also asked about the degree to which current production would be able to satisfy changed consumer preferences.

Results and discussion

In this section our presentation of the results and discussion follows the five steps of the SURE-Farm framework for assessing resilience (Fig. 1). We present the characteristics of the farming systems (1), current trends in and key challenges for farming systems (2), and the systems' essential functions (3). The resilience attributes describing the current situation are used to identify resilience capacities (robustness, adaptability, transformability) (4). Departing from the essential functions of the farming systems and the two scenarios, we assess which resilience attributes would need to be enhanced for farming systems to become more resilient (5).

Characteristics of the farming systems

Due to the selection of the municipalities, agriculture within all municipalities comprised bovine milk and meat production and sheep farming. Other types of production included fodder, fruit (including berries), and pig and goat farming, as well as cereals, eggs, and vegetable production. Interviewees in a few municipalities mentioned the use of other bio-based resources, such as fish, forest, game, and fur-bearing animals.[3] Product diversity at farm-level (farms with more than one product) varied a lot among municipalities (ca. 15–85%). In about one-quarter of the municipalities more than half of the farms had at least two types of production. Typical combinations were suckler cows and sheep, and dairy cows and sheep. Sheep were also combined with, for example, cereal and berry production. Furthermore, farm sizes varied. At county level, Hordaland and Sogn og Fjordane had a larger share of smaller farms than Oppland and Rogaland (Fig. 2). Production on the largest farms reflected the dominating type of production in the counties.

In all municipalities, grass from infields was ensilaged (as bales, in silos). Slightly more than half of the interviewees mentioned the production of some hay. In Norway, the amount of concentrated feed versus roughage varies according to production type: 7% concentrated feed for suckler cows, 12% for sheep, 45% for dairy cows, and 100% for pig and poultry (Nysted et al. 2020). We found that while outfields served as pastures, the amount of fodder intake in them differed between the municipalities. With a few exceptions, the intake in the outfields was 10–30% of the total fodder intake, but in some municipalities it was as much as 50–60% for sheep.

In about three-quarters of the municipalities, the share of part-time farmers was higher than the share of full-time farmers. Typically, part-time farmers kept

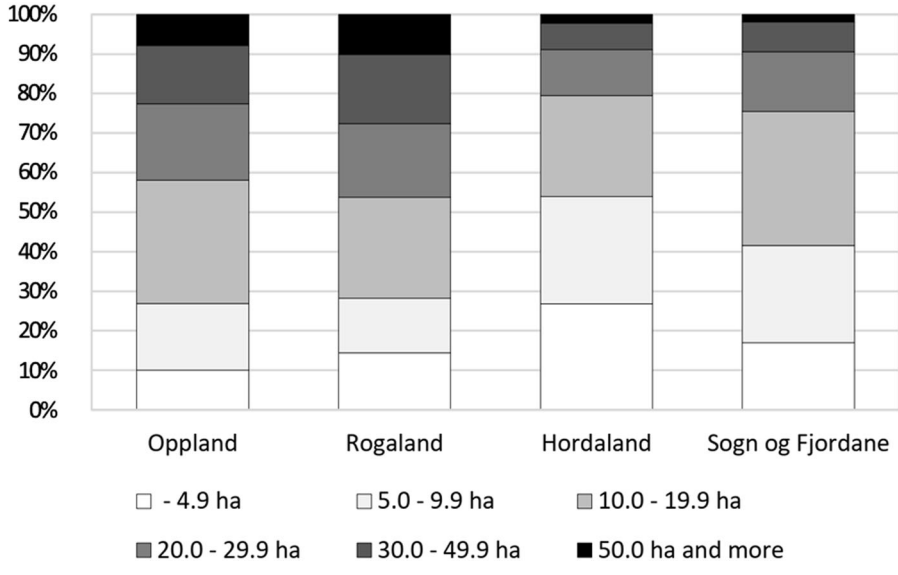

Fig. 2. Farm size at county level in Norway in 2017 (Statistics Norway n.d.,e)

[3]Fur farming will be prohibited in 2025, and therefore the sector is currently readjusting (Landbruks- og matdepartementet 2019).

sheep or suckler cows, while full-time farmers were dairy farmers. Interviewees from municipalities in Oppland mentioned also cereal production and plant-based products in general as common for part-time farmers. Employment of seasonal workers was not very widespread, but the share of seasonal workers within berry, other fruit, or vegetable production was very high.

Since the late 2000s, the most important investments had been the renewal of farm buildings (mainly cowsheds and sheep sheds). Within most municipalities, farmers had invested in improving drainage, and especially in Rogaland and Oppland farmers had invested in the cultivation of new land. The degree to which investments were delayed and hence the degree to which new farmers would face the necessity of making investments varied greatly among the municipalities. Based on the municipalities for which percentages were obtained, it seemed that municipalities in the counties of Hordaland and Rogaland had the highest delays; more than 50% of the farms were affected. By contrast, 50% or less of the farms in the municipalities in the counties of Oppland and Sogn og Fjordane faced delays. The types of investments not made were similar and mainly concerned investments in buildings and drainage.

Current trends and challenges in farming

Changes in number of farms, agricultural land, and production

From 2007 to 2017, the number of farms declined in all municipalities by ca. 3–23% (Statistics Norway n.d.,d) (Fig. 3). The interviewees provided several reasons for farm exit, among them low revenues, availability of better-paid other jobs, and farms too small for upscaling production. At county level, these reasons were linked to overall trends of rationalization, technological development, and specialization. The interviews at municipality-level did not reveal any clear relationship between the number of generation-shifts and farm exits.

Declining farming communities are a social and economic challenge for farmers because local farming communities provide important arenas for knowledge exchange, cooperation, and neighborly help (Eriksen & Selboe 2012; Juhola et al. 2017; Daugstad 2019; Beitnes et al. 2022). The interviewees pointed to the importance of first movers who start a business, thereby showing that it is possible to succeed as a farmer and help to create arenas for knowledge exchange.

In contrast to changes in number of farms, changes in agricultural land did not show a similarly clear trend and comprehensive changes. In three municipalities the amount of agricultural land in use increased (ca. 2–12%), while in the remaining municipalities it declined by between 0.1% and 15%. No clear relationship existed between the changes in number of farms and amount of land (Fig. 3). Thus, land available after farm exit was taken into use by other farmers to varying degrees. The reasons provided for the decline in agricultural land at county level were abandonment of fields that were difficult to cultivate, development of land for other purposes, and cows kept in the immediate surroundings of cowsheds were grazing smaller areas. The interviewees pointed to differences within the counties where agricultural land in economically marginal areas was most prone to abandonment. Conversely, decline in other industries, such as the oil industry, had resulted in an increased interest in farming and hence also agricultural land.

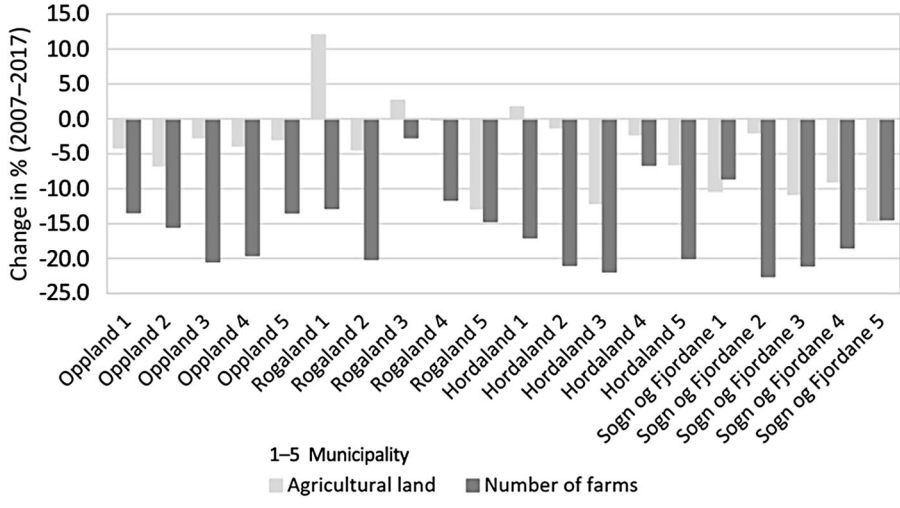

Fig. 3. Change in agricultural land (Statistics Norway n.d.,d) and change in the number of farms (Statistics Norway n.d.,c) in four counties in Norway between 2007 and 2017

The impression that land was available, albeit in differing amounts, was confirmed by the interviews. Except for in one municipality, all interviewees evaluated the challenge to gain access to infield areas as medium or big, and they evaluated the challenge to gain access to outfield areas as medium or small. However, access to land could be more challenging in more densely settled areas than in more sparsely settled areas. Thus, although land may be available, long-distance driving is an economic and ecological challenge for farmers (Sim et al. 2007; Meisterling et al. 2009; Tullberg 2010; Kårstad et al. 2015; Stokka et al. 2018).

In addition to the availability of land, the price of land may be a challenge for farmers who want to increase their production. Interviewees in about half of the municipalities considered the price of renting and buying land a medium challenge and interviewees in only two municipalities considered it a big challenge. In all municipalities, little land was sold. Prices were commonly held low by the Concession Act of 2004 (Landbruks- og matdepartementet 2004b), which allows the state to control the price of farm property (for more information about the Concession Act see Forbord et al. 2014); however, the degree to which the municipalities used this possibility seemed to differ.

The interviewees explained some clear trends in livestock production at county level between 1998 and 2017 (Fig. 4). The number of milking cows declined, while heads of cattle for meat production increased. The number of sheep increased, and pig and poultry production grew; however, in the latter case (pig and poultry), the trend differed among counties. The main reasons for these changes were different types of regulations, changes in the market, and development in animal production. The increase in milk production per cow and the quota system regulating the amount of milk were explained as reasons for the decline in number of milking cows. However, produced milk volume remained rather stable. Farmers who stopped milk production commonly focused on sheep. The increase in numbers of sheep was also influenced by changes in rules for subsidies. Increased production of different types of meat were primarily a response to market demands, although one interviewee also mentioned a county-level project to increase farmers' interest in beef production.

Agricultural land used for cereal production declined between 1999 and 2017 (Fig. 5). One interviewee pointed out that due to climate change cereal production had become more challenging. Another interviewee indicated that potato production had declined due to changes in the market. Moreover, areas for fruit (including berries) production had declined, while at the same time the productivity levels had increased. Although specialization was an ongoing trend at farm level, product diversity had increased at county level to some degree, for example through greater diversity in vegetables and through the processing of products.

Environmental concerns and animal welfare

Interviewees in slightly more than half of the municipalities considered access to areas for spraying manure was a small challenge, while interviewees in only two municipalities considered it to be a large challenge. Even in municipalities with intensive production, farmers seemed to have found solutions to gaining access to areas for spraying. The most common solutions were to rent more land that also would allow farmers to increase production and to take the manure to other farmers who either had enough land or even lacked manure. This could, for example, be the case for famers who only produced grain. Interviewees in some municipalities mentioned that they accepted infield grazing areas as areas for manure spraying.

Adhering to environmental regulations did not seem to be a very big challenge, at least considering the low number of famers who did not receive agricultural land support and cultural landscape support or only received reduced payments. According to interviewees, in about half of the municipalities no payments had been held back during about the five years prior to when the interviews were held in 2018. One municipality reported that as many as 5–10 farmers had received a reduced payment. The main reasons for holding back payments were the handling of manure (e.g., spraying too late or lack of a manuring plan). However, it needs to be considered that municipalities may differ regarding how strict they are in holding back payments.

Most interviewees expected a reduction in number of cattle farmers when cowsheds that allow cows to move freely become a requirement in 2024. The main assumption was that farmers would use their old cowsheds as long as allowed and stop farming when the new regulations come into force. The interviewees assumed that mainly small producers would terminate their businesses. A new cowshed is a large investment and would mean to also investing in an automated milking robot, which requires at least ca. 50–60 milking cows to be economically viable (Rønningen et al. 2021). In 2017, the national average was ca. 27 milking cows per farm (Statistics Norway n.d.,f). However, the interviews held in Rogaland pointed to Innovation Norway's plans to support

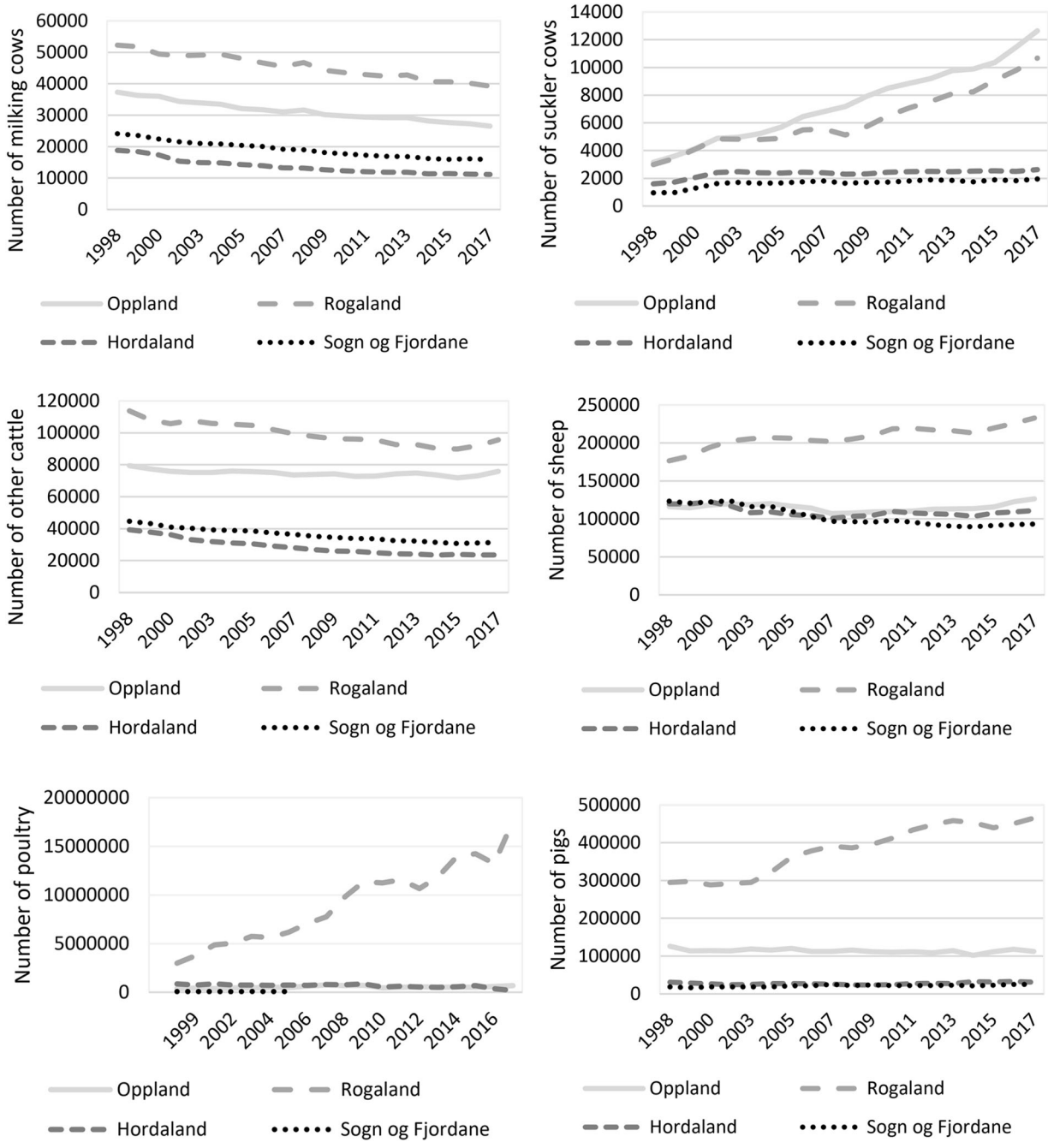

Fig. 4. Changes in types of livestock production at county level from 1998 to 2017; data for poultry unavailable for several years for Sogn og Fjordane (Statistics Norway n.d.,h)

cowsheds for smaller numbers of cattle.[4] A division into those farmers exiting milk production and those expanding was expected, and a few interviewees expected reduced milk volumes. A few interviewees assumed that due to the long-term perspective farmers would be able to adjust to the new regulations, and they therefore expected a limited decline in number of farmers. In all counties, the number of farms with cowsheds for freely moving cattle had increased between 1999 and 2013, showing that adjustments have been ongoing for some time (Statistics Norway n.d.,b).

Interviewees were somewhat divided regarding the potential consequences of the upcoming requirements regarding access to outdoor areas for cattle throughout the whole year. While interviewees mainly from

[4]Innovation Norway is a state-owned company that provides business support for Norwegian enterprises.

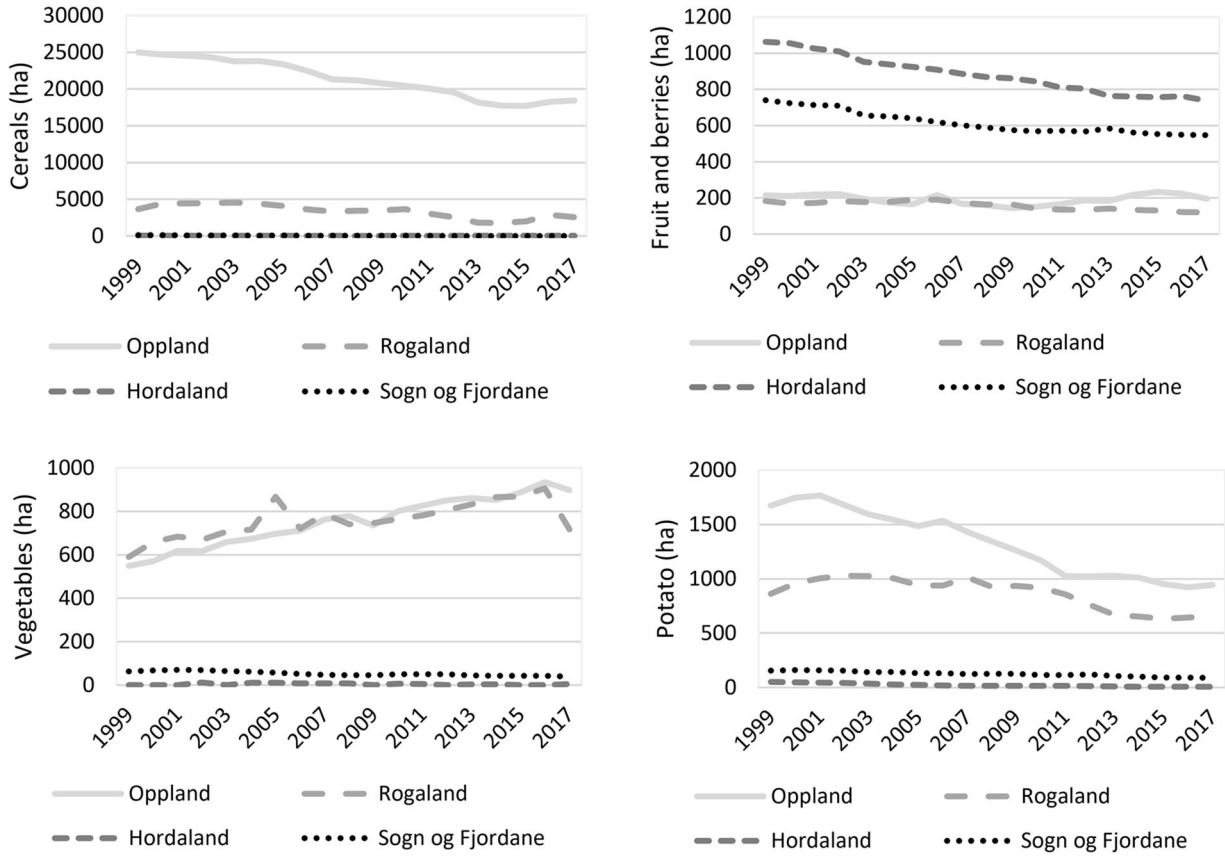

Fig. 5. Changes in production of cereals, fruit (including berries), and vegetables (including potatoes) between 1999 and 2017 (Statistics Norway n.d.,g)

Rogaland and Oppland assumed that farmers would be able to adjust, interviewees from Hordaland and Sogn og Fjordane expected that farmers would experience challenges. Farmers had little grazing land close to the cowsheds, and especially during winter, those areas would be trampled and become muddy.

Local food production and processing, and organic production

A range of different agricultural products was sold either directly or processed, and the most common were meat, fruit (including berries), eggs, and honey, and products thereof. Sales were mainly localized at the producers' farms, and sometimes at farm shops. Delivery to shops, hotels, or restaurants was mentioned for about one-quarter of the municipalities. Also, sales from local markets and fixed selling points were mentioned for one-quarter of the municipalities. All interviewees believed that a market to expand sales of local food products existed. However, two pointed out that the market may be somewhat restricted due to the size of their municipalities. Only one interviewee underlined that a lot of local products were processed and sold. In most municipalities between one and two new businesses that had been established had either processed or sold local food products during the five years preceding the interviews in 2018. Most interviewees estimated that the amount of local processing and sales was small.

Challenges were mainly related to the sales of products (e.g., strong connection to existing processing and sales channels, access to market and local shops, access to processing localities) and hygiene-related requirements for the processing of products. Additionally, time was an important issue, both for full-time farmers who were already occupied with their ongoing business and for part-time farmers who had additional job responsibilities. Lack of an environment that created interest and synergies among producers/potential producers was a challenge in terms of increased sales and processing of local food products.

The percentage of farmers engaged in organic production varied between 0% and 5.8% among the municipalities in 2017 (Statistics Norway n.d.,d and data provided directly by Statistics Norway). The degree of interest in starting organic production seemed to be small. In three-quarters of the municipalities, the interviewees did not know of any farmer interested in

starting organic production. Challenges varied among the municipalities but can be grouped into challenges related to organic production, which requires good agronomic knowledge (e.g., to tackle weeds in grazing areas without the use of pesticides), challenges to fulfil sometimes changing regulations (e.g., requirements relating to buildings, provision of necessary documentation), economic challenges (one interviewee underlined that also the expectation of lower income might prevent farmers from changing to organic production, although in practice the income might not necessarily be lower), challenges related to local conditions (e.g., poor soil conditions that make farming without artificial fertilizer challenging), and challenges related to the farming community (e.g., lack of supportive environment).

Innovation, investments, and collaboration

The most important technological innovations within livestock farming between the late 2000s and 2018 were the automated milking robot and other forms of automatization in big livestock farming (e.g., feeding robot). The degree to which this innovation had been taken into use on farms with milk production varied between 0% and ca. 40% among the municipalities. On average, ca. 25% of farms with milk production in the municipalities in Oppland and Rogaland had milking robots and the corresponding percentage for Hordaland and Sogn og Fjordane was ca. 15%. Other types of innovation were production of bales, innovation in manure application and fruit harvesting, and the use of GPS. These innovations gave farms the opportunity to grow bigger.

About three-quarters of the municipalities had varying numbers of cowsheds and/or varying numbers of seasonal farms (1–12) owned by several farms. Jointly used cowsheds eased investments in milking robots, which can be too high for small farms, and they reduced farmers' workloads. Burton & Farstad (2020) point out that farmers do not take milking robots into use to increase productivity but mainly as a means to pursue lifestyle goals, such as having the opportunity to spend more time with their families. At county level, collaboration among farmers increased until 2008, but parts of the cooperative farms were terminated when farmers could rent unfilled milk quotas, meaning that production could be increased, thereby making the installation of a milking robot viable without becoming a member of jointly used cowsheds.

The two most common other types of collaboration were shared used of machinery and control of livestock while grazing in outfields and/or collecting them from the pastures. Further types of collaboration occurred within other farm operations, such as slaughtering, machinery and vehicle driving services, and fodder production. One interviewee pointed out that collaboration among farmers had been declining as a result of decreasing numbers and increasing sizes of farms, and the fact that the time window to carry out certain farm operations was small.

Importance of farming: its essential functions

Farming contributed to both public and private goods in the municipalities. Most interviewees underlined the importance of agriculture for employment and maintenance of cultural landscapes. Cultural landscapes were valued not only because they were attractive for tourists, but also because cultural landscapes, maintained or otherwise, per se were considered an asset. Interviewees in some municipalities mentioned agriculture's contribution to the upkeep of settlements and to the rest of the economy, for example in terms of multiplier effects and local tax revenues. Moreover, interviewees in some municipalities considered agriculture part of the local identity and culture, while on a more general level some interviewees pointed to agriculture's importance for food production.

Robustness, adaptability, and transformability: the current situation

The resilience attributes describing the situation current at the time the interviews were held (i.e., 2018) and based on the interviews and statistical data (Table 1) give an impression of farming systems that are quite robust and that implement incremental adaptations. Although the number of farms is declining, technological innovations are being implemented, productivity has increased, and different types of production are adapting to changes in the subsidy system and the market. Farming systems seem to be resource-strong in terms of adhering and adjusting to the situation current in 2018 and coming environmental and animal welfare regulations, although the coming regulations for animal welfare may put farms under pressure and result in farm exit, especially in the municipalities in Hordaland and Sogn og Fjordane.

When disregarding farm exit as a transformative process, we could not identify any common trends that could be considered to reflect transformation. Our interview questions focused on changes within agricultural production and we might have missed transformative processes, such as engaging in tourism and cabin (*hytter*) rental. One interviewee mentioned tourism as potential market for local and small-scale production, while several considered maintained cultural landscape as attractive for tourists.

Table 1. Resilience attributes in 2018 (when interviews were held), and in SSP1 Sustainability and SSP5 Fossil-fueled development

Resilience attributes	Situation when interviews were held	SSP1 Sustainability	SSP5 Fossil-fueled development
Resources to implement sustainable production	*Compliance with requirements for agricultural land and cultural landscape support* • Payments had been held back in rather few cases	• Although assumed stricter environmental laws result in stricter requirements for agricultural land and cultural landscape support, most farmers are able to adhere to these requirements.	• The assumed focus on local environmental problems comprises stricter environmental laws resulting in stricter requirements for agricultural land and cultural landscape support. However, most farmers are able to adhere to these requirements.
	Availability of areas for spraying manure • In most municipalities, farmers either experienced few challenges with access to spraying areas or they had found solutions to handle potential challenges.	• Assumed stricter environmental laws causing a need for larger spraying areas have become a serious problem for some municipalities, not at least since availability of agricultural land decreases. • In other municipalities, livestock farmers can still enter into agreements with farmers who have enough land or lack manure. However, the former solution is less available due to decreased availability of agricultural land.	• The assumed focus on local environmental problems that comprise stricter environmental laws causing a need for larger spraying areas is not a challenge for farms since availability of agricultural land is not a limiting factor.
	Availability of agricultural land • Access to infields was a medium to big challenge. • Access to infields was a greater challenge in densely settled areas than in more economically marginal areas. • Outfields were readily available to some extent.	• Due to the assumed increase in environmental restrictions and following reduced availability of land, especially farmers in centrally located areas will experience challenges to gaining access to infield areas. • Outfield areas will most likely still be more available than infield areas, but reduced imports of ingredients for concentrate feed production may result in increased interest in and competition for outfields. • Assumed increased costs of fuel may result in even stronger competition for land located in close vicinity of the farms. • Use of technological innovation and other developments in types of production resulting in higher productivity may reduce competition for land.	• Due to the assumed availability of land as a result of increased productivity, access to both infields and outfields is not a challenge for farmers. • Land is available irrespective of where it is located within the municipalities.
	Price of agricultural land • The price of agricultural land was either a medium or small challenge. • Little land was sold.	• Assumed increased prices of agricultural land might result in serious problems in some municipalities but cause medium challenges in others.	• Due to the assumed availability of agricultural land, the price of land remains a medium or small challenge.
	Investments in the farm • Farmers had mainly invested in the renewal of farm buildings, drainage, and cultivation of new land. • Investments had been delayed to varying degrees.	• Cultivation of new land may become restricted due to assumed stricter environmental regulations. • To keep up with the use of technological innovation and other developments in types of production, comprehensive investments are necessary, especially regarding machinery. • Farms already lagging in terms of investments may decide to practice farm exit.	• Cultivation of new land may become restricted due to assumed stricter environmental regulations. • To keep up with the use of technological innovation and other developments in types of production, comprehensive investments are necessary, especially in machinery. • Farms already lagging in terms of investments may decide to practice farm exit.
	Share of part-time versus full-time farmers • Within about three-quarters of the municipalities, the share of part-time farmers was higher than the share of full-time farmers.	• Part-time farmers are challenged by the time needed to produce food, such as vegetables, that would satisfy the assumed change in consumer preferences.	• Assumed low prices of food, increased productivity, increased spending on feedstuff and imports of meat challenge the

(*Continued*)

Table 1. Continued.

Resilience attributes	Situation when interviews were held	SSP1 Sustainability	SSP5 Fossil-fueled development
		• The assumed increased food prices may make it attractive for part-time farmers to become full-time farmers.	economic viability of meat production, despite higher meat consumption. • Full-time farmers may have a larger capacity to handle the situation, while part-time farmers may have to rely on additional sources of income.
	Use of local fodder resources • Silage and, in about half of the municipalities, some amounts of hay were produced. • Outfields were used as pasture, and ca. 10–30% of the total fodder uptake was in outfields.	• Due to an assumed focus on own feed resources, the use of local fodder resources increases. • Use of technological innovation and other developments in types of production will be necessary to produce enough fodder, also in outfields, and to produce concentrated feed without the need for imported ingredients. • Increased use of local fodder resources is challenged by a reduced availability of agricultural land.	• Due to assumed import of concentrated feed, the need for local fodder resources is declining. This concerns fodder from infields, as well as from outfields.
	Employment of foreign seasonal workers • Foreign seasonal workers were to a little degree employed in milk and meat production. • Fruit (including berries) production was strongly dependent on seasonal workers.	• The assumed moderate availability of a labor force does not result in many challenges for milk and meat producers but fruit producers face increasing challenges in finding seasonal workers.	• The assumed easy availability of laborers has not resulted in challenges for many producer.
	Resources to provide cowsheds in accordance with coming regulations • Farms that were big enough or that had the potential to grow would be able to provide appropriate cowsheds. • Other farms would exit milk production. • Availability of outdoor areas for cattle close to the cowsheds varied among the five counties.	• Stricter environmental laws do not comprise new regulations for animal welfare.	• Stricter environmental laws do not comprise new regulations for animal welfare.
Farm heterogeneity	*Product diversity at farm level* • Product diversity varied among municipalities; between 15% and 85% of the farms had at least two types of production. • Farms had become more specialized.	• The assumed changed consumer preferences towards less milk and meat consumption and increased fruit and vegetable consumption challenge farmers with meat and milk production, especially those focusing entirely on those products. Most interviewees at county level agreed that the changed consumer preferences would result in declined production and farm exit. • Farmers combining sheep and cereal/berry production may find it easier to respond to consumer preferences. • Specialization at farm level may make it difficult to respond to consumer preferences.	• Specialized farms may be able to respond more easily to increased meat demand than more diverse farms but lower prices and increased competition with imported food will also challenge specialized farms.
Region diversity and redundancy	*Product diversity at county level* • Product diversity at county level had increased.	• Increased product diversity at county level (especially a greater selection of vegetables) may allow larger regions to respond to changed consumer preferences. • A diversity at county level may allow to offer a greater selection of products over a larger part of the year.	• Specialization at county level may be necessary to develop strong enough regions to respond to the need for increased productivity.

	Types of collaboration		
Opportunities for collaboration	• Joint use of cowsheds increased farmers' opportunities to implement technical innovations and to reduce their workloads. • The possibility to rent unfilled milk quotas had reduced the need for collaboration. • Other types of collaboration occurred within livestock keeping and shared machinery, but they might have been decreasing due to growing farms and declining farming communities.	• A potential demand to change types of production to satisfy consumer needs may increase the need for knowledge exchange and cooperation • Use of technological innovations and other developments in types of production many increase the need to make investments in the farm, which in turn may increase the need for cooperation.	• Cooperation, especially in the form of knowledge exchange, among farmers may be needed to enable farmers to develop specialized regions to respond to increased competition with imported food and reduced food prices. • Use of technological innovations and other developments in types of production many increase the need to make investments in the farm, which in turn may increase the need for cooperation.
	Local food production and processing		
Stakeholder engagement	• With the exception of in one municipality, few farmers were involved in local food production and processing.	• Producers are not prepared to meet the changed consumer preferences. However, the interviewees saw opportunities for increased production.	• Consumer preferences are not assumed to require more production and processing of local food.
Open attitude to innovation	• With the exception of in one municipality, little local food production and processing occurred in the municipalities.	• Producers are not prepared to meet the changed consumer preferences. However, the interviewees saw opportunities for increased production.	• Consumer preferences are not assumed to require more production and processing of local food.
	Organic production		
	• Few farmers had organic production. • There seemed to be little interest in starting organic production.	• Producers are not prepared to meet the changed consumer preferences. • The interviewees pointed out that increased demand might result in a producer response in terms of increased production. However, they feared that increased demand might be covered by imports.	• Consumer preferences are not assumed to require more organic production.
	Use of technological innovation and other developments in types of production		
	• Technological innovations had been taken into use. However, it would take time before they would become widespread. • To make the use of milking robots economically viable, the number of cows per farm needed to be higher than the national average in 2017. • Productivity per cow had increased.	• Technological innovations such as precision agriculture are important in order to increase productivity.	• Technical innovations, such as precision agriculture, are the key to increase productivity in order to tackle low prices and competition from imported food.

According to Innovation Norway's VisitNorway home page, none of the farms in the investigated municipalities offered stays or visits at mountain summer farms or farms in September 2021 (Innovation Norway n.d.). Nine farms within a total of six municipalities offered facilities for overnight stays, but only in two cases the description mentioned either livestock or farm products. Thus, it remained open as to whether farming had terminated on the other farms. Although it is most likely that the VisitNorway web page does not include all farm-related tourism offers, the information provided on the web page indicates that not many farmers use tourism as a transformative pathway (Innovation Norway n.d.). Local food production and processing, and organic production, all of which are potential pathways to transformation of farming systems, were ongoing to a small extent with the exception of in one municipality. The interviewees pointed to comprehensive challenges for these types of production.

Thus, the findings relating to the situation of farming systems in our case study were similar to findings of SURE-Farm case studies in terms of robustness being higher than adaptability and transformability (Meuwissen et al. 2020; Nicholas-Davies et al. 2020; Reidsma et al. 2020; Manevska-Tasevska et al. 2021; Paas et al. 2021). The findings are also in line with findings relating to Swedish and Finnish agricultural systems in which farmers rather applied incremental adaptive measures, while transformational activities were carried out to a lesser degree (Juhola et al. 2017). Robustness may thus be a common resilience capacity of farming systems in countries with politically strongly influenced agricultural sectors. Within these countries, agricultural policy provides a rather stable framework for production but requires continuous adjustments to changing regulations and subsidy schemes. The adjustments move farming systems towards specialization and rationalization. It can be argued that such a situation is similar to a conversion phase within an adaptive cycle, reflecting a time period of stability, but during which increasing specialization becomes a stressor for farming systems (Darnhofer et al. 2010). Several studies show that continuous structural changes towards rationalization and specialization may put agricultural production under pressure (Kvalvik et al. 2011; Abson et al. 2013; Urruty et al. 2016; Flemsæter et al. 2018; Burton & Farstad 2020; Beitnes et al. 2022). Within such a framework, aiming for robustness may be an appropriate strategy to become resilient. However, as Beitnes et al. (2022) argue, resilience is context dependent and not a given state. Potential contextual changes, such as climate change, may lead to the need for activities that add diversity and flexibility (Darnhofer et al. 2010; Martin et al. 2013).

To what degree is enhancement of resilience needed?

One way to estimate the need of enhanced resilience is to assess the degree to which farming systems are able to fulfil their essential functions. So far in this article, the discussion has shown that at the time when the interviews were carried out farming systems appeared to be rather robust and able to provide at least three essential functions: (1) maintained cultural landscapes in those areas that are still in use, (2) food production, which despite changes in types of production and amount produced, seems to be well anchored in the municipalities and hence also (3) living local communities. The provision of these functions, especially the occurrence of living local communities, is not merely dependent on farming systems. Other factors, such as the availability of services (e.g., local health care, schools, and grocery stores) contribute to making rural areas attractive places in which to live. However, our further discussion focuses on the role of farming systems.

Continuous farm exit, lack of investments, and more marginal areas of minor interest for farming may all be signs of farming systems under pressure and indicate that other resilience capacities than robustness may need to be strengthened. While SSP5 anticipates social, technological, and economic trends that most likely will result in a progression of rationalization and specialization (i.e., increasing the stress on farming systems), SSP1 sees agricultural production moving in a new direction, including changes that are potential shocks for farming systems. Thus, both scenarios may require enhanced resilience through adaptation and transformation. Resilience attributes for SSP1 and SSP5 in Table 1 are our interpretations.

Maintained cultural landscapes: abandoned landscapes are a lost opportunity for adaptation and transformation

Maintained cultural landscapes require use. The developments indicated by SSP1 could allow for a greater opportunity to maintain cultural landscapes due to a greater need for agricultural land (also for spraying manure) and the need to expand the use of local fodder resources (Table 1). The latter could even mean more comprehensive use of outfield areas. However, increased costs of fuel and restricted possibilities for cultivation of new land may enhance competition for land

in terms of availability and price, especially in the immediate vicinity of the farms. This competition could result in farm exit. If increased prices of farm products make farming an attractive livelihood, another potential development could be stimulation of production in decentralized areas. Higher prices of farm products could also reduce the need to intensify, thereby making it easier for farmers to adhere to stricter environmental regulations. Thus, developments such as those portrayed in SSP1 could mean that the extent of cultural landscapes maintained would stabilize or even increase, unless changed consumer preferences result in comprehensive farm exit.

SSP5 assumes easy access to land due to high productivity enabled by technological innovations. Reduced need for local fodder resources and easy access to agricultural land may result in an even stronger concentration of agricultural production and hence in a comprehensive decrease in maintained cultural landscapes. Abandoned and regrowing cultural landscapes may result in opportunities for local communities. As an example, the introduction of large herbivores such as the Konik horse breed and European bison in regrowing agricultural areas in Latvia was expected to create tourism opportunities for the local population (Zarina et al. 2018; 2022). Moreover, Filho et al. (2017) report some potential benefits of abandonment such as decreases in soil erosion and pollution. However, regrowth of agricultural land may also mean loss of transformative and adaptive opportunities for farming systems. Comprehensive regrowth may make areas less attractive for tourists because vistas may disappear, and cultural heritage sites and areas for recreational activities may become difficult to access (Fyhri et al. 2009; Hemsing & Bryn 2012; Kuiper & Bryn 2013). For agricultural production, availability of different types of resources, including outfield areas, offers flexibility. Access to outfield resources was important to make farming systems robust during the dry summer of 2018 in Norway (Beitnes et al. 2022).

Food production: resilient or not—a question of trade-offs and scale

To be saleable on the market, food produced on farms must meet consumers' needs. SSP1 envisions comprehensive changes in consumer preferences, and while interviewees saw increased demand for, for example, organic products, as an opportunity for farmers, the demand could also be covered by imports (Table 1). Farmers have adjusted to changes in the market in the past, and although at the time when the interviews were carried out they were not prepared to meet demands for organic and local and regional products, especially vegetable and fruit producers may gain from new consumer preferences. Milk and meat producers may experience comprehensive challenges, especially those producers who have invested and upscaled production. Most interviewees agreed that a decline in milk and meat production, as well as farm exit would probably be a consequence of changed consumer preferences.

Moderate labor availability envisioned by SSP1 may challenge the production of vegetable and fruit that is dependent on seasonal workers. The COVID-19 pandemic has shown how strongly production of, for example, vegetables and berries, suffers if foreign seasonal workers are unavailable (see Meuwissen et al. 2021 for how the pandemic impacted the SURE-Farm case studies). The news media reported about non-harvested berries and vegetables, and about vegetable seedlings that were thrown away due to an anticipated lack of seasonal workers for harvesting. Thus, farming systems would have to adjust and transform in order to remain resilient in light of new consumer preferences. Both upscaling and downscaling of production would be necessary.

Continuous rationalization and specialization as envisioned in SSP5 may in the long run result in declining resilience because trade-offs exist between maximizing efficiency and increased resilience. High efficiency and stability often mean less flexibility and resilience (Schiere et al. 2012). Flexibility is, for example, needed to respond to climatic shocks and to carry out farm operations, such as ploughing and harvesting, during the most optimal times in the farming year. The advantages of rationalization may cease when farmers have to carry out farm operations under suboptimal weather conditions (Vik & Flø 2017; Beitnes et al. 2022). Trade-offs already seem to occur in milk production, in which investments in milking robots and larger herds may "lock-in" producers into a development path on which downscaling is no option (Burton & Farstad 2020; Rønningen et al. 2021).

Whether farming systems can be considered resilient and able to satisfy consumer preferences is not only a question of producing the right amount of the right type of food but is also a question of scale. Farms in the studied municipalities have become more specialized. Such a reduction in product diversity may make it difficult for producers to respond to changed consumer preferences and farming systems could be considered non-resilient. However, product diversity had increased to some degree at county level. Diversity at county level could mean that farming systems would be able to respond to changes in consumer preferences.

Living local communities: the tipping point

In Europe, countries' policies underline the importance of agriculture for life in rural areas. While rural employment and settlement has been one argument for farm support, to 'keep the rural economy alive by promoting jobs in farming, agri-food industries and associated sector' is one main aim of the EU's Common Agricultural Policy (Bjørkhaug & Rønningen 2014; European Commission n.d.).

Although the current existence of farms in the municipalities (i.e., in 2023) indicates that farming systems are contributing to living local communities, it is questionable whether they will be able to do so if farm exit continues. Tipping points can be understood as thresholds, meaning that only a small change, such as in the number of farmers, would be needed for a non-linear change in the farming system to happen (e.g., farm exit of the remaining farmers or most of them in a local community) (Milkoreit et al. 2018). Investigations of farm exit in Northern Norway have shown that in 1999 slightly less than 7% of the farmers had no farming neighbor within a 3 km travelling distance, while in 2006 12% of the farmers were lacking a farming neighbor (Puschmann et al. 2011). Although the number of farmers needed to support a living local community will be context-dependent, an estimate would be of interest in order to be able to detect farming systems that are close to the tipping point for comprehensive farm exit and thus not resilient.

Conclusions

Agricultural production in the investigated municipalities is characterized by increasing specialization and rationalization. The number of farms has declined, and types of productions have changed (e.g., heads of cattle for meat production have increased). The introduction of the automated milking robot—the most important technological innovation in recent years—required an increase in the number of milking cows per farm in order for milk production to be economically viable. When the interviews were carried out in 2018, farming systems seemed to be robust and able to handle incremental measures to implement technological innovations and to adjust to new environmental and animal welfare regulations and changed markets. This resilience capacity may be common for farming systems that are strongly politically controlled and that operate in a rather stable framework. Our findings show that farming systems provide important public and private goods. Assessment of the consequences of development trends envisioned by the two scenarios (SSP1 and SSP5) underlined that the provision of these goods may be challenged in the future. This concerns, for example, maintained cultural landscapes and food production that is in line with consumer preferences. Depending on the scenario, different measures would be required to enhance resilience. The increased electricity prices in Norway, and the current war in Ukraine and its impacts on the food market are examples of contextual changes that may challenge agricultural production and emphasize the need to assess/reassess the resilience of farming systems.

Acknowledgements

Research assistant, Mari Gjeraker, is thanked for organizing and conducting the interviews, transcribing them, and preparing the analysis. Synnøve Beitnes is thanked for helpful suggestions on the development of an earlier draft of the manuscript. The project on which the article is based was funded by the Research Council of Norway (Project No. 283415).

ORCID

Kerstin Potthoff http://orcid.org/0000-0002-4125-8556
Birgit Kopainsky http://orcid.org/0000-0002-1271-8365

Disclosure statement

No potential conflict of interest was reported by the authors.

References

Abson, D.J., Fraser, E.D.G. & Benton, T.G. 2013. Landscape diversity and the resilience of agricultural returns: A portfolio analysis of land-use patterns and economic returns from lowland agriculture. *Agriculture & Food Security* 2, 1–15.

Accatino, F., Paas, W., Herrera, H., Appel, F., Pinsard, C., Shi, Y., Schütz, L. et al. 2020. *D5.5 Impacts of Future Scenarios on the Resilience of Farming Systems across the EU Assessed with Quantitative and Qualitative Methods*. https://research.wur.nl/en/publications/d55-impacts-of-future-scenarios-on-the-resilience-of-farming-syst (accessed 5 September 2023).

Arnoldussen, A., Forbord, M., Grønlund, A., Hillestad, M.E., Mittenzwei, K., Pettersen, I. & Tufte, T. 2014. *Økt matproduksjon på norske arealer*. Rapport 6-2014. Oslo: AgriAnalyse.

Beitnes, S.S., Kopainsky, B. & Potthoff, K. 2022. Climate change adaptation processes seen through a resilience lens: Norwegian farmers' handling of the dry summer of 2018. *Environmental Science & Policy* 133, 146–154.

Bjørkhaug, H. & Rønningen, K. 2014. Crisis? What crisis? Marginal farming, rural communities and climate robustness: The case of Northern Norway. *International Journal of Sociology of Agriculture and Food* 21, 51–69.

Burton, R.J.F. & Farstad, M. 2020. Cultural lock-in and mitigating greenhouse gas emissions: The case of dairy/beef farmers in Norway. *Sociologia Ruralis* 60, 20–39.

Darnhofer, I. 2014. Resilience and why it matters for farm management. *European Review of Agricultural Economics* 41, 461–484.

Darnhofer, I., Fairweather, J. & Moller, H. 2010. Assessing a farm's sustainability: Insights from resilience thinking. *International Journal of Agricultural Sustainability* 8, 186–198.

Darnhofer, I., Lamine, C., Strauss, A. & Navarrete, M. 2016. The resilience of family farms: Towards a relational approach. *Journal of Rural Studies* 44, 111–122.

Daugstad, K. 2019. Resilience in mountain farming in Norway. *Sustainability* 11, 1–11.

Eriksen, S. & Selboe, E. 2012. The social organisation of adaptation to climate variability and global change: The case of a mountain farming community in Norway. *Applied Geography* 33, 159–167.

European Commission. 2022. Towards SUstainable and REsilient EU FARMing systems. https://cordis.europa.eu/project/id/727520 (accessed 1 September 2023).

European Commission. n.d. The common agricultural policy at a glance. https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/cap-glance_en (accessed 14 October 2021).

FAO. 2018. *The State of Agricultural Commodity Markets, Agricultural Trade, Climate Change and Food Security*. Rome: FAO.

Filho, W.L., Mandel, M., Al-Amin, A.Q., Feher, A. & Jabbour, C.J.C. 2017. An assessment of the causes and consequences of agricultural land abandonment in Europe. *International Journal of Sustainable Development & World Ecology* 24, 554–560.

Flemsæter, F., Bjørkhaug, H. & Brobakk, J. 2018. Farmers as climate citizens. *Journal of Environmental Planning and Management* 61, 2050–2066.

Folke, C., Carpenter, S.R., Walker, B., Scheffer, M., Chapin, T. & Rockström, J. 2010. Resilience thinking: Integrating resilience, adaptability and transformability. *Ecology and Society* 15(4): Article 20.

Forbord, M., Bjørkhaug, H. & Burton, R.J.F. 2014. Drivers of change in Norwegian agricultural land control and the emergence of rental farming. *Journal of Rural Studies* 33, 9–19.

Ford, J.D. & Berrang-Ford, L. 2011. Introduction. Ford, J.D. & Berrang-Ford, L. (eds.) *Climate Change Adaptation in Developed Nations: From Theory to Practice*, 3–20. Dordrecht: Springer.

Fyhri, A., Jacobsen, J.K.S. & Tømmervik, H. 2009. Tourists' landscape perceptions and preferences in a Scandinavian coastal region. *Landscape and Urban Planning* 91, 202–211.

Helse- og omsorgsdepartementet, Klima- og miljødepartementet & Landbruks- og matdepartementet. 2003. *Forskrift om gjødselvarer mv. av organisk opphav*. https://lovdata.no/dokument/SF/forskrift/2003-07-04-951 (accessed 30 August 2023).

Hemsing, L.Ø. & Bryn, A. 2012. Attgroing, hytter og sau. *Sau og Geit* 65, 8–11.

Innovation Norway. n.d. Welcome to Norway. https://www.visitnorway.com/ (accessed 15 September 2021).

Jervell, A.M. & Borgen, S.O. 2000. Distribution of dairy production rights through quotas: The Norwegian case. Schwarzweller, H.K. & Davidson, A.P. (eds.) *Research in Rural Sociology and Development*, 355–378. Emerald. https://doi.org/10.1016/S1057-1922(00)80018-9 (accessed 15 August 2023).

Juhola, S., Klein, N., Käyhkö, J. & Neset, T.-S.S. 2017. Climate change transformations in Nordic agriculture? *Journal of Rural Studies* 51, 28–36.

Klassen, S. & Murphy, S. 2020. Equity as both a means and an end: Lessons for resilient food systems from COVID-19. *World Development* 136: Article 105104.

Kuiper, E. & Bryn, A. 2013. Forest regrowth and cultural heritage sites in Norway and along the Norwegian St Olav pilgrim routes. *International Journal of Biodiversity Science, Ecosystem Services & Management* 9, 54–64.

Kvalvik, I., Dalmannsdottir, S., Dannevig, H., Hovelsrud, G., Rønning, L. & Uleberg, E. 2011. Climate change vulnerability and adaptive capacity in the agricultural sector in Northern Norway. *Acta Agriculturae Scandinavica, Section B – Soil and Plant Science* 61, 27–37.

Kårstad, S., Haukås, T. & Hegrenes, A. 2015. *Analyse av kjørekostnader i mjølkeproduksjonen*. NIBIO Rapport 1(9). [Ås]: Norsk institutt for bioøkonomi.

Landbruks- og matdepartement. 2004a. *Forskrift om hold av storfe*. https://lovdata.no/dokument/SF/forskrift/2004-04-22-665?q=forskrift om hold av storfe (accessed 30 August 2023).

Landbruks- og matedepartementet. 2004b. Lov om konsesjon ved erverv av fast eiendom mv. (konsesjon sloven). https://lovdata.no/dokument/NL/lov/2003-11-28-98?q=Konsesjonsloven (accessed 30 August 2023).

Landbruks- og matdepartement. 2015. *Forskrift om produksjonstilskudd og avløsertilskudd i jordbruket*. https://lovdata.no/dokument/SF/forskrift/2014-12-19-1817 (accessed 30 August 2023).

Nærings- og fiskeridepartement & Landbruks- og matdepartement. 2017. *Forskrift om økologisk produksjon og merking av økologiske landbruksprodukter, akvakulturprodukter, næringsmidler og fôr*. https://lovdata.no/dokument/LTI/forskrift/2017-03-18-355 (accessed 30 August 2023).

Landbruks- og matdepartementet. 2019. *Lov om forbud mot hold av pelsdyr*. https://lovdata.no/dokument/LTI/lov/2019-06-21-63 (accessed 5 July 2020).

Manevska-Tasevska, G., Petitt, A., Larsson, S., Bimbilovski, I., Meuwissen, M.P.M., Feindt, P.H. & Urquhart, J. 2021. Adaptive governance and resilience capacity of farms: The fit between farmers' decisions and agricultural policies. *Frontiers in Environmental Science* 9. https://www.frontiersin.org/articles/10.3389fenvs.2021.668836/full (accessed 15 August 2023).

Martin, G., Martin-Clouaire, R. & Duru, M. 2013. Farming system design to feed the changing world: A review. *Agronomy for Sustainable Development* 33, 131–149.

Mathijs, E., Decker, J., Kopainsky, B., Nitzko, S. & Spiller, A. 2018. *D1.1 Scenarios for EU farming*. https://www.researchgate.net/publication/325201433_D12_Scenarios_for_EU_Farming (accessed 29 September 2021).

Meisterling, K., Samaras, C. & Schweizer, V. 2009. Decisions to reduce greenhouse gases from agriculture and product transport: LCA case study of organic and conventional wheat. *Journal of Cleaner Production* 17, 222–230.

Meld. St. 11 (2016–2017). *Endring og utvikling – En fremtidsrettet jordbruksproduksjon*. Oslo: Landbruks- og matdepartementet.

Meuwissen, M.P.M., Paas, W.H., Slijper, T., Coopmans, I., Ciechomska, A., Lievens, E., Decker, J. et al. 2018. *Report on Resilience Framework for EU Agriculture*. Wageningen University & Research. https://edepot.wur.nl/443054 (accessed 5 September 2023).

Meuwissen, M.P.M., Feindt, P.H., Spiegel, A., Termeer, C.J.A.M., Mathijs, E., de Mey, Y., Finger, R. et al. 2019. A framework to assess the resilience of farming systems. *Agricultural Systems* 176: Article 102656.

Meuwissen, M.P.M., Feindt, P.H., Midmore, P., Wauters, E., Finger, R., Appel, F., Spiegel, A. et al. 2020. The struggle of farming systems in Europe: Looking for explanations through the lens of resilience. *EuroChoices* 19, 4–11.

Meuwissen, M.P.M., Feindt, P.H., Slijper, T., Spiegel, A., Finger, R., de Mey, Y., Paas, W. et al. 2021. Impact of Covid-19 on farming systems in Europe through the lens of resilience thinking. *Agricultural Systems* 191: Article 103152.

Milkoreit, M., Hodbod, J., Baggio, J., Benessaiah, K., Calderón-Contreras, R., Donges, J.F., Mathias, J.-D., Roach, J.C., Schoon, M. & Werners, S.E. 2018. Defining tipping points for social-ecological systems scholarship—an interdisciplinary literature review. *Environmental Research Letters* 13: Article 033005.

Neset, T.-S., Wiréhn, L., Klein, N. & Käyhkö, J. 2019. Maladaptation in Nordic agriculture. *Climate Risk Management* 23, 78–87.

Nicholas-Davies, P., Fowler, S. & Midmore, P. 2020. Telling stories – farmers offer new insights into farming resilience. *EuroChoices* 19, 12–17.

Nysted, T.E., Uldal, S.H. & Vakse, I. 2020. Hva spiser norske husdyr – egentlig. Kjos, A.-K., Nafstad, O., Odden, H., Ruud, T.A., Saltnes, T. & Ytterdahl, M. (eds.) *Kjøttets tilstand 2020: Status i norsk kjøtt- og eggproduksjon*, 6–11. Animalia. https://www.animalia.no/contentassets/3dce35cde68a47b091097fa8c6ec2dd5/kt20-komplett-origi-web.pdf (accessed 15 August 2023).

OECD. 2021. *Making Better Policies for Food Systems*. https://www.oecd.org/publications/making-better-policies-for-food-systems-ddfba4de-en.htm (accessed 5 July 2023).

Paas, W., Coopmans, I., Severini, S., van Ittersum, M.K., Meuwissen, M.P.M. & Reidsma, P. 2021. Participatory assessment of sustainability and resilience of three specialized farming systems. *Ecology and Society* 26(2): Article 2.

Puschmann, O., Krøgli, S.O. & Stokstad, G. 2011. *Økende avstand mellom aktive bruk i Nord*. Fakta 07/11. Ås: Skog og landskap.

Reidsma, P., Meuwissen, M., Accatino, F., Appel, F., Bardaji, I., Coopmans, I., Gavrilescu, C. et al. 2020. How do stakeholders perceive the sustainability and resilience of EU farming systems? *EuroChoices* 19, 18–27.

Rønningen, K., Fugestad, E.M. & Burton, R. 2021. Path dependencies in Norwegian dairy and beef farming communities: Implications for climate mitigation. *Norsk Geografisk Tidsskrift–Norwegain Journal of Geography* 75, 65–78.

Schiere, J.B., Darnhofer, I. & Duru, M. 2012. Dynamics in farming systems: Of changes and choices. Darnhofer, I., Gibbon, D. & Dedieu, B. (eds.) *Farming Systems Research into the 21st Century: The New Dynamics*, 337–363. Dordrecht: Springer.

Sim, S., Barry, M., Clift, R. & Cowell, S.J. 2007. The relative importance of transport in determining an appropriate sustainability strategy for food sourcing: A case study of fresh produce supply chains. *The International Journal of Life Cycle Assessment* 12, 422–431.

Statistics Norway. n.d.,a. 03790: Jordbruksbedrifter med husdyr per 1. mars, etter husdyrslag (F) 1998 - 2017. https://www.ssb.no/statbank/table/03790/tableViewLayout1/?rxid=a68488a8-c76d-4c3c-9ea6-f6c0013132c0 (accessed 19 January 2017).

Statistics Norway. n.d.,b. 10714: Jordbruksbedrifter med kufjøs, kuplassar og mjølkerobotar (F) 1999 - 2013. https://www.ssb.no/statbank/table/10714 (accessed 3 April 2018).

Statistics Norway. n.d.,c. 06462: Jordbruksareal etter bruken (dekar) (K) 1969 - 2020. https://www.ssb.no/statbank/table/06462 (accessed 6 July 2021).

Statistics Norway. n.d.,d. 08646: Jordbruksbedrifter i alt og jordbruksbedrifter med ymse vekstar (K) 1969 - 2020. https://www.ssb.no/statbank/table/08646 (accessed 6 July 2021).

Statistics Norway. n.d.,e. 03313: Jordbrudsbedrifter, etter jordbruksareal i drift (F) 1969 - 2021. https://www.ssb.no/statbank/table/03313 (accessed 25 August 2021).

Statistics Norway. n.d.,f. 05986: Husdyr per jordbruksbedrift, etter husdyrslag og jorbruksareal i drift 2000–2022. https://www.ssb.no/statbank/table/05986 (accessed 15 October 2021).

Statistics Norway. n.d.,g. 11506: Jordbruksareal, etter bruken (dekar) (F) 1969 - 2021. https://www.ssb.no/statbank/table/11506 (accessed 7 September 2021).

Statistics Norway. n.d.,h. 03791: Husdyr per 1. mars, etter husdyrslag (F) 1998 - 2021. https://www.ssb.no/statbank/table/03791 (accessed 27 August 2021).

Stokka, T., Dramstad, W.E. & Potthoff, K. 2018. The use of rented farmland in an area of intensive agricultural production in Norway. *International Journal of Agricultural Sustainability* 16, 243–254.

Tullberg, J. 2010. Tillage, traffic and sustainability—A challenge for ISTRO. *Soil & Tillage Research* 111, 26–32.

Uleberg, E., Hanssen-Bauer, I., van Oort, B. & Dalmannsdottir, S. 2014. Impact of climate change on agriculture in Northern Norway and potential strategies for adaptation. *Climatic Change* 122, 27–39.

Urruty, N., Tailliez-Lefebvre, D. & Hyghe, C. 2016. Stability, robustness, vulnerability and resilience of agricultural systems: A review. *Agronomy for Sustainable Development* 36. Article 15.

Vik, J. & Flø, B.E. 2017. *Scenarioer for norsk landbruksproduksjon: En snål rapport, et tverrfaglig eksperiment, og et diskusjonsgrunnlag*. Ås: NIBIO.

Webb, P., Flynn, D.J., Kelly, N.M., Thomas, S.M. & Benton, T.G. 2021. *COVID-19 and Food Systems: Rebuilding for Resilience*. https://www.glopan.org/wp-content/uploads/2021/05/FSS_Brief_COVID-19_and_food_systems.pdf (accessed 5 July 2023).

Wiréhn, L. 2018. Nordic agriculture under climate change: A systematic review of challenges, opportunities and adaption strategies for crop production. *Land Use Policy* 77, 63–74.

Zarina, A., Vinogradovs, I. & Škinkis, P. 2018. Towards (dis)-continuity of agricultural wetlands: Lativa's polder landscapes after Soviet productivism. *Landscape Research* 43, 455–469.

Zarina, A., Treija, D. & Vinogradovs, I. 2022. Bison in the Latvian ethnoscape: A contingency of not(becoming). *Letonica* 44, 153–167.

Appendix 1. SURE-Farm scenarios SSP1 (Sustainability) and SSP5 (Fossil-fueled development) (Mathijs et al. 2018) adjusted to a Norwegian context

SSP1 (Sustainability)

Increased awareness of environmental protection has resulted in stricter laws and regulations for environmental protection, such as on the spraying of manure, as well as agricultural land and cultural landscape support. Other pro-environmental strategies are taking into account pollution costs, meaning higher prices for pesticides and fuel, and hence also for transport, which in turn impacts the prices of artificial fertilizers. Prices of imported food increase, also as a result of increased costs of transport. Consumer preferences have changed towards low meat consumption and reduced milk and milk products consumption, while the demand for vegetables and fruit (including berries) has increased. Food waste has declined strongly. Consumers prefer local and regional products in accordance with the seasons and are interested in healthy and natural products. Prices of all types of food are high, but they are restricted by increased productivity through, for example, precision agriculture, genetic improvement, and ecological intensification. There is a strong reduction in imports of ingredients for concentrated feed production. Meat and milk production is based on own feed production. Due to environmental restrictions, little agricultural land is available and the price of land is high. Farm laborers are available to a moderate degree.

SSP5 (Fossil-fueled development)

Environmental protection is geared towards local environmental problems, while global environmental problems are considered only to a small degree. Open trading results in regional specialization. Meat consumption is high, as well as demand for a broad selection of food from the whole world. The meat is both produced in Norway and imported from other countries, and meat production relies on concentrated feed. Import of concentrated feed and ingredients for feed production increases. Reducing waste of food receives little attention. Food prices are low due to strongly increased productivity but also very variable. Technological advancement is fossil fuel-based but with a strong focus on saving resources due to precision agriculture. Agricultural land and farm laborers are easily accessible due to high productivity and open trading.