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Farm sustainability as a sustainability learning process in Arctic Norway

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Acknowledgments

As I get closer to the finish line of my PhD journey, it seems like a small eternity since it started. It has been a bumpy and sometimes steep road, but I have experienced and learned a great deal along the way.

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Abstract

Sustainability has been proposed as a solution to the many negative consequences of modern agriculture. However, although science and policy have aimed for sustainability for more than two decades, it seems that we are not making enough progress. This can be attributed to the complexities surrounding the concept of sustainability and the fact that we need to have a better understanding of how we can create change. In seeing sustainability as a learning process, this thesis aims to understand how to enhance farm sustainability in Arctic Norway. This is achieved by combining four research rationales: stakeholders' perspectives on sustainability, sustainability assessments, sustainability learning, and participatory approaches. The advantage of this combination is that it ensures that stakeholders' specific perspectives on sustainability are considered; that farm sustainability is not evaluated randomly, ensuring a strategy for bringing farms toward enhanced sustainability; and that relevant stakeholders in the specific context of Arctic Norway agriculture engage in collaboration. These four rationales are commonly discussed in agricultural research. However, what is new in this thesis is that the combination allows for seeing farm sustainability in Arctic Norway as a learning process. Therefore, this thesis aims to address its main research question:

> *How can farm sustainability in Arctic Norway be conceptualized as a learning process?*

To answer this question, I use a case study strategy involving farms in Arctic Norway and apply a multimethod (predominantly) qualitative approach. I explore the topic through three empirical papers (Papers I–III) wherein stakeholder participation plays a prominent role.

In Paper I, we studied Arctic Norway farmers' perspectives on sustainability through a qualitative approach applying the SAFA framework. The paper's main contribution is that it provides insights into farmers' perspectives, including how their values and contextual factors influence farm sustainability. In Paper II, we characterized the sustainability learning process of farmers in Arctic Norway, using sustainability assessments as a starting point for learning in a qualitative approach through interviews with farmers and stakeholder workshops. The paper provides insights into sustainability learning, stakeholders' perspectives, sustainability assessments, and the use of participatory approaches. In Paper III, a transdisciplinary project for improving self-sufficiency was evaluated, thus generating insights into participatory approaches and sustainability learning processes in Arctic agriculture.

The findings from the three papers are discussed against theory from the sustainability and sustainability learning literature, as well as the literature regarding learning processes in agriculture. To conceptualize farm sustainability as a learning process, I utilized a framework that distinguished the important parts of the learning process.

I find that three overarching features frame farm sustainability in Arctic Norway. First, it is a long-term process entailing constant negotiations on trade-offs, synergies, and long-term effects. Second, it is a multilevel concept wherein farm sustainability develops concurrently with societal, political, and market developments. Third, farm sustainability must be embedded in the very process of farm production, wherein the process itself should be a learning environment enabling holistic farm sustainability.

I also found several important factors after further distinguishing farm sustainability in Arctic Norway as a learning process. In particular, external motivations connected to the economy serve as a driving force; however, internal motivations for holistic sustainability are keys to enhancing farm sustainability. The farmer alone cannot bring about the necessary changes; instead, several stakeholders must learn, with the common aim of farm sustainability. A starting point for learning is understanding stakeholders' perspectives combined with sustainability assessments to find contextualized measures enhancing farm sustainability. Using transdisciplinary methods not only helps researchers take advantage of farmers' strength for collaborations, but also facilitates double-loop learning. The timing must be flexible, and the process cannot be pre-described, as it depends on prior learning outcomes.

The relevance of these findings is that farm sustainability must be embedded as the way of farming and aligned with change toward improved sustainability in society at large. Context plays a major role in what, why, and how we can learn, as well as in who we can learn with. Therefore, farm sustainability as a learning process must be translated to fit the empirical context. Approaching the thesis' aim of understanding the process of enhancing farm sustainability in Arctic Norway through the combination of the four research rationales contributes to theory development in the field of agricultural sustainability. Furthermore, it deepens our understanding of how values and context influence farm sustainability, demonstrates the relevance of combining sustainability assessments with a learning process, and broadens our understanding of sustainability learning in agriculture. In combining 'sustainability as a theory' and 'sustainability as a practice', lies the key to farm sustainability in Arctic Norway.

Keywords: Arctic Norway, farm sustainability, sustainability learning, participatory approach

List of papers and contributions

I. Halland, H., Bertella G., and Kvalvik I. (2021a). Sustainable value: the perspective of horticultural producers in Arctic Norway. International Food and Agribusiness Management Review: 24 (1), 51–70.

II. Halland, H., Lamprinakis, L., Kvalvik, I., and Bertella, G. (2021b). Learning for sustainability in horticultural production in Arctic Norway. Frontiers in Sustainable Food Systems, 5(320). doi:10.3389/fsufs.2021.686104

III. Halland, H., Martin, P., Dalmannsdóttir, S., Sveinsson, S., Djurhuus, R., Thomsen, M., Wishart, J. and Reykdal, Ó. (2020). Transnational cooperation to develop local barley to beer value chains. Open agriculture, 5(1), 138–149. doi:10.1515/opag-2020-0014

Contributions:

	Paper I	**Paper II**	**Paper III**
Concept and idea	HH, GB, IK	HH, GB, IK, LL	HH, ÓR, SD
Study design and methods	HH, GB, IK	HH, GB, IK, LL	HH
Data gathering and interpretation	HH	HH	HH, ÓR, PM, SD, SS, RD, MT, JW
Manuscript preparation	HH, GB, IK	HH, GB, IK, LL	HH, PM, ÓR, SD

HH = Hilde Halland

GB = Giovanna Bertella

IK = Ingrid Kvalvik

LL = Lampros Lamprinakis

ÓR = Ólafur Reykdal

PM = Peter Martin

SD = Sigridur Dalmannsdóttir

SS = Sæmundur Sveinsson

RD = Rólvur Djurhuus

MT = Mette Thomsen

JW = John Wishart

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Abbreviations

ESD	Education for Sustainable Development
FAO	United Nations' Food and Agricultural Organization
IPBES	The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	The Intergovernmental Panel on Climate Change
KSL	Kvalitetssystemer i landbruket (Quality systems in Agriculture)
MRQ	Main Research Question
NIBIO	The Norwegian Institute of Bioeconomy Research
NSD	The Norwegian center for research data
R&D	Research and Development
SAFA	Sustainability Assessment of Food and Agricultural systems
SMART	Sustainability Monitoring and Assessment RouTine
SRQ	Sub-research question
UiT	The University of Tromsø - The Arctic University of Norway
UN	United Nations
UNESCO	The United Nation Educational, Scientific and Cultural Organization
WCED	World Commission on Environment and Development

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1. Introduction

Food is a necessity for life. Globally, most of the daily food intake comes from agriculture, with 27% of the 2019 global workforce being employed in this sector (FAO, 2020). Throughout the 20th century, tremendous global developments have been achieved in agricultural food production, including technical advancements, utilization of chemical fertilizers and plant protection, and breeding (Clapp, 2018; Pretty, 2018). Consequently, there occurred a shift from self-sufficient agricultural systems to the current market-oriented, specialized, and—to a large degree—globalized agricultural systems, where we are now able to produce more food globally. Due to this shift, food production is increasingly seen as part of a food system (FAO, 2018). Nevertheless, agricultural food production is still dependent on land and on natural and local conditions connected to such land areas; furthermore, agricultural products worldwide are produced mainly on typical family-run farms that serve as the main production units (Darnhofer et al., 2012; FAO, 2019a).

The abovementioned agricultural development has had negative effects globally (Darnhofer et al., 2010b; Pretty 2018). Agricultural food production is one of the largest contributors to global warming (FAO, 2019b) due, for instance, to its dependency on fossil fuels for agronomical operations, emissions from soil due to intensive land use, and the globalization of the transport of both inputs and food products. The expansion of agricultural land, the predominance of monocultures, and the negative effects of the use of chemical fertilizers and pesticides have also contributed to a severe reduction of biodiversity (IPBES, 2019). Given that the large expansion of the world's population requires the production of more food, and in consideration of the negative effects of global warming on the possibilities for future food production (IPCC, 2022), it is imperative to change the way we produce our food.

Much the same development has occurred in agriculture in Norway, and in the northernmost region of Arctic Norway, which consists of the two counties of Nordland and Troms and Finnmark (Knutsen et al., 2021). Arctic Norway is situated on the outer limit for the agricultural production of many of our common food sources. Especially for plant products for human consumption, climatic factors with a short and cool summer season and a long and harsh winter season restrict what can be produced in the region (Nøstvold et al., 2019). Nonetheless, technical and agronomical advancements have partly reduced the environmental impacts of harsh arctic conditions and allowed for increased production possibilities (Natcher et al., 2021).

However, the negative effects of agricultural production in terms of global warming and biodiversity can also be observed in Arctic Norway (Statistics Norway, 2021). Apart from this, other negative effects can be found. For instance, structural changes into fewer and larger farms have restrained the availability of useable land for plant production locally, thus exerting negative effects on local farm communities (Knutsen et al., 2021). Population growth and the expansion of infrastructure have also led to land degradation and the reduction of the already low proportion of land used for food production (Aune-Lundberg and Ulfeng, 2020). The increase in the use of plastics, for instance in fodder preservation or for plant protection, has led to waste and pollution problems (NIBIO, 2019). Furthermore, the globalization of food distribution is challenging Norwegian self-sufficiency due to difficulties of Norwegian produce to compete with global market prices (White Paper 11, 2016–2017).

Sustainable agriculture has been proposed as a solution to the negative consequences of agricultural food production that we are increasingly facing (Alrøe and Noe, 2016; Hubeau et al., 2017; FAO, 2018b; Nøstvold et al., 2019; Natcher et al., 2021). According to the Brundtland Report (WCED, 1987) and as stated in United Nations (UN) resolutions, sustainable development is defined as a development that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p.16). It balances the three core elements of economic growth, social inclusion, and environmental protection (UN, 2015). Therefore, achieving enhanced holistic sustainability at the farm level requires the simultaneous consideration of the environment, the economy, and society in all farm-related decisions and operations (Schader et al., 2016). The Brundtland report also states that, "sustainable development is not a fixed state of harmony, but rather a process of change" WCED (1987, p.17). The definition implies that it is not possible, for instance, for a farm to *be* sustainable but that it entails a continuous process *toward* enhanced sustainability.

There is an increasing focus on sustainable food production in political documents at the local, regional, national, and global levels. In Norway, the Ministry of Agriculture and Food emphasizes that agricultural food production should aim for sustainable food production (White Paper 39, 2008–2009; White Paper 11, 2016–2017). However, "although sustainability is directly or indirectly included in all main goals in food and agricultural policy, the discussion on sustainability in political documents [in Norway] is not comprehensive," thus leading to the possibility of losing sight of important synergies and trade-offs (Bardalen et al., 2020, p.11).

To contribute scientifically to this complex concept of sustainable development, a new discipline emerged at the turn of the millennium: sustainability science (US NRC, 1999; Kates et al., 2001). It aims to integrate and bridge barriers across research disciplines and between sectors, geographical scales, and styles of knowledge creation based on the notion that the "the problems of sustainability are not bounded by either disciplines or expertise" (Miller et al., 2014, p.243). Sustainability science is considered a problem-driven and solution-oriented science, the success of which depends on its "salience," or how practically relevant the research results are to the involved parties (US NRC, 1999; Kates et al., 2001; Sala et al., 2013).

In many ways, the challenges related to producing food sustainably are global, but solutions must be based on local conditions (Bardalen et al., 2020). In this thesis, I aim to contribute to the sustainability science literature by studying sustainability in the specific case of agricultural food production in Arctic Norway. Few previous studies have been undertaken on sustainability in this context. Therefore, little is known about what constitutes sustainable food production and what can be considered a sustainable farm in Arctic Norway. The main aim of this thesis is to better understand how farm sustainability can be enhanced in this context, and this is addressed through three independent empirical studies (Papers I–III).

1.1 How to enhance sustainability on farms in Arctic Norway

Despite the immense emphasis on sustainability in political documents and research worldwide, and even though much is known and understood about the challenges we are facing, it seems that we are not making enough progress toward enhanced sustainability (Tàbara and Chabay, 2013; UN, 2019; El Bilali et al., 2021). One apparent reason for this lack of progress toward sustainability is that solutions to sustainability challenges are not straightforward because the "complexity is high, uncertainty is rampant, values are in dispute and trade-offs are the norm" (Miller, 2014, p.6). Therefore, sustainability is described as a "wicked problem" (Rittel and Webber, 1973; Glass et al., 2012; Wals, 2015a). There is also a growing recognition that there exists a disconnection between what we know and what we do because "we are not studying how we can create change" (Apetrei et al., 2021, p.1).

In this thesis, I contribute to fill this research gap by investigating how to improve sustainability on farms in Arctic Norway. This is achieved by combining four well-established rationales within research on sustainability:

i. The importance of including stakeholders' perspectives on sustainability (Triste et al., 2014; Galli et al., 2015; Galli et al., 2016; Alrøe and Noe, 2016; Coteur et al., 2016).
ii. The emphasis on sustainability assessments to determine which aspects to enhance in terms of sustainability and to serve as a starting point for learning (Alrøe et al., 2016; de Olde et al., 2016; Coteur et al. 2020).
iii. Sustainability learning as a strategy to further the process towards enhanced sustainability (Tàbara and Pahl-Wostl, 2007; Hansmann, 2010; Darnhofer et al., 2010a; Restrepo et al., 2018).
iv. The benefits of using participatory approaches to solve sustainability challenges (Reed, 2008; Eksvärd, 2010; Lang et al., 2012; Hubeau et al., 2017; Hubeau et al., 2018; Restrepo et al., 2018; Restrepo et al., 2020).

1.1.1 Inclusion of stakeholders' perspectives

The first rationale I utilized is the importance of including stakeholders' perspectives on sustainability (Triste et al., 2014; Galli et al., 2015; Galli et al., 2016; Alrøe and Noe, 2016; Coteur et al., 2016; De Olde et al., 2016). In this thesis, the term "perspective" is defined as "how a person in his or her particular context understands the world" (Paper I, p.52). Including various perspectives in the study of sustainability is important because no one has the template on what sustainability is, "underlying the shallow consensus that appears to be triggered by the introduction of sustainability, there are still norms, values, and interests that are in conflict" (Wals and Jickling. 2002, p.224). Therefore, what is considered sustainable is value-based and varied, leading Herrero et al. (2019, p.754) to state that sustainability is, fundamentally, an ethical concept of "raising questions regarding the value of nature, responsibilities for future generations and social justice." In addition, the context-bound nature of sustainability entails that for actual change to occur, the meaning of the term must be translated to fit the reality at a particular place or context, as well as implemented by stakeholders within such a context (Triste et al., 2014).

"Stakeholders" are defined as "those who will bear the consequences and carry out actions for change" (Alrøe and Noe, 2016, p.2). Farmers are considered key stakeholders in agricultural food production (de Olde et al., 2018). However, studying sustainability at the farm level heightens the importance of the economic (the farm as a market actor) and social aspects (the farm as a working place and a contributor to society), as well as the fact that agricultural

production is directly dependent on the environment and on natural resources. This means that a range of stakeholders must be included, where the breadth of stakeholders can be particularly diverse concerning environmental aspects (Govindian, 2017). In addition, placing the farm within a food system (FAO, 2018a) further broadens potential stakeholders connected to farm sustainability (Roux et al., 2017), thus implying that there will be a wide diversity of stakeholder perspectives on farm sustainability.

In agricultural research, farmers' values and their contexts affect which changes they make and how they learn (Blackmore et al., 2012; Darnhofer et al., 2012; Lamine et al., 2014). Although their perspectives on sustainability may sometimes serve as bottlenecks, they can also serve as a premise for more sustainable food production (Coteur et al., 2016; de Olde et al., 2016). In this thesis, I thus unraveled Arctic Norway farmers' perspectives on sustainability, in general, and how these are linked to their own farm and production, in particular (Paper I). In addition, including qualitative approaches to reveal stakeholders' perspectives on sustainability can "help identify issues to deal with and critical gaps, thus representing a starting point for further empirical research" (Galli et al., 2015, p.13). In Paper II, I further include several stakeholders' perspectives to study farmers' sustainability learning in Arctic Norway.

1.1.2 Sustainability assessments

The second rationale that I utilized is the emphasis on sustainability assessments to determine which aspects to enhance in terms of sustainability and its role as the starting point of learning (Alrøe et al., 2016; de Olde et al., 2016; Coteur et al., 2020). Although the concept of sustainability is complex, leaving the definition of its content only to subjective perspectives may lead to the concept being diluted and less useful as a guideline for better development. In addition, this may lead to "green-washing," for instance, in marketing, wherein only the benefits of production are communicated but not its unfortunate consequences (Dahl, 2010). In the worst case, choosing the wrong indicators to measure sustainability can result in unsustainable development (Meadows, 1998; Gasparatos, 2010). A sustainability assessment is based on knowledge concerning relevant environmental, economic, and social indicators. However, what constitutes these relevant indicators, including their comparative relevance, is value-based. In addition, for a sustainability assessment to be useable and understandable to

the end user, the chosen indicators must also be relevant in the specific context in which the assessment is undertaken.

In the sustainability assessment literature, undertaking an assessment is seen as "a starting point for discussion, reflection and learning" (de Olde et al., 2016, p.398). The importance of better connecting sustainability assessments with learning processes toward more sustainable practices has been emphasized in several studies over the last decade (Binder et al., 2010; de Mey et al., 2011; Bond et al., 2012; Sala et al., 2015; Alrøe et al., 2016; de Olde et al., 2016; de Olde et al., 2018; Whitehead et al., 2020). However, in a literature review concerning sustainability assessment studies at the farm level, de Olde et al. (2018) found that only one of the 67 examined studies discussed the process by which such assessments can contribute to improved farm sustainability.

In this thesis, I lean on the work conducted by the Food and Agriculture Organization, which defined sustainability in the Sustainability Assessment of Food and Agricultural systems (SAFA; FAO, 2014). SAFA is a thoroughly developed framework for assessing sustainability in food production and is utilized globally in various studies (Bonisoli et al., 2019). It is used as a framework for revealing farmers' perspectives of sustainability in Paper I. In Paper II, we use the sustainability assessment method SMART (Sustainability Monitoring and Assessment RouTine) farm, which is based on SAFA, as a starting point for sustainability learning (Schader et al., 2016; Schader et al., 2019).

1.1.3 Sustainability learning as a strategy for enhanced farm sustainability

The third rationale from the sustainability research that I utilized in this thesis is sustainability learning as a strategy to facilitate enhanced sustainability (Tàbara and Pahl-Wostl, 2007; Hansmann, 2010; Darnhofer et al., 2010; Restrepo et al., 2018). This is in line with the concept of sustainability increasingly being understood as a learning process (Tàbara and Pahl-Wostl, 2007; Darnhofer et al., 2010a; Wals and Rodela, 2014; Brunori et al., 2016), wherein learning is defined as "the human response to tackle issues that require change" (Blackmore et al., 2012, p.162). Sustainability learning, which is based on the idea of understanding how we can learn sustainability, has emerged as a distinct research concept (Apetrei et al., 2021). It is defined by Hansmann (2010, p.2877) as "the learning of individuals and human systems, such as groups, organizations, and human societies, which aims to achieve and facilitate sustainable development."

Farmers' learning and learning for sustainability in the field of agriculture has been studied in recent years, with researchers focusing, for instance, on the sources of learning, the learning processes involved, and the outcomes of such learning processes (Darnhofer et al., 2010a; Lankester, 2013; Restrepo et al., 2018; Šumane et al., 2018). In particular, farmers' ability and motivation for learning is crucial to farm sustainability (Darnhofer et al., 2010a; de Olde et al., 2018; Triste et al., 2018). Studies have also emphasized the context-dependent nature of learning at the farm level (Jarvis, 1992; Folke et al., 2005; Blackmore et al., 2012). Farmers learn sustainability in several ways; however, learning in collaboration with others, particularly other farmers, primarily characterizes the learning process required to ensure farm sustainability (Darnhofer et al., 2010a; Ingram et al., 2018; Cooreman et al., 2018; Kouchner et al., 2019). In addition, Suškevičs et al. (2018) found that the constitution of the learning process (e.g., participants, resources, facilitation, and context) and which learning theories or methods are utilized affect learning outcomes.

In this thesis, I employ a qualitative approach with stakeholder involvement to examine the sustainability learning process in the context of agricultural food production in Arctic Norway (Paper II). This sustainability learning process is studied by using learning theories from social learning, that is, learning that occurs through social interactions that also change the participants' understanding (Folke et al., 2005; Beers et al., 2014; Glass et al., 2012). In addition to loop learning (Argyris and Schön, 1978), where single loop leads to performing routine processes in a more efficient or better way (Argyris, 1992), while double-loop learning occurs when "the learner becomes aware of the assumptions and values that he or she holds and is capable of major shifts" (Tàbara and Pahl-Wostl, 2007, p.4). In Paper II, by analyzing important parts of the learning process (who learns and where, when, what, why, and how it is learned), we characterized the learning process in the Arctic Norway agricultural context.

1.1.4 Participatory approaches

The fourth rationale that I utilized refers to the benefits of using participatory approaches to solve sustainability challenges (Reed, 2008; Eksvärd, 2010; Lang et al., 2012; Hubeau et al., 2017; Hubeau et al., 2018; Restrepo et al., 2018; Restrepo et al., 2020). Participation is defined as "a process where individuals, groups and organizations choose to take an active role in making decisions that affect them" (Reed, 2008, p.2418). Several aspects related to

participation have been found to influence the quality of sustainability learning processes in agriculture. First, it is important to consider realism in participatory processes for what is possible to attain in terms of enhanced sustainability regarding, for instance, time and resource limitations (Wesselink et al., 2011; Mascarenhas et al., 2021). Second, it is important to consider who needs to be included in sustainability initiatives and the rationales for their participation (Schmidt et al., 2020). In relation to this, the quality of the participatory processes depends on participants' motivation to participate (Restrepo et al., 2020). Interpersonal aspects, such as power structures between participants, are also important in this regard (Eksvärd, 2010). Third, it must also be considered that the learning environment, "the conditions under which participation occurs," also influences the learning process (Rodela, 2014, p.19).

Agricultural science is interdisciplinary in that it integrates knowledge from several academic disciplines (Tress et al., 2005). Research to support sustainable agriculture requires broad participation. Thus, to develop integrated knowledge between science and society (Tress et al., 2005), transdisciplinary approaches are commonly applied (Hubeau et al., 2018; Restrepo, 2020), including participation between researchers from various academic disciplines and stakeholders. In transdisciplinary processes, stakeholder involvement ensures that "the 'right problem' gets addressed 'in the right way'" (Maasen and Lieven, 2006, p.400). It should also ensure an outcome that is more accurate, holistic, and relevant to the context (Triste et al., 2014). However, given that there may be a lack of mutual understanding among researchers and stakeholders, one solution is to attain greater awareness of divergent perspectives among participants (Alrøe and Noe, 2016). Thus, transdisciplinary processes to enhance sustainability in agriculture depend on contextual factors, aside from requiring flexible processes (Hubeau et al., 2018).

In this thesis, I evaluate the participatory nature (as transnational cooperation and transdisciplinarity) of a three-year developmental project based on how project outcomes are developed (Paper III). Participatory approaches are also the basis for the research in Papers I and II, because stakeholder participation, particularly farmers' participation, is crucial in understanding how farm sustainability can be enhanced in Arctic Norway (Alrøe and Noe, 2016).

1.2 The novelty of this thesis and the research questions

The theoretical novelty of this research lies in its combination of the four research rationales (i.e., stakeholders' perspectives (Section 1.1.1), sustainability assessments (Section 1.1.2), sustainability learning (Section 1.1.3), and participatory approaches (Section 1.1.4)) to answer the question of how to enhance sustainability in Arctic Norway's farms. The advantage of this combination is that it ensures that stakeholders' distinct perspectives on sustainability are taken into account (stakeholder perspectives); that farm sustainability is not evaluated randomly, but through the lens of global standards (sustainability assessments); that a comprehensive strategy is applied for bringing farms toward enhanced sustainability (sustainability learning); and that the collaboration of relevant stakeholders in the specific context of Arctic Norway's agricultural sector is achieved (participatory approach). These four rationales are commonly discussed in agricultural research. However, what is new in this thesis is that the combination of the four rationales allows us to see farm sustainability in Arctic Norway as a learning process.

The process view is prominent in this thesis. Previous research on processes that aim to achieve enhanced sustainability has provided much knowledge that will be vital in understanding and advancing such processes in Arctic Norway. First, these processes will not happen by chance but by design, planning, and facilitation (Reed, 2008; Hubeau et al., 2018). Another aspect is that such processes are long-term and do not follow a pre-paved path; rather, they show an iterative nature as new knowledge, new perspectives, or new motivations arise (Hansmann, 2010; Havet et al., 2014; Hubeau et al., 2018; Mascarenhas et al., 2021). Such processes should also be flexible (Reed, 2008; Darnhofer et al., 2012; Hubeau et al., 2018). Moreover, because they do not succeed in isolation, an enabling social, political, and economic setting is crucial (Hansmann, 2010; Darnhofer et al., 2012; Lamine et al., 2014; Darnhofer et al., 2017; Eksvärd and Marquardt, 2018).

Thus far, no prior research has been undertaken on holistic sustainability in Arctic Norway agriculture. Thus, this thesis adds empirical novelty that may be of great interest to local stakeholders and policymakers in the region.

This thesis aims to address the following main research question (MRQ):
MRQ: *How can farm sustainability in Arctic Norway be conceptualized as a learning process?*

The following are the sub-research questions that can help answer the MRQ:

SRQ1: *How can farmers' perspectives on sustainability inform the sustainability learning process in Arctic Norway?*

SRQ2: *How can sustainability assessments contribute to farmers' sustainability learning processes in Arctic Norway?*

SRQ3: *What are the characteristics of farmers' sustainability learning in Arctic Norway?*

SRQ4: *How is a participatory approach important in sustainability learning processes in Arctic Norway?*

1.3 Positioning of the papers to answer the research questions

To answer the research questions, three independent studies were conducted (Papers I–III). All papers are empirical studies in which stakeholder participation played a central role. Two of the papers are set in the Arctic Norway agricultural context, focusing on the farm level (Papers I and II). One of the papers is set in a wider North-Atlantic cereal value chain context (Paper III) but also informing the Arctic Norway agricultural farm-level context.

Paper I, *Sustainable value: the perspective of horticultural producers in Arctic Norway*, studies Arctic Norway farmers' perspectives on sustainability through a qualitative approach applying the SAFA framework. This paper is the main contributor to answering SRQ1 regarding stakeholder values and perspectives on sustainability and connects these to contextual factors. In addition, Paper I is a pre-study for Paper II, thus adding insights as a component of a participatory learning process (SRQ3–4).

Paper II, *Learning for sustainability in horticultural production in Arctic Norway*, examines the characteristics of the sustainability learning process of farmers in Arctic Norway using a framework that distinguishes among contextual factors, knowledge, motivation, and process. Sustainability assessments were conducted at Arctic Norway farms, which were used as the starting point for further discussions on sustainability learning in farmers' interviews and

stakeholder workshops. This paper is the main contributor to addressing SRQ2 and SRQ3. In addition, as it was a participatory process with stakeholder involvement, stakeholder values and perspectives were revealed, thus helping to address SRQ1 and SRQ4.

Paper III, *Transnational cooperation to develop local barley to beer value chains*, evaluates a transdisciplinary process in a research and development (R&D) project (the Northern Cereals project) to increase local production in the barley to beer value chain. Preferably, the study should have followed a long-term sustainability learning process for farmers in Arctic Norway, but due to time and resource limitations during the PhD period, this was not possible. However, evaluating the Northern Cereals project can add similar knowledge. First, the project's focus was on self-sufficiency and local production, which is a top priority of the Norwegian governmental agenda for sustainable agriculture (White Paper 11, 2016–2017) and a main perspective of sustainability found in farmers in Arctic Norway (Paper I). Second, although the project adopted a value chain perspective, it emphasized the farm level because local cereal production was a main challenge. The main strength of the Northern Cereals project is the extensive involvement of 310 stakeholders, who collaborated closely with research partners from four countries to produce numerous outcomes. In this paper, the transdisciplinary approach is evaluated by this collaboration and outcome production. The paper especially contributes to answering SRQ4; however, to some degree, it also discusses issues concerning stakeholder's values and perspectives (SRQ1) and complexities and learning (SRQ3), in addition to adding contextual information to the thesis.

In combination, all three papers add insights that can help answer the MRQ (*How can farm sustainability in Arctic Norway be conceptualized as a learning process?*). Table 1 shows the positioning of the four papers and how they relate to answering the MRQ.

Table 1. Positioning of Papers I–III to answer the thesis' main research question (MRQ)

MRQ. How can farm sustainability in Arctic Norway be conceptualized as a learning process?				
	Paper's research question	**Related to SRQ**	**Theory**	**Methods**
I.	What are the horticultural farmers' perspectives on sustainability in Arctic Norway?	This shows farmers' values and perspectives on sustainability (SRQ1), connected to contextual factors. As a pre-study for Paper II, the article is part of a participatory learning process (SRQ3–4).	Sustainability in food production, including SAFA, Stakeholders' values and perspectives	A qualitative study: A desk study of the empirical context Eleven semi-structured interviews with farmers and managers of a processing plant Qualitative analysis
II.	What are the characteristics of sustainability learning in the context of horticultural farms in Arctic Norway?	This is the main contributor to knowledge on the sustainability learning process (SRQ3) and sustainability assessments (SRQ2). It is also a participatory process that reveals stakeholder values and perspectives, so it provides answers to SRQ1 and SRQ4 and provides contextual insights.	Learning theories; sustainability learning, social learning, loop-learning theories Learning for sustainability at the farm level	A mixed methods study: A desk study of the empirical context Five SMART-farm sustainability assessments Five review sessions with farmers, including semi-structured interviews Four workshops with stakeholder groups Qualitative analysis
III.	Can a framework of transnational and transdisciplinary cooperation promote development in local barley to beer value chains?	Exemplifies a participatory process (SRQ4). It also adds insights into stakeholder´s values and perspectives (SRQ1) and examples of complexities and learning (SRQ3), as well as giving contextual information.	Transnational and transdisciplinary cooperation in R&D.	A qualitative study: Descriptive, explanatory desk study of a completed North-Atlantic R&D project with an emphasis on stakeholder participation Qualitative and semi-quantitative analyses

1.4 Empirical background - Sustainability in Arctic Norway agriculture

Although Norwegian national agricultural policy promotes sustainable farming (White Paper 11, 2016–2017), few studies on sustainability have been undertaken in Arctic Norway. In this thesis, the focus is on sustainability at the farm level, particularly at farms engaged in horticultural production. In Arctic Norway, food is produced on a family farm, which is part of an industry, its local community, and the nation. At the same time, the farm is connected to the whole world through the purchase of inputs, food imports, climate change, etc.

Arctic Norway agriculture is the northernmost agricultural producing area in the world (Natcher et al., 2021), stretching between 65ºN to 71ºN and comprising approximately 3,000 farms (Norwegian Digitalization Agency, 2019). These are mainly dairy and meat producers because of the favorable grazing areas and natural conditions that are best suited for fodder production (Natcher et al., 2021). Only 5% of the farms are horticultural producers, producing

either potatoes, vegetables, or berries (Norwegian Digitalization Agency, 2019). However, from a sustainability perspective, especially connected to increased self-sufficiency and local production of food, increased plant production for human consumption is an aim (Prop. 120 S, 2018–2019; Grøntsektoren mot 2035, 2020).

An increased horticultural production in Arctic Norway should be based on a sustainable production. However, since few studies have investigated sustainable food production in this region, little is known about what comprises a sustainable farm in Arctic Norway and how we can ensure a more sustainable production of berries, vegetables, and potatoes in the future. Arctic Norway, as the empirical case for this thesis, is an interesting subject because farm communities are small, and sociopolitical structures are relatively transparent. Thus, making qualitative approaches to study sustainability processes at farms ideal.

Challenges connected to the environmental dimension of sustainability are mainly attributed to climatic conditions, particularly the short and cool growing season, which limits production possibilities to species and varieties that mature early and have low temperature requirements. The production of perennials is limited by the long winter season with harsh conditions. Only 0.8% of the total land area is cultivated due to topographical features, and only a fraction of this land contains suitable soil for horticultural productions (Nøstvold et al., 2019). However, conditions are good for some products, such as potatoes and root vegetables. In addition, technical and agronomic advancements have provided new opportunities in overcoming climatic challenges and the lack of suitable land (e.g., the table-top production of production-ready strawberries in tunnels).

Challenges in the economic dimension of sustainability partly reflect the environmental challenges that stem from annual fluctuations in yields and, therefore, incomes. However, the income of horticultural production was reported by the farmers as being satisfactory (Paper I). The short production season necessitates a combination of horticultural production with other income sources. Today, 75% of horticultural producers in the region also practice animal husbandry (Norwegian Digitalization Agency, 2019). Moreover, long distances and a scarce population make logistics costly. Market options are few, and a lack of infrastructure, such as wholesalers and processors, makes direct sales the most common option, limiting potential production volume (Troms Fylkeskommune, 2014).

Challenges in the social dimension of sustainability are mainly due to demographic characteristics and property structures in Arctic Norway. Arctic horticultural production is a

knowledge-intensive production (Mølmann et al., 2021). In general, farmers have good access to expertise from agricultural extension services. However, the presence of an active farming community nearby is essential in maintaining or increasing farm production due to its importance for maintaining for instance, competence, services, and network (Bayr et al., 2020). In recent decades, developments have led to fewer farms and reduced populations in rural areas (Knutsen et al., 2020; NOU, 2020). For instance, farmers now face difficulties recruiting local workers and have become dependent on foreign seasonal workers. Moreover, the historic farming traditions in a community are reflected in the property structures, with numerous small units with different landowners. This makes effective farming difficult because farmers are often highly dependent on rented land (Eldby, 2017).

Figure 1 shows the aggregated production yield of potatoes, vegetables, and berries in hectares per municipality in Arctic Norway in 2019. Differences in the sizes of hectares farmed among the municipalities are due to the challenges mentioned above, including the availability of arable land and infrastructure, local climatic conditions, the presence of an active farming community, and prevailing farming traditions (Nøstvold et al., 2019).

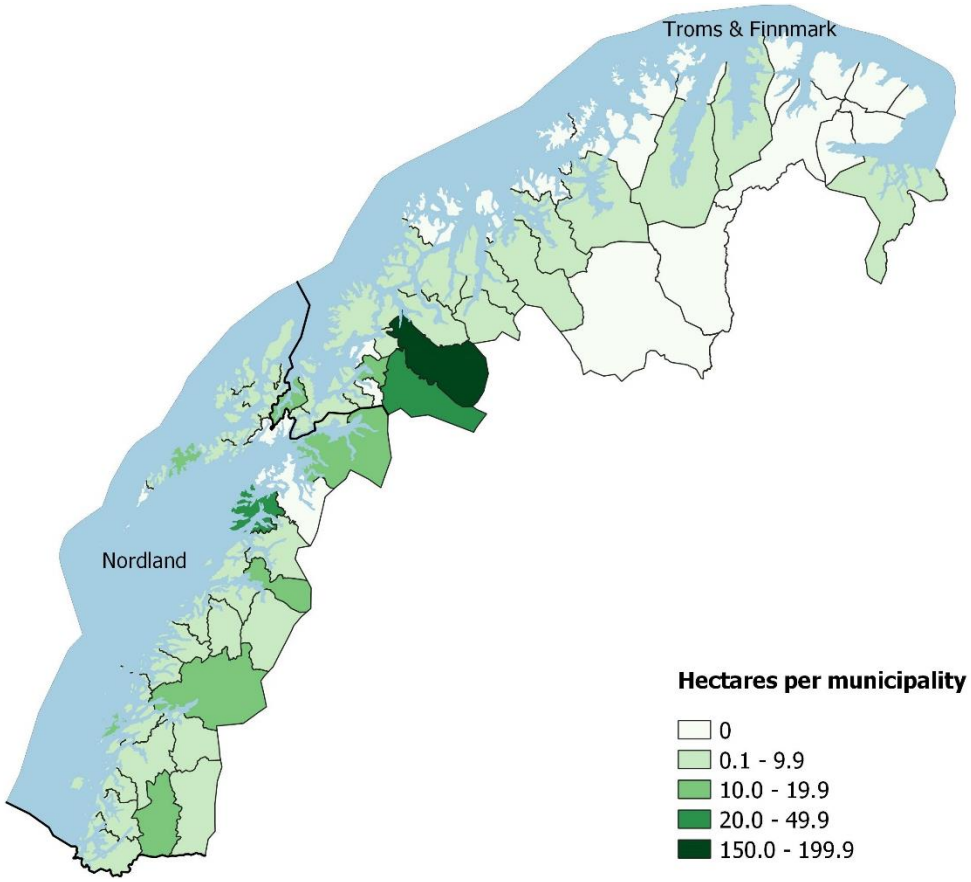

Figure 1. Production of potatoes, vegetables, and berries in Arctic Norway in 2020 (Directorate of Agriculture, 2020, PT-912).

The sustainability of a farm is not only dependent on local factors, such as climate, topography, geography, demography, etc., but is also dependent to a high degree on the sociopolitical systems in which farms operate. In Norway, the agricultural sector is strongly regulated, and documentation requirements are high. Farmers are required to conduct an annual self-audit of their farm operations through the quality system for agriculture (KSL), in addition to abiding by general laws and regulations regarding, for instance, workers' rights or accounting. Yet, although Norway's documentation requirements are high, the requirements are fragmented and do not focus on holistic sustainability (Bardalen et al., 2020).

Cooperation is a ground pillar in farming communities in Norway, as exemplified by unions, sales, and market cooperatives, and farmers being active members in their local communities. In addition, in Arctic Norway, agricultural research in the last century has worked toward improving farming in this region. In particular, in the last two decades, heightened cooperation among farmers, researchers, and extension services has resulted in several R&D projects, for instance through initiatives from the North Norwegian Agricultural Council (Nordnorsk landbruksråd).

The theoretical concept of sustainability learning is not formally known to farmers, but in practice, much of the content of this concept has already been practiced on farms and in farming communities. Although not introduced as learning processes for improved sustainability, continuous processes of improved or altered production are an integral part of farming. Furthermore, necessary changes in production due to shifts in political priorities, new market preferences, or, for instance, natural disturbances have made farmers adaptable to changes (Troms Fylkeskommune, 2014).

2. Theoretical background

The theoretical approach for answering the SRQs, which lead to the MRQ (*How can farm sustainability in Arctic Norway be conceptualized as a learning process?*) is twofold. First, looking closer at the content of the study, which is sustainability, and second, applying the strategy to advance sustainability via sustainability learning. In Section 2.1, I examine the specificities connected to the sustainability concept, showing the complexities involved both in general and in connection to agriculture. In Section 2.2, I examine specificities connected

to the sustainability learning process in research, in general, and in connection to the agricultural sector in particular.

2.1 What is sustainability?

Sustainability is said to be a consensus frame (Brunori et al., 2016). Consensus is an agreement "that satisfies everyone's primary interests and concern" (Susskind et al., 1999, p.5). Political documents on sustainability, such as the Brundtland Report (WCED, 1987) or the UN Sustainable Development Goals (UN, 2015), are developed through a consensus process. On the one hand, an advantage of consensus is that agreements can be reached by keeping what is agreed upon in general terms that all find to be true and good (Susskind et al., 1999). On the other hand, the disadvantage is that it can lead only to general principles and, to a lesser degree, to operational principles, thereby shifting "the ultimate goal away from reaching a quality decision and moves it toward reaching an agreeable one" (Reed, 2008; Coglianese, 1999, p.4).

Nevertheless, sustainability is said to be "defined in practice" (Kates et al., 2005, p.17). When trying to determine what sustainability entails for an individual or a society—or for farms in Arctic Norway as in this thesis, the reality is that this depends on a diversity of values, norms, and interests, on contextual factors; and on the topics involved that are complex and riddled with uncertainties (Wals and Jickling, 2002; Miller, 2014). Moreover, on any farm, there are numerous possible paths on which farming practices to pursue, and looking for the correct path toward sustainability could lead to failure (Darnhofer et al., 2010a; Darnhofer et al., 2010b; Hubeau et al., 2017).

To work with such complexities, we must make this process manageable without compromising the reality of the real-life challenges at hand (Roux et al., 2017). Although this thesis sees sustainability as a learning process, and not a status to achieve, we still need to know what to develop and have a vision of what we are aiming toward (Hubeau et al., 2017; Mascarenhas et al., 2021). This section, therefore, discusses specificities connected to determining what sustainability means, how the concept is viewed in research in general, and how it is viewed in connection to food production and at the farm level, in particular. The following subsections discuss the multidimensionality of sustainability (Section 2.1.1), that sustainability depends on values and on context (Section 2.1.2), and how to assess sustainability (Section 2.1.3).

2.1.1 A multidimensional concept

Sustainability is a multidimensional concept (Neven, 2014). It is multidimensional as in balancing factors from the three sustainability dimensions social, economic, and environmental (Binder et al., 2010; UN, 2015), as in spatial scale from local to global or from different sectors (sociopolitical) (Brunori and Galli, 2016; Darnhofer et al., 2010b; Darnhofer et al., 2012), and as in timescale (WCED, 1987; Darnhofer et al., 2010b; Bond and Morrison-Saunders, 2011).

Working for enhanced holistic sustainability, one must consider the interactions among different dimensions, and consider aspects within each dimension (Darnhofer et al., 2010b; Darnhofer et al., 2012). It is important to include all three sustainability dimensions in sustainability studies, because it is in the trade-off and synergy discussions that the best holistically sustainable solutions can be found (Schader et al., 2016; Hubeau et al., 2017; FAO, 2018a). In research, several such tradeoffs and synergies are recognized, such as trade-offs between the environmental and the economic dimensions, as well as synergies between the governance dimension and the environmental, economic, and social dimensions (Schader et al., 2016). Studies focusing only on environmental sustainability, for instance, can yield unintended results, such as unwanted effects on the economic aspects of running a farm towards enhanced sustainability (Binder et al., 2010; Hubeau et al., 2017).

For the spatial scale (i.e., from local to global) of sustainable food production, the farm level and the local community can be seen as the main drivers of sustainable development (Darnhofer et al., 2010b; Schader et al., 2016). Over the years, food production has been increasingly recognized as part of a food system (FAO, 2018). As the food systems of the world are becoming increasingly globalized, it is crucial to know and recognize the impact factors on regional and global scale has on farm sustainability (Fridman and Kissinger, 2019). In addition, farm sustainability cannot be studied isolated from its surroundings, so adding to the dimensionality are factors stemming from the local to the global societal as well as issues on political influence on sustainable food production (Darnhofer et al., 2012).

For the time scale of sustainable food production, working for sustainability means considering the long-term effects of current actions (Galli et al., 2016). Agricultural production depends on natural conditions and processes, which, because of their nature, are long-term, for instance soil formation. A farm, as a means of livelihood, has a short-term need to produce annual yields and incomes. Striking a balance between humans' short-term needs

and nature's long-term needs is crucial, and such a task is made more difficult by uncertainties and the lack of knowledge regarding long-term effects (Galli et al., 2016). In the time scale dimension, many researchers have stressed the importance of the past (i.e., the historical context) to understand paths taken toward enhanced sustainability (Bond and Morrison-Saunders, 2011; Wiek et al., 2011; Hubeau et al., 2018). Furthermore, for sustainability assessments, one study asserts that "there is no consensus on what appropriate time scales should be", and that at best they are intra-generational, and most often constrained by the lifetime of the assessment plan (Bond and Morrison-Saunders, 2011, p.5).

2.1.2 Values and context dependence

Another aspect of the multidimensionality of the sustainability concept is that what sustainability ultimately means depends on the stakeholders' differing values and the context in which a study is performed. Values can be seen as "expressions of, or beliefs in, the worth of objects, qualities, or behaviors," often invoking feelings (Kates et al., 2005, p.16). Galli et al. (2016, p.15) noted that "legitimate but differing perspectives tend to shape the debate on sustainability (…) and [that] the higher the uncertainty the stronger the dispute in terms of value judgments." This is not the least present in the environmental dimension, where there is a huge gap, for instance, between persons who value nature for its intrinsic value and those who value nature for its utility for humans (Kates et al., 2005). To a large degree, values also determine how motivated a stakeholder (e.g., a farmer) is to enhance sustainability (Hansmann, 2010). In this regard, context influences values: "Cultural surroundings, social norms, laws, and education and learning can influence human values, and orientate motivational forces towards positive developmental ends" (Hansmann, 2010, p.2885).

What is considered sustainable food production also depends on the context, i.e., on "all the factors and features that are relevant to a situation" (Dillon, 2006, p.266). In relation to farm sustainability, the interplay among social, economic, and environmental factors will affect one another differently depending on the context (Gibson, 2006). The factors discussed in Section 2.1.1 related to the time and spatial scale vary significantly with context (Darnhofer et al., 2010). Therefore, what these differing factors (e.g., climatic, topography, demography, policy, and market) mean for a farm's sustainability, must be understood locally. Indeed, context is vital to understanding the case (Arctic Norway agricultural farms in this thesis),

because “context guides which issues are found important as well as influences perceived possibilities to act on them” (Hugé et al., 2013, p.196).

In this thesis, I study farmers’ perspectives on sustainability. The day-to-day management of a farm is shaped by farmers’ perspectives (Darnhofer et al., 2010b). Therefore, understanding these is crucial when aiming for enhanced farm sustainability. Darnhofer et al. (2012, p.11) described an example wherein a “scientist might assume that the goal is to maximize production or income, whereas the farmer might strive for satisfactory production level, limited workload, and financial autonomy.” Such differing perspectives, if not uncovered, are bound to yield dissatisfactory results for both researchers and farmers. Furthermore, farmers might hold conflicting perspectives because they play several roles on a farm: a farm manager who wants to optimize production, a worker who wants to have good working conditions, and a community member who wants to comply with community norms (Darnhofer et al., 2012).

However, “the farm reflects the farmer’s goals and preferences only to some extent” (Darnhofer et al., 2010b, p.194). Thus, to understand how to enhance sustainability at the farm level, all social, cultural, historical, and political aspects must be considered to capture the complete real-life situation on the farm (Darnhofer et al., 2010; Darnhofer et al., 2012). For one thing, farmers’ choice of actions often depends on the values and perspectives shared with other members of their social communities (Darnhofer et al., 2012). Given that farm sustainability depends on the perspectives of several stakeholders, it can be challenging to combine multiple perspectives in a single sustainability learning process (Wesselink et al., 2011; Hubeau et al., 2017, Mascarenhas et al., 2021). Therefore, aligning and co-evolving farmers’ perspectives and those found in the sociopolitical context is crucial in enabling sustainability changes (Darnhofer et al., 2010b).

2.1.3 Assessing sustainability

Even though, or rather because of these complexities discussed in Sections 2.1.1 and 2.1.2, it is important to define sustainability in a study or in an assessment (Bond et al., 2013; Coteur et al., 2016). Clearly establishing the meaning of sustainability will ease communication, avoid confusion, and provide improved sustainability outcomes (Gaspartos, 2010; Bond et al., 2013). Moreover, arbitrarily choosing indicators for sustainability could lead to the concept being useless as a guiding principle (Meadows, 1998).

In this thesis, sustainability is viewed through the lens of the SAFA framework (FAO, 2014). SAFA is a holistic and global framework that is frequently utilized in research to assess sustainability along food and agricultural value chains (Bonisoli et al., 2019). SAFA is established so that all enterprises involved in food production can "have a clear understanding of the constituent components of sustainability and how strength, weakness and progress could be assessed (FAO 2014, p.3). The benefits of using sustainability assessments as a starting point for learning have been emphasized in the literature (de Olde et al., 2016). In particular, SAFA assesses trade-offs and synergies among four dimensions of sustainability (i.e., Good Governance, Environmental Integrity, Economic Resilience, and Social Well-Being) by examining 21 themes and 58 subthemes (Table 2).

The values and context-dependent nature of sustainability (Section 2.1.2) also poses a challenge to the conduct of sustainability assessments (e.g., SAFA) that utilize expressions, such as equity, well-being, freedom, diligence, integrity, and so on (Table 2). These are expressions of values, of which there are numerous meanings. The inclusion of a broad range of stakeholders is vital in developing assessments that, in turn, would make it possible to assess farm sustainability and direct a farm in a more sustainable direction (Gasparatos et al., 2008; FAO, 2014). Furthermore, the choice of indicators and how they are weighed depend on local conditions (Alrøe et al., 2016). Therefore, the contextualization of a farm's assessment result is necessary to make it fit the specific farm and its farmer's values (Schmitt et al., 2016).

Table 2. SAFA dimensions, themes, and subthemes.

Dimension	Theme	Subtheme
Good Governance	Corporate Ethics	Mission Statement
		Due Diligence
	Accountability	Holistic Audits
		Responsibility
		Transparency
	Participation	Stakeholder Dialogue
		Grievance Procedures
		Conflict Resolution
	Rule of Law	Legitimacy
		Remedy, Restoration & Prevention
		Civic Responsibility
		Resource Appropriation
	Holistic Management	Sustainability Management Plan
		Full-Cost Accounting

Environmental Integrity	Atmosphere	Greenhouse Gases
		Air Quality
	Water	Water Withdrawal
		Water Quality
	Land	Soil Quality
		Land Degradation
	Biodiversity	Ecosystem Diversity
		Species Diversity
		Genetic Diversity
	Materials and Energy	Material Use
		Energy Use
		Waste Reduction & Disposal
	Animal Welfare	Animal Health
		Freedom from Stress
Economic Resilience	Investment	Internal Investment
		Community Investment
		Long-Ranging Investment
		Profitability
	Vulnerability	Stability of Production
		Stability of Supply
		Stability of Market
		Liquidity
		Risk Management
	Product Quality & Information	Food Safety
		Food Quality
		Product Information
	Local Economy	Value Creation
		Local Procurement
Social Well-Being	Decent Livelihood	Quality of Life
		Capacity Development
		Fair Access to Means of Production
	Fair Trading Practices	Responsible Buyers
		Rights of Suppliers
	Labor Rights	Employment Relations
		Forced Labor
		Child Labor
		Freedom of Association and Right to Bargaining
	Equity	Non-Discrimination
		Gender Equality
		Support to Vulnerable People
	Human Safety & Health	Workplace Safety and Health Provisions
		Public Health
	Cultural Diversity	Indigenous Knowledge
		Food Sovereignty

2.2 A sustainability learning process

In this thesis sustainability learning is seen as the strategy for going from the current sustainability level towards an enhanced sustainability level of farms in Arctic Norway. This entails stakeholders' participation and long-term commitment, wherein farm sustainability is the topic and enhanced sustainability is the specific aim. In this section, I first conduct a literature review to determine how the concept of sustainability learning is utilized in research (Section 2.2.1). Then, I review how such processes for agricultural sustainability are studied in the literature, including how stakeholder participation is viewed in various sustainability processes (Section 2.2.2).

2.2.1 A literature review on the concept of sustainability learning

This thesis sees sustainability as a learning process and utilizes the concept of "sustainability learning" (Tàbara and Pahl-Wostl, 2007; Hansmann, 2010; Brunori et al., 2016). I performed a literature review to investigate how this concept is utilized in existing studies. Figures 2 and 3 present the search results from the Scopus database (performed on August 31st 2021). A total of 13,668 results were obtained using the search words "sustainability" AND "learning" with the criteria TITLE-ABS-KEY. Figure 2 shows an increasing trend in the usage of these terms. In addition, 206 results were obtained by using the search term "sustainability learning" with the criteria TITLE-ABS-KEY. Figure 3 shows the rising number of studies published on the topic.

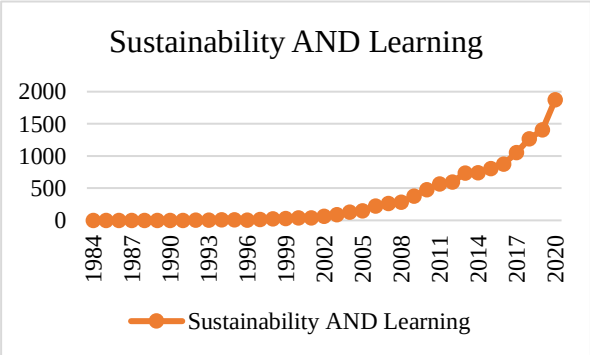

Figure 2. Search results using "Sustainability" AND "Learning" as search words. Source: Scopus, Accessed August 31st 2021.

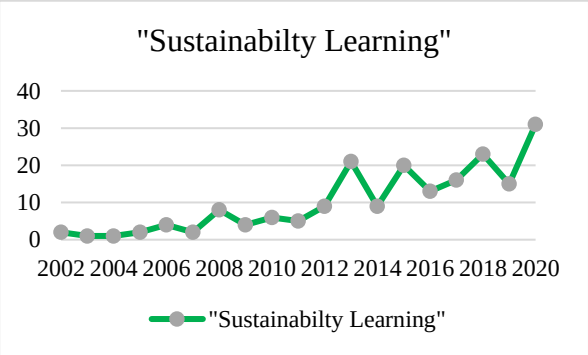

Figure 3. Search results using "Sustainability learning" as search words. Source: Scopus, Accessed August 31st 2021.

As can be seen, many studies have focused on "sustainability" AND "learning," and this seems to have gained momentum over the last decade. However, the concept "sustainability learning" has only been investigated in less than 2% of the documents using the concepts "sustainability" AND "learning." In a recent review of concepts used in sustainability science literature, Apetrei et al. (2021, p.13) found that "not many papers employ the concept of sustainability learning, but those that do are quite homogenous in their understanding of it." Given that Apetrei et al. (2021) dedicated only a small section of their review to sustainability learning, I wanted to conduct a more in-depth literature review to investigate the following questions: *How is the concept defined? What are the theoretical origins of the concept and in which study fields is it utilized?* and *What are the main aspects of the concept discussed?* The methods utilized and the discussions of the findings in the studies I reviewed are presented below. They are discussed here with the aim of increasing our understanding of the concept of "sustainability learning."

2.2.1.1 Methods

This literature review is based on a systematic review approach (Saunders et al., 2019; Randolph, 2009). Table 3 shows the categorization of this literature review, which I adopted from Cooper's taxonomy of literature reviews (Cooper, 1988). The research questions correspond to a conceptual analysis, which, according to Jickling (2014, p.62), is about "clarifying [the] meanings of those key concepts that are central to our collective work."

Table 3. Cooper's taxonomy of literature reviews (Cooper, 1988)

Characteristics	**Categories utilized in the literature review**
Focus	Theories and constituents of the concept
Goal	Identification of central issues
Perspective	Both qualitative and quantitative traditions; Attaining a neutral position
Coverage	Exhaustive review with selective citations
Organization	Conceptual
Audience	Primary: scientific community

A systematic data collection revealed relevant publications that address the research questions (Randolph, 2009). First, I conducted a systematic search in the Scopus (206 hits) and Web of Science (128 hits) databases using the term "sustainability learning" as the search term. Second, I delimited this literature by excluding duplicates and including only scientific

publications that used the term “sustainability learning,” both in the theoretical background and in the discussion sections. These publications were downloaded and imported into NVivo for further coding (134 publications). I added four more publications, which I obtained through cross-referencing (from the downloaded papers) and by searching for additional literature. I then proceeded with an initial coding in NVivo to account for the definition, theoretical origin, and aspects discussed concerning sustainability learning. Publications that contained elements of all three factors (definition, origin, and aspects) were included in the further analysis. In the end, 43 scientific publications were included. A list of the selected publications can be found in Appendix 1.

Thematic analysis involving the coding of selected publications to distinguish themes or patterns related to the research question (Saunders et al., 2019) was conducted using NVivo 12 and matrix analysis. The initial coding was performed in the data collection procedure described in the previous paragraph. The subsequent analysis focused on addressing the research questions by finding patterns (similarities and common features) as well as divergences in definition, theoretical origin, and aspects discussed concerning sustainability learning. Trajectories in the development of the theoretical origins were also examined. Although the analysis was mainly qualitative, it was also semi-quantitative, as I utilized the NVivo application text search and word frequency functions to assess, for instance, the use of concepts, learning theories, or references.

2.2.1.2 Findings

The majority of the papers on sustainability learning are connected to topics related to higher education and sustainability (23 papers). Five papers are conceptual, and the rest are connected to sustainability learning through/in community-based research (4), theater (3), businesses related (2), government institutions (2), forestry (1), digital games (1), development projects (1), and sports (1). Table 4 lists eight journals that have published two or more of these publications. The remaining publications were published in 16 other journals.

Table 4. Publication channels and number of publications per journal

Journal	**No.**
International Journal of Sustainability in Higher Education	9
Environmental Education Research	4
Current Opinion in Environmental Sustainability	3
Sustainability	3
Ecology and Society	2
Journal of Cleaner Production	2
Journal of Transformative Education	2
World Sustainability Series	2

How is sustainability learning defined?

The first finding from the analysis is that very few of the publications *explicitly* define sustainability learning. However, the definitions used in four of the earliest works in this review, namely, Scholz et al. (2006), Tàbara and Pahl-Wostl (2007), Sipos et al. (2008), and Hansmann (2010), outlined how sustainability learning is understood and which aspects are discussed in the publications to follow (Table 5).

Table 5. How sustainability learning is defined/understood

Publication	**Definition of sustainability learning**
Scholz et al. (2006)	A transdisciplinary approach aiming for sustainable development in a mutual learning process between policies and various stakeholders
Tàbara and Pahl-Wostl (2007)	A social learning process with the aim of improving long-term sustainability
Sipos et al. (2008)	Referred to the concept as "learning that facilitates personal experience for participants resulting in profound changes in knowledge, skills and attitudes related to enhancing ecological, social and economic justice" (p.74)
Hansmann (2010)	Referred to the concept as "learning of individuals and human systems such as groups, organizations, and human societies, which aims to achieve and facilitate sustainable development" (p.2877)

What are the theoretical origins of sustainability learning?

Sustainability learning is constructed from two words: *sustainability* and *learning*. Therefore, I concentrated on the publications' theoretical origin of the concept of sustainability (Table 6) and on the learning theories utilized in these publications (Table 7).

Among the studies, sustainability is the main topic for learning. Due to the complex and paradoxical nature of this concept (Alrøe and Noe, 2016), it is important to place one's research within a theoretical orientation of sustainability. This orientation frame refers to *sustainability* in the sustainability learning literature, and Table 6 shows the most common

origins and their implications for the studies. Direct references to the UN and UNESCO are found in 25 of the 43 papers.

Table 6. Theoretical origins of the concept of "sustainability"

Theoretical origin	**Implications**
United Nations (UN) documents: For example, WCED (1987) and UN (2015)	Places research in a global frame wherein sustainability is viewed as consisting of three dimensions (environment, economic, and social) and where a timeframe is inherent in the definition; also refers to studies aiming for advancements that can help achieve the UN's 17 Sustainable Development Goals
UNESCO documents concerning Education for Sustainable Development (ESD): For example, UNESCO (2006), (2010), and (2017)	Places research in connection with the UN's Education for sustainable development, which is recognized as a key enabler for the UN's 17 Sustainable Development Goals
Research connected to ESD: For example, Tilbury (2011), Sterling (2001), and Wals and Corcoran (2012)	Places research into the sustainability education or education for sustainable development literature
Sustainability science: For example, Kates et al. (2001), Miller et al. (2014), and Wiek et al. (2011)	Places research into a wider sustainability science literature
Elkington's (1999) notion of the "triple bottom line"	Connecting sustainability to business-related research

Overall, 31 of the 43 papers refer to specific learning theories. Transformative learning, that is, learning that "enables the individual to come to a deeper understanding and critically reflect on their frames of reference" (Harmin et al., 2017, p.1490), is the learning theory most frequently referred to in the sustainability learning literature. Other learning theories dealing with change are evident, especially referring to loop learning theory (Argyris and Schön, 1978) and social learning (Folke et al., 2005; Tábara and Pahl-Wostl, 2007). Table 7 shows the learning theories associated with the sustainability learning literature and their implications for the studies. Combining different learning theories (and pedagogies) is also commonly found in the literature.

Table 7. Learning theories utilized in the sustainability learning literature

Learning theories	**Implications**
Transformative learning: For example, Sipos et al. (2008), Sterling (2010, 2011), and Mezirow (1978)	Studies understanding learning as transformative, thus changing deep levels of values and beliefs (Sterling, 2003); often in combination with other learning theories (e.g., experiential-, action-, or participatory learning pedagogies)
Social learning: For example, Tábara, and Pahl-Wostl (2007), Folke et al. (2005), and Milbrath (1989)	Studies understand learning as occurring through social interactions (Folke et al., 2005); often in combination with other theories, such as loop-learning theories
Loop-learning theories: For example, Argyris and Schön (1978) or Tabara, and Pahl-Wostl (2007)	Studies understanding learning as change either in efficiency (single-loop) or as changing norms and values (double-loop), (Argyris, 1992); often in combination with other theories, such as social learning theories
Others: action learning, experiential learning, problem-based learning, and participatory learning For example, Wiek et al. (2014), Kolb (1984), and Sipos et al. (2008)	Studies wherein notions of action and participation are evident in the learning processes; often combined with transformative learning theories

What are the main aspects of sustainability learning that have been discussed in the literature?

Tàbara and Pahl-Wostl (2007, p.6) argued that "a main difficulty in the delimitation of the concept of sustainability learning lies in providing a specific content about what is to be learned." This being an initial challenge entering into sustainability learning, the analysis focused on the main aspects of sustainability learning discussed in the literature. In Table 8, these aspects are grouped into four main characteristics, in which sustainability learning is set in frameworks of change and transformation, entails changing values and perceptions, focuses on outcomes, and involves a participatory process.

Sustainability learning is set in transitional frameworks, and in 18 of the 43 papers reviewed, there is a notion of sustainability learning as a process that attains a radical or paradigmatic change. Explained by the fact that the severity of many of today's social and ecological challenges, which are included in the sustainability concept, require us to follow a new and sustainable path. This long-term process commonly involves systemic approaches (explicitly expressed in 24 papers). In 32 of the papers, it is understood that sustainability learning entails changing values and perceptions. The framework by Sipos et al. (2008) on transformative sustainability learning has influenced much of the literature, in addition to the double-loop learning theory (Argyris and Schön, 1978) and social learning theories (Folke et al., 2005; Tábara and Pahl-Wostl, 2007). The focus on sustainability outcomes or actions from sustainability learning is prominent in 18 of the papers, where such actions and

outcomes lead to changes in a more sustainable direction. Most of the papers also refer to "sustainability learning" as a participatory process, and 16 of the papers describe this as a transdisciplinary process.

Table 8. Characteristics of sustainability learning and the aspects discussed in the literature

Sustainability learning is set in frameworks of change and transformation
The transition entails a radical or a paradigmatic shift (Tàbara and Pahl-Wostl, 2007, Sipos et al., 2008; Bull, 2013; Noy et al., 2021).
Systemic or holistic approaches are prominent (Scholz et al., 2006; Tàbara and Pahl-Wostl, 2007; Burns, 2015; Sandri et al., 2018).
It entails a long-term collective commitment (Heras and Tàbara, 2016; Pereira et al. 2020).
It occurs within ongoing social discourses on sustainability (Tàbara and Pahl-Wostl, 2007; Hansmann, 2010).
Sustainability learning entails changing values and perceptions
The "head," "hands," and "heart" principles (Sipos et al., 2008) entails the integration of cognitive processes (head), psycho-motoric processes (hands), and affective domain (heart), aiming for a theoretical understanding, tangible experiences, and opportunities to reflect upon them (Burns, 2015; Orr et al., 2020).
It is exemplified by double-loop learning (Argyris and Schön, 1978), "in which the learner becomes aware of the assumptions and values that he or she holds and is capable of major shifts" (Tàbara and Pahl-Wostl, 2007, p.4).
It recognizes the role of social learning in creating new ways of thinking and radical change in values (Tàbara and Pahl-Wostl, 2007).
Sustainability learning focuses on outcomes
There are close connections and reciprocity between the sustainability learning process and an outcome. Learning results in sustainable actions (Ofei-Manu and Didham, 2018) that can lead to change (Heras and Tàbara, 2016).
An essence of the outcomes is that they are "specifically directed towards the goal of creating a sustainable future" (Greig and Priddle, 2019, p.4).
Sustainability learning is a participatory, specifically transdisciplinary process
There is a need to establish inclusive, participatory platforms to bring together multiple perspectives (Heras and Tàbara, 2016).
There is a reliance on participatory processes between academic disciplines and society (Edwards et al. 2020).
There should be an integration of socially relevant knowledge from both science and society (Scholz et al., 2006).
There is a need to combine a variety of "ways of learning, knowing, and valuing reality," especially because dealing with several uncertainties about the future (Heras et al., 2016, p.2).

2.2.1.3 Discussion and conclusions

The findings of this review demonstrate how sustainability learning is conceptualized in existing research by revealing the definitions and theoretical origins of the concept, as well as highlighting relevant aspects discussed in the literature. A question remains as to whether sustainability learning can be seen as a consolidated concept in research today. As the concept

is used in only a fraction of the total literature discussing sustainability and learning, where many of the same origins can be found and aspects discussed, it remains unclear how distinct this concept is. For instance, in a literature review focusing on transformative learning, Aboytes and Barth (2020) found that transformative learning theory is widely used throughout the field of sustainability.

However, based on my own analysis, there are three main research strains that can be detected. First, the literature that situates sustainability learning within the field of sustainability science and connects it with social learning and loop learning (Tàbara and Pahl-Wostl, 2007); second, the literature that views the concept of sustainability learning as transformative sustainability learning (Sipos et al., 2008), which is often connected with the Education for Sustainable Development (ESD); and third, the literature that mainly connects sustainability learning with higher education, specifically sustainability science (citing, for instance, Scholz et al., 2006; Brundiers et al., 2010; Wiek et al., 2011) or sustainable education (citing for instance Wals and Jickling, 2002; Tilbury, 2011; Wals and Corcoran, 2012). In addition, a small stream of literature has utilized business-related theoretical framings of the concept, such as organizational learning and the "triple bottom line" (Elkington, 1999). However, the divisions are not strict because many of the publications utilize elements of both social and transformative learning, and studies from the ESD field are used throughout the publications. This thesis adheres to the first and third strains of research on sustainability learning, in which research is situated within sustainability science, wherein the participation of both stakeholders and different academic disciplines is prominent. Furthermore, learning theories from social learning and loop learning are utilized, and various studies from ESD research are cited.

The notion of change and transformation is present in all of the sustainability learning literature that I reviewed. This is not surprising, given that Argyris and Schön (1978) juxtaposed learning with change, and since the fundamental objective of ESD is perspective change (Bull, 2013). However, at the farm level in Arctic Norway, it is meaningful to question how radical a change for enhanced sustainability can be, or if only gradual changes are obtainable due to constraints arising from political, societal, economic, or environmental factors.

In general, the majority of the publications utilizing the concept of sustainability learning are connected to higher education. However, in line with Hansmann's (2010, p.2876) description that "sustainability learning represents a much broader concept than sustainability education

or education for sustainable development," the theoretical contribution of the concept and its potential as a driver for sustainable development could be strengthened by conducting more studies in other research fields.

Through my own research on sustainability learning in an Arctic Norway farming context, and by drawing on the definitions (Table 5) and aspects (Table 8) discussed, I find that process, change, and outcomes are the core elements of this process. In this particular context, such a process is long-term, both due to natural climatic conditions and because it is closely connected to sociopolitical conditions on the local, regional, and global scale (i.e., it is multileveled). Furthermore, due to the complexity of the sustainability concept explored in this thesis, in which I used stakeholders' perspectives and SAFA, this process is found to be transdisciplinary. The two elements, change and outcomes, entail going from present-day farm sustainability in Arctic Norway toward a future of enhanced sustainability. Therefore, in concluding this literature review, I draw upon the definitions from Scholz et al. (2006), Tàbara and Pahl-Wostl (2007), and Hansmann (2010) and define sustainability learning in my research as "a long-term and multi-level transdisciplinary learning process aiming for enhanced sustainability."

2.2.2 Learning processes for enhanced sustainability in agriculture

Although the specific concept of sustainability learning is not utilized in studies focused on enhancing sustainability in agriculture (Section 2.2.1.2), learning is also commonly considered the enabler of sustainability initiatives in this field. Although initiatives and projects aiming to improve sustainability in agriculture vary in nature, they share a common characteristic: they are all based on participatory approaches (Eksvärd, 2010; Hubeau et al., 2017; Restrepo et al., 2018). Several aspects must be considered to attain successful sustainability learning processes in agriculture. In Section 2.2.2.1, I discuss practical and interpersonal aspects to consider in stakeholder participation, including taking realism into account, considering rationales for stakeholder involvement, and understanding the importance of the learning environment. In Section 2.2.2.2, I discuss aspects connected to learning for sustainability in agriculture, while in Section 2.2.2.3, I discuss the procedural aspects of sustainability learning processes in this sector. Finally, in Section 2.2.2.4, I present a framework for assessing sustainability learning processes.

2.2.2.1 Stakeholder participation - Practical and interpersonal aspects to consider

In the empirical research on farmers' sustainability learning, studies excluding stakeholder participation seem impossible. This is because learning processes necessitate learners, and advancing the goal of sustainability requires the inclusion of various academic professionals and other stakeholders who can affect or are affected by such possesses. There are several claimed benefits from stakeholder participation in sustainability initiatives, such as attaining enhanced quality decisions and finding solutions that are better adapted to the context at hand (Reed, 2008). However, whether these claims are met depends on the nature of the participatory process (Reed, 2008).

The first reflection considers the role of realism in relation to participatory processes (Wesselink et al., 2011). Constraints due to time and resource limitations are commonly expressed in sustainability learning processes (Hubeau et al., 2017; Hubeau et al., 2018; Mascarenhas et al., 2021). Concerning this thesis, a learning process toward sustainability at the farm level will take time. Building knowledge and awareness, considering inputs from several disciplines, and building trust among participants take time and effort, which are limited resources in farmers' practice. In addition, given that the Norwegian agricultural sector is highly regulated, how much actual change toward enhanced sustainability can, for example, farmers' sustainability learning amount to, without changes being made on the governance level? According to Reed (2008), early in a project, it is important to plan for participation, select relevant stakeholders, have clear objectives and skilled facilitators, and integrate local and scientific knowledge. To ensure the realistic expectations of a participatory learning process, reflexivity on the process and possible outcomes is proposed (Wesselink et al., 2011).

There are several rationales as to why stakeholders should be included in sustainability initiatives. In a review of transdisciplinary studies, Schmidt et al. (2020) distinguished four objectives of stakeholder involvement: normative, substantive, social learning, and implementation objectives. For processes toward enhanced sustainability, this would mean that the normative objective relates to the democratic principle that people should have a saying in processes that affect them. The substantive objective relates to the goal in sustainability science of being context-specific and relevant to the involved parties. The social learning objective relates to the view that sustainability is a learning process wherein changes in understanding occur through social interactions. Finally, the implementation objective relates to the act of enhancing sustainability to ensure the impact of the process.

In practice, however, the objectives of participation from the perspectives of researchers and stakeholders may vary (Wesselink et al., 2011). Stakeholders, such as farmers, will invest their time and resources in processes that support their goals, while researchers might have more theoretical objectives for stakeholder participation (Schmidt et al., 2020). The objectives might also change and develop during the sustainability learning process. Two factors regarding the objectives of stakeholders' participation is emphasized in research: first, to make the "rationale(s) explicit when developing methods and tools for participation so they are fit for purpose" (Wesselink et al., 2011, p.2699), and second that, "jointly negotiating, clarifying, communicating, and reflecting the underlying objectives" held by various stakeholders to make the expectations clear to everyone involved, and thus result in a better process (Schmidt et al., 2020 p.1).

The learning environment in each learning process may vary, along with the contextual factors that can influence such a process (Reed, 2008; Hubeau et al., 2018). These factors include interpersonal aspects, such as the power relations between participants and the composition and size of the group (Reed, 2008; Rodela, 2014; Hubeau et al., 2018, Mascarenhas et al., 2021). Eksvärd (2010) also emphasized the important role of a facilitator, while Restrepo et al. (2020) concluded that farmers' enthusiasm for participation is enhanced when they are given more power during the research process. A similar finding is presented by Eksvärd (2010), who explained that all participants were equally responsible for the group's dynamic and inquiry process, which means that progress was the responsibility of both the participants and the facilitator. In general, trust, respect, and positive communication among the participants are imperative for a good learning environment (Alexopoulos et al., 2021; Cooreman et al., 2018). This, however, is not opposed to having disagreements and varying viewpoints between the participants, as this can lead to deeper learning (Rodela, 2014; Cooreman et al., 2018; Mascarenhas et al., 2021). Furthermore, Eksvärd (2010) found that diversity among group members can be considered a group's strength.

2.2.2.2 Learning for sustainability in agriculture

Aspects connected to the concept of sustainability learning are thoroughly covered in Section 2.2.1. However, that section did not include specific aspects connected to farmers' learning for sustainability and learning as a strategy to enhance sustainability in the agricultural sector.

Therefore, this subsection covers these aspects, including motivations for learning, sources for learning, learning processes, and outcomes of sustainability learning processes in agriculture.

The quality of the learning process depends on stakeholders' motivations to participate, and for farm sustainability, farmers' motivation for learning is a crucial component (Darnhofer et al., 2010a; Restrepo et al., 2020). Farmers are the ones who thoroughly know the challenges and will implement the changes; ultimately, their motivation will be a decisive factor in how sustainable their farms can be (de Olde et al., 2016). Farmers' diverse motivations to engage in learning for sustainability stem from both internal (e.g., own curiosity and interest) and external (e.g., learning process as a means to an end) factors (Ryan and Deci, 2000; Hansmann, 2010; Triste et al., 2018), of which internal motivation is particularly important (Hansmann, 2010).

Farmers learn through various sources, such as their own experiences, peer learning, and external sources or institutions (Darnhofer et al., 2010a; Lankester, 2013; Cooreman et al., 2018; Restrepo et al., 2018; Šumane et al., 2018; Kouchner et al., 2019). Among these, the main sources are their fellow farmers, considering successful colleagues as experts (Cooreman et al., 2018; Kouchner et al., 2019; Šumane et al., 2018). Farmers also refer to external sources, such as agricultural extension services and agricultural research institutions, particularly if they use more advanced technologies on their farms (Šumane et al., 2018; Kouchner et al., 2019). In general, mixing sources of both formal (theory-oriented) and informal (practice-oriented) knowledge is beneficial for learning (Darnhofer et al., 2010). Furthermore, most of the knowledge accumulated on a farm is context-dependent, in which farmers learn while engaged in farming practices (Folke et al., 2005). Such knowledge is especially important in relation to sustainability, as it addresses the farm more holistically and is embedded within its context (Šumane et al., 2018).

Farmers' learning process can be seen as a combination of collaborative (learning in cooperation with others), experiential (building experience between theory and practice), and experimental (through practical experiments) learning (Thompson and Scoones, 1994; Darnhofer et al., 2010a; Lankester, 2013; Restrepo et al., 2018). Several methods have been utilized in sustainability learning processes, such as active learning, learning from practice, farmer-to-farmer learning, and facilitated dialogue (Restrepo et al., 2018; Cooreman et al., 2018; Cooreman et al., 2021). What they have in common is that they are all collaborative methods, and collaborative learning is found to be the key feature of the learning process for farm sustainability (Darnhofer et al., 2010a; Ingram et al., 2018; Restrepo et al., 2018;

Restrepo et al., 2020). Through collaboration, farmers' assumptions and beliefs are challenged, and this process enables them to find relevant solutions for the sustainability challenges they face in their farms (Restrepo et al., 2018). When dealing with a complex matter, such as sustainability, farmers' learning can benefit from collaborations with a wide variety of stakeholders (Darnhofer et al., 2010; Šumane et al., 2018).

As sustainability learning aims to enhance sustainability, it is important to determine the outcomes of such learning processes (Armitage et al., 2008). The outcomes of a learning process in agriculture comprise motivations for further sustainability learning as well as new knowledge and knowledge in action (Hansmann, 2010; Tilbury, 2011). Related to this, Restrepo et al. (2020) found that a sense of progress toward outcomes, in ways that have direct effects on their production systems, sustained farmers' enthusiasm and motivation for continuing with the learning process.

2.2.2.3 Procedural aspects of sustainability learning processes in agriculture

There are several common aspects found in the current research on sustainability learning processes in agriculture: the processes are long-term, have an iterative nature, require flexibility in terms of procedures, and are multilevel processes (Brunori et al., 2016; Darnhofer et al., 2017; Hubeau et al., 2017; Hubeau et al., 2018). In addition, these are commonly described as transdisciplinary processes, as they are connected with the complexity of the sustainability concept (Section 2.1) and the participatory nature of sustainability learning processes in agriculture (Section 2.2.2.1) (Hubeau et al., 2018; Restrepo et al., 2020).

Sustainability learning processes are long-term processes, and therefore assuring enough time is crucial - a feature shared with participatory processes in general (Reed, 2008; Hubeau et al., 2017). These processes also demonstrate an iterative nature, which means that the process constantly entails "returning to problem framing and readjusting or reaffirming" (Hubeau et al., 2018, p.1151). By going through many "rounds" of learning, stakeholders gain new knowledge to address a variety of conditions (Havet et al., 2014). In addition, these processes should be flexible (Reed, 2008; Darnhofer et al., 2012; Hubeau et al., 2018). There is no single correct pathway toward sustainability, and the methods or procedures must be adjusted to each context, including the consideration of practical issues in each process (Hubeau et al., 2018; Mascarenhas et al., 2021). In this regard, using monitoring and evaluation tools during the learning process strengthens learning by giving continuous feedback on progress,

reflecting on deviations, or identifying new solutions (Restrepo et al., 2018; Parry et al., 2020; Liberloo et al., 2021). Encouraging reflexivity, "to make choices consciously" (Darnhofer et al., 2012, p.25) from both researchers and stakeholders can also aid in monitoring the process and maintaining its flexibility (Wesselink et al., 2011; Liberloo et al., 2021). Related to this, Hubeau et al. (2017) emphasized the importance of providing decision support to achieve a real-world impact from the learning process.

The interconnectedness among the farm level, the broader food system, the social surroundings, and policy levels makes the sustainability learning process a multilevel process (Hansmann, 2010; Darnhofer et al., 2017; Hubeau et al., 2017, 2018; Eksvärd and Marquardt, 2018). This entails that farmers' sustainability learning needs to focus beyond the farm scale, because the learning processes of farmers and society are interlinked (Lamine et al., 2014; Fridman and Kissinger, 2019). For instance, it has been reported that progress toward farm sustainability may be hampered if the necessary changes in policy and farmers' practice are incompatible (Darnhofer et al., 2017; Eksvärd and Marquardt, 2018). Thus, policy, society, and market influence how sustainable a farm can be (Darnhofer et al., 2012; Lamine et al., 2014; Darnhofer et al., 2017; Eksvärd and Marquardt, 2018).

Sustainability learning processes in agriculture are commonly described as transdisciplinary processes (Hubeau et al., 2018; Restrepo, 2020). Lang et al. (2012, p.28) described the principles of an ideal transdisciplinary process as a process in three phases: (1) "Collaborative problem framing and building a collaborative research team," (2) "Co-creation of solution-oriented and transferable knowledge through collaborative research," and (3) "(Re-)integrating and applying the co-created knowledge." Such transdisciplinary processes are also described in detail in agricultural research (Hubeau et al., 2017, 2018; Restrepo et al., 2018, 2020). In particular, Hubeau et al. (2018) evaluated a two-year agri-food initiative in Belgium in terms of its fulfillment of its three transdisciplinary principles (Lang et al., 2012) and found that many of the premises were fulfilled, although contextual factors should play a major role in planning such processes. In addition, they found that practicalities and the need to stress the flexibility of the transdisciplinary process posed challenges to its design. However, a common thread through research findings on transdisciplinary processes is that they view transdisciplinarity as "a context-specific negotiation" (Klein, 2004, p.521).

2.2.2.4 A framework for assessing a sustainability learning process

To assess learning processes for sustainability, Mascarenhas et al. (2021) developed a framework (Figure 4) that shows the necessity of examining the following: the purpose for learning, what is to be learned, which actors need to be involved, the methods to be utilized, and the timing of the various stages in the process. This framework can also be utilized to plan a sustainability learning process, as the various assessment topics in the framework do not follow a particular sequence (Mascarenhas et al., 2021).

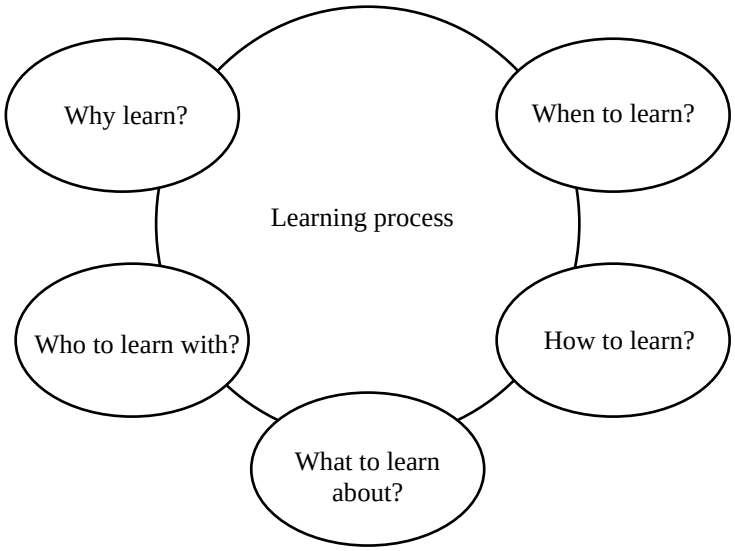

Figure 4. Framework from Mascarenhas et al. (2021, p.2) distinguishing a learning process through the following five questions:

i. Why learn? (the purpose of knowledge generation and sharing)
ii. Who to learn with? (the actors involved in the learning process)
iii. What to learn about? (the knowledge, insights, ideas, and perspectives involved in the learning process)
iv. How to learn? (the methods and tools used in the learning process)
v. When to learn? (the timing of different stages in the learning process)

This framework resembles the framework used in Paper II to depict farmers' sustainability learning. The difference, however, lies in the presence of more learners (Who?), the timeline of events (When?), and its inclusion of methods and tools used in the process (How?). In this thesis, I will utilize the framework from Mascarenhas et al. (2021) to conceptualize farm sustainability in Arctic Norway as a learning process (Section 5.1.5).

3. Methodology and methods

There is not one best way to conduct research; there are many methodological choices a researcher must take, and these impact the knowledge gained from the study (Saunders et al., 2019). In this chapter, I discuss the choices made while undertaking this research and their implications for the results. The remainder of the chapter is structured as follows. In Section 3.1, I discuss that this thesis is undertaken within a pragmatist philosophical paradigm and how this guides my assumptions on how I view reality (ontological assumptions) and knowledge (epistemological assumptions) (Saunders et al., 2019). I continue by reflecting on the research process (Section 3.2) and then on a section dedicated to the considerations related to research quality (Section 3.3). Then, I explain that the thesis utilizes a case study design that employs multiple methods (Section 3.4). This chapter ends with a discussion of the ethical considerations underlying this research (Section 3.5).

3.1 Philosophical paradigm - Pragmatism

Cognizant of the fact that there are various ways of interpreting the world and conducting research, this thesis is undertaken using a pragmatist philosophical paradigm (Saunders et al., 2019). Pragmatism is not new. It originated from the late 19th to the early 20th century, during which the works of, among others, John Dewey—a philosopher and educational reformer—served as important sources for pragmatism as a research philosophy. Explaining Dewey, Morgan (2014, p.1046) stated that a foundation for this philosophy is that "experiences create meaning by bringing beliefs and actions in contact with each other," and that any experience always occurs within a context. Recently, pragmatism has regained renewed interest, also in the field of sustainability science (König and Ravetz, 2017; Maarouf, 2019; Caniglia et al., 2021).

As a researcher, I have undertaken many of my undergraduate studies in natural science and most of my work experience in applied science, such as participatory projects concerning agricultural business development. In undertaking a PhD in social science, neither constructivism nor positivism—the two extremes of philosophical views—fit my view on how best to conduct research. However, my stance as a researcher found resonance when I became acquainted with pragmatism. According to Saunders et al. (2019, p.151), for a pragmatist "research starts with a problem and aims to contribute practical solutions that inform future practice." As a researcher, I believe this is my main driver for engaging in

research, that it is relevant for the industry, for agriculture in general, or for farmers in particular. Moreover, that it aims to make a positive impact in the form of concrete new products, practices, or policies, or as changes in prevalent values and thoughts. Extending this to practical research, a study must be accompanied by participatory approaches and/or duly considered dissemination plans for such an impact to occur. Pragmatism as a problem-solving philosophy (Farjoun et al., 2015) has a parallel aim with sustainability science in its goal of contributing to practical solutions as in enhanced sustainability (US NRC, 1999; Kates et al., 2001; Sala et al., 2013).

Ontologically, the current thesis recognizes the existence of one reality, although there are multiple perceptions of this reality (Maarouf, 2019, p.7): "There is only one reality [that] exists in a certain context at a certain point of time (…) however, this reality is perceived differently by the social actors which causes reality to change in a continuous process." This procedural view of the world, where the world is a "'work in progress' rather than a final product" and where the focus is on relationships and connections between entities and incidents (Farjoun et al., 2015, p.1789), is also very well connected to the view of farm sustainability expressed in this thesis. The pragmatist ontology is also well suited for working with complex matters, such as sustainability. As a practical example from this thesis, this means, for instance, the possibility of utilizing the SMART-farm tool to assess farm sustainability and adding to this reality the nuances and depths obtained from qualitative interviews (Paper II). Similarly, the necessity of understanding the context is stressed throughout the thesis. Given that contextual factors, such as climate, topography, demography, cultural history, and so on, will affect the stakeholders' perceptions of their reality, understanding context is the key to making sense of stakeholders' reality.

Epistemologically, the project focuses on knowledge and theories that are relevant for solving the "problem" using various sources and ways of knowing (Saunders et al., 2019; Maarouf, 2019). The example of the SMART-farm and qualitative interviews above is a good demonstration of what Maarouf (2019, p.9) describes as follow: "Sometimes, we have the goal of describing reality in like-law generalizations for practical benefits and other times we are examining social actors' perceptions for more detailed and deep understanding of this reality." The focus is on the outcome, and valuable knowledge is the knowledge that works. This thesis' MRQ concerns process, and the valuable knowledge that can answer this question comprises the knowledge that can drive this process.

3.2 Reflections on the research process

This thesis is an exploratory research process, which means that the process is flexible and adaptable to change (Saunders et al., 2019). I will discuss this through its relevance in developing the research objectives as well as its importance for myself, the candidate, as I undergo the process of becoming a researcher. Learning is the topic of this thesis, and it is also an instrument for these exploratory processes.

Since the onset of the PhD period, I have focused on studying sustainable food production in an Arctic Norway agricultural context. This is based on my academic (an M.Sc. degree in Horticulture) and professional backgrounds (two decades of experience as a project manager for R&D projects for developing agricultural companies), as well as my personal interest and the topic's perceived societal relevance. Sustainability is studied in myriad ways, also connected to agriculture. During the start of my PhD, I emerged in broad scope reading, as well as taking courses on both life cycle assessments and sustainability transition theories. However, it was the sustainability assessment literature, particularly the indicator-based holistic sustainability assessments, that stood out for me as the most relevant path on which to study sustainability in Arctic Norway. I focused on SAFA, which was specifically targeted at the agricultural sector. The broad (holistic) content of SAFA, as well as the realization that sustainability must reflect the context and the values of the affected stakeholders, led to the completion of Paper I (*Sustainable value: The perspective of horticultural producers in Arctic Norway*).

In the early days of my PhD study, the project had a value chain focus due to my professional background in the development of local food production in the agricultural sector and my being a project leader of the Northern Cereals project. Development (business improvements), process (long-term commitment), and cooperation (combining stakeholders and experts from various disciplines) were elements connected to my past professional experience. Combining this with enhanced knowledge from the sustainability literature led to Paper III (*Transnational cooperation to develop local barley to beer value chains*). At the same time, I participated in writing a book chapter, *Sustainable value: the perspective of microbreweries in peripheral northern areas* (Bertella et al., 2021), although this was subsequently excluded in the final thesis as it focused on value chain actors upstream in the agricultural value chain.

This thesis' focus on the farm level and on farmers' learning can also be found in Paper I and is evident in Paper III. This became the main thesis focus when I took a course in the

SMART-farm assessment, where I assessed sustainability at the farm level and investigated learning as the strategy for change, from the current sustainability level toward an enhanced level. This focus was consolidated throughout the second half of this PhD period. As learning necessitates a learner, designating the farmer as the learner was an obvious choice from a farm-level perspective. Much of the second part of this PhD process was then devoted to in-depth studies on learning, including learning theories, in general, and learning theories utilized in sustainability research and farmers' learning for sustainability, in particular. An intense period of empirical investigations, analysis, and a thorough review process resulted in Paper II (*Learning for sustainability in horticultural production in Arctic Norway*).

The PhD process has also been exploratory in its aim of educating a researcher (myself, the candidate) who is learning the craft of research. This process has unfolded in a parallel and interconnected way with the process of developing the thesis objectives and research outcomes (the published papers), as described above. Having worked for several years in a research institution (The Norwegian Institute of Bioeconomy) prior to starting this PhD period, I thought I knew the research world quite well. However, it turned out that I still had much to learn. Throughout this period, I have learned by taking various courses (scientific writing, qualitative methods, statistics, the publishing process including open access, and philosophy and ethics). I have learned through discussions with my supervisors, fellow PhD students, colleagues, and others. In addition, I have learned through my own reflections on the practical endeavors of doing research.

This process has had its ups and downs. I discovered that I like the writing process, and I found being in a "flow zone" of writing very rewarding. However, when the reviewing process results in a substantial critique of the writings I was quite satisfied with, this can be quite harsh. Fortunately, such a difficult experience can be transformed into learning and a new understanding of the research text and process. I also discovered that it was difficult for me to go from a descriptive analysis to a more in-depth analysis of the empirical material. In a way, I felt that so much of the empirical data were relevant given the broad and complex field of sustainable food production. Furthermore, by excluding parts of the material, I would not pay due respect to the stakeholders who had devoted their time to participating in the research. However, in the process of becoming a researcher, I realized that the analysis phase was one of the most important aspects that separated the knowledge derived through research from all other kinds of knowledge. For instance, this realization culminated in my reanalysis of all the empirical data behind Paper II in the first review of the submitted article.

During the PhD period, I also had to face externally imposed difficulties related to learning to be a researcher through social interactions because of restrictions caused by the COVID-19 pandemic. In the last two years of my PhD study, nearly all of my contact with supervisors and fellow PhD students, as well as courses and empirical data collection, had to occur through MS Teams. It worked, but it was not an optimal experience.

3.3 Quality in research

In this section, I discuss the research design based on two quality parameters: coherence and transparency. Quality in research is also dependent on the validity and reliability of the study. I will conclude this section with some reflections on how to deal with the researcher's own values in research.

First, for research to be reliable, its design must be based on the coherence (connections) between the philosophical paradigm in which the research is undertaken, on the one hand, and the methodology, strategy, and methods applied in the research process, on the other hand (Justesen and Mik-Meyer, 2010; Saunders et al., 2019). This thesis positions itself within sustainability science and follows a participatory methodology. It is also interdisciplinary due to the composition of a broad disciplinary spread of the researchers involved in the various studies (Papers I–III) and the supervisors of this thesis. Complementing this composition is my own broad background from various disciplines, including close connectivity to the practice field. This interdisciplinarity, combined with the high focus on stakeholder participation, has proven advantageous, resulting in a stronger contribution toward the broad focus intrinsic to the concept of sustainability (Hansmann, 2010). All the studies in this thesis are empirical investigations in which stakeholder participation plays a prominent role. Participatory research is well-established within the pragmatic stance (Maarouf, 2019). As this thesis was a predominantly researcher-led exploratory research, the studies were not co-created in all aspects of the process, as is central in transdisciplinary research (Lang et al., 2012). However, cooperation with the stakeholders has been very good, and without the stakeholders' active involvement, there would have been no results to analyze.

The second quality parameter is that a research design must be based on transparency (openness), in which the research process must be explicitly described and explained so that other researchers can understand how the results have emerged and the research can be replicated (Olsen, 2003; Lenhard et al., 2006; Justesen and Mik-Meyer, 2010). The

methodology chapters of the three papers (Papers I–III) thoroughly explain the research processes in detail, including (where relevant) the stages in the process of data collection, the criteria for selecting participants, description of the data analyses, ethical considerations, and the limitations of the studies. The quality of the research, along with its validity and reliability, is linked to the following question: Has the research been carried out in a trustworthy way? (Thagaard, 2013). A thorough planning of the research is necessary to ensure quality. However, in my opinion, this is one of the key challenges for a PhD student to learn, as doing research to some degree is a craft in which skills must be attained through practice, through performing research. Thus, enhancing the transparency of the research process has been a recurring theme in the review processes conducted by my supervisors and by external reviewers completing publishers' review processes. Many lessons have been learned; for example, keeping a diary for continuous and immediate self-reflections has proven valuable in this regard.

It is not possible for researchers to be entirely free of their own values and experiences (Johnson and Onwuegbuzie, 2004). In the pragmatic stance, "Values play an important role in conducting research and interpreting results" (Pansiri, 2005, p.198). Examining my own values toward the research in this PhD, I find that I am positive to continued agriculture in Artic Norway, I trust and have prior knowledge of the stakeholders, and I believe in and respect the farmers' competence and good intentions toward their farming practice. In addition, I possess thorough knowledge of farming and other contextual factors. These factors may have influenced the research.

Maroof (2019, p.9) talks about "the necessary bias principle," which means "a pragmatic researcher should be biased only by the degree necessary to enhance his research and helps to answer his research questions." This was a topic of reflection in my research, especially in Paper II, for which I conducted the assessments and interviews, facilitated the workshops, and performed the analysis as the sole executive of the practical activities of the study. I felt that it was quite risky that my own values could influence the findings to an unnecessarily high degree. To reduce this risk, this concern was dealt with and made transparent by presenting my background in the paper using an external, well established assessment method, and by facilitating the workshop: "the facilitator did not actively engage in the discussions, but only had a timekeeping and a subject-boundary keeping function" (Paper II, p.7). In addition, the coauthors and reviewers thoroughly reviewed the manuscript. In doing so, I believe I have achieved what Maarouf (2015, p.9) explained as follows: "Having a previous knowledge or

perceptions should only enrich the qualitative research by helping the researcher to add more insights and discover more sides of this shared reality not manipulating research results in a certain direction."

3.4 Case study strategy utilizing multiple methods

This thesis uses a case study strategy wherein the specific case consists of farms in Arctic Norway. Papers I and II specify that these include horticultural farms in Arctic Norway, while in Paper III, the farms in focus are cereal producing farms. Case study, the research strategy in this thesis, is defined as a "research strategy that involves the empirical investigation of a phenomenon within its real-life context, using multiple sources of evidence" (Saunders et al., 2019, p.797). Case studies are relevant in this thesis, as the aim is to gain an in-depth and holistic perspective of the sustainability learning process in the context of farms in Arctic Norway. Furthermore, to understand the case, it cannot be understood in isolation but only through the interaction between the case and the context (Yin, 2013; Yin, 2014). Therefore, understanding the context is central to this case study (Saunders et al., 2019). Although about 150 farms in Arctic Norway produce horticultural goods, the case is dealt with holistically as one unit (Saunders et al., 2019). This is done by utilizing multiple methods that allow the inclusion of several perspectives to understand the case as a whole.

This thesis utilizes multiple methods, including qualitative (desk studies, semi-structured interviews, and workshops) and semi-quantitative methods (sustainability assessment and outcome quantification). Table 9 gives an overview of the different methods utilized in the three studies (Papers I–III). Even if many methods are utilized (qualitative and semi-quantitative), the data are mainly analyzed qualitatively, and this can thus be described as a multimethod (predominantly) qualitative approach (Saunders et al. 2019). A pragmatist recognizes that there are many ways of interpreting a phenomenon; thus, many research methods can be considered valid for a single study and included in a case study strategy, resulting in a rich picture and a more complete understanding of the research problem at hand (Maarouf, 2019; Saunders et al., 2019). From a pragmatic stance, the chosen methods should be selected based on available resources and whether they are appropriate for answering the aim of the study (Philips and de Wet, 2017). In addition, the qualitative methods utilized in this thesis are all methods in which stakeholders are included. In qualitative studies, these

stakeholders are “not seen as mere respondents, but as participants in the collection of data” (Saunders et al., 2019, p.179).

Table 9. Overview of methods utilized in the various studies

Paper	Methods
I. Sustainable value: the perspective of horticultural producers in Arctic Norway	Desk study of the context of sustainable horticultural production in Arctic Norway Semi-structured interviews with 11 farmers and two wholesaler managers in the Arctic Norway horticulture sector. Qualitative analysis utilizing the NVivo tool
II. Learning for sustainability in Arctic Norway horticultural production	Desk study of the context of sustainable horticultural production in Arctic Norway SMART-farm sustainability assessments on five farms with horticultural production in Arctic Norway Review session of the SMART-farm results, including semi-structured interviews with the five farmers on the assessed farms Presentations of the combined SMART-farm results to workshop participants Workshops with stakeholders who are closely connected to the production of horticultural products in Arctic Norway Qualitative analysis utilizing the NVivo tool
III. Transnational cooperation to develop local barley to beer value chains	Descriptive, explanatory desk study of a completed North-Atlantic R&D project Analysis is qualitative and semi-quantitative in evaluating its transdisciplinary; transnational effort resulting in diverse outcomes in a participatory approach

3.5 Ethical considerations

This thesis was undertaken with the understanding that ethics, as a scientific requirement, must be the foundation of all research. Research ethics guidelines are core documents both at UiT-The Arctic University of Norway (where my PhD is affiliated) and at the Norwegian Institute of Bioeconomy Research (where I am employed), and the principles they express are those that have guided this thesis. Both guidelines are based on the four principles from the National Research Ethics Committees’ general guidelines (The Norwegian National Committees for Research Ethics, 2014):

i. Respect. People who participate in the research, as informants or otherwise, shall be treated with respect.
ii. Good consequences. Researchers should seek to ensure that their activities produce good consequences and that any adverse consequences are within the limits of acceptability.

iii. Fairness. All research projects shall be designed and implemented fairly.
iv. Integrity. Researchers shall comply with recognized norms and behave responsibly, openly, and honestly toward their colleagues and the public.

Transparency (as discussed in Section 3.3.) is a quality criterion that is closely related to fulfilling ethical principles, because without transparency in planning, process, and implementation, ethical conduct cannot easily be verified. Participatory studies are particularly subject to ethical considerations, and in Norway, the Norwegian Center for Research Data (NSD) requires researchers to "ensure that data about people and society can be collected, stored and shared, both safely and legally, today and in the future." Papers I and II were approved by the NSD, indicating that the participants were informed about and consented to the terms of the research in terms of ensuring their anonymity, specifying secure time-limited data storage, and informing them about their possibility of withdrawing from the study at any moment. By following these guidelines and ensuring anonymity for the participating stakeholders, there have been few challenges of ethical character connected to this thesis.

4. Results - Summary of papers

4.1 Paper I

Halland, H., Bertella G., and Kvalvik I. (2021). Sustainable value: the perspective of horticultural producers in Arctic Norway. International Food and Agribusiness Management Review: 24 (1), 51–70. doi:10.22434/IFAMR2019.0211

As the concept of sustainability is fundamentally based on values, one challenge in assessing sustainability is stakeholders' different perspectives on sustainable food production. Farmers are key stakeholders in agricultural value chains and upon whom changes toward sustainability depend. Therefore, understanding their perspectives is essential. At the same time, contextualizing sustainability is a prerequisite for making it understandable. In this study, we utilized the SAFA framework, with a qualitative approach with in-depth interviews, to unravel the perspectives on sustainability of 10 horticultural farmers in Arctic Norway.

The findings indicate that sustainability is not used in farmers' everyday language; however, they all relate sustainability to how they run the farm. The greatest focus is on the environmental dimension, and some respondents highlighted the interconnectedness of the different dimensions of sustainability. Few have shown a holistic perspective by intuitively mentioning all three dimensions; however, the more detailed questions based on the SAFA framework reveal that the farmers are working on all aspects of sustainability. For example, one reason for their good performance is the high level of public documentation requirements.

The study discusses implications for sustainability related to the findings on four sustainability dimensions. In the governance dimension, improving long-term planning can increase the level of overall sustainability performance. In the economic dimension, some of the strategies to secure income are to increase the product portfolio, reduce the impact of fluctuating yield, and focus on high-value quality crops rather than on volume. Furthermore, trade-off discussions with the environmental dimension are central. In the social dimension, farmers find their work meaningful, mainly due to their contribution to the local community. They also focused on establishing good networks of producers. In the environmental dimension, regulations are strict, and they face the challenges of gaining access to and dealing with the fragmentation of agricultural land. Technical improvements are also crucial.

The study discusses the SAFA framework set in an Arctic Norway context and concludes that a good contextual understanding is important in determining farmers' perspectives, the strategies available for improving sustainable agriculture, as well as a prerequisite for an assessment to fit the real-world.

4.2 Paper II

Halland, H., Lamprinakis, L., Kvalvik, I., and Bertella, G. (2021). Learning for sustainability in horticultural production in Arctic Norway. Frontiers in Sustainable Food Systems, 5(320). doi:10.3389/fsufs.2021.686104

Sustainability is seen as a learning process, - sustainability learning. In this study, the authors sought to reveal the characteristics of the sustainability learning process of horticultural farmers in Arctic Norway by using a framework that distinguishes among contextual factors (where? and when?), knowledge (what?), motivation (why?), and process (how?). We employed theories from sustainability learning, double-loop learning, and social learning, as well as reviewed research on learning at the farm level. The study uses a mixed methods approach in a participatory case study, wherein SMART-farm sustainability assessments are conducted to contextualize sustainability, and as a starting point for further discussions on sustainability learning in farmers' interviews and stakeholder workshops.

The findings demonstrate the specificities regarding the questions in our framework, revealing several examples of both single-loop and double-loop sustainability learning processes. Through an analysis of this detailed work, we found five principal aspects characterizing sustainability learning in horticultural farms in Arctic Norway: (1) The complexity of sustainability and immense level of conflicting issues entail constant negotiations on trade-offs, synergies, and long-term effects. (2) The complexities are reflected in the diversity of both internal and external motivations for sustainability learning. Here, economic motivations are often the main motivational factor, although seldom the sole factor. (3) Building sustainability awareness is often the main cause and outcome of sustainability learning. Raising awareness can lead to double-loop learning wherein the outcome comprises changes in farmers' values and perceptions. (4) Sustainability learning is predominantly a transdisciplinary social learning process, optimally combining formal and informal knowledge from a variety of different sources. (5) Sustainability learning is highly interconnected with contextual factors, and what sustainability means must ultimately be understood locally.

The study concludes with a presentation of the empirical and theoretical considerations and an emphasis on their contribution to the call for empirical studies on how to go from farm sustainability assessments toward sustainability implementation. However, the paper also concludes that learning platforms for holistic sustainability are needed.

4.3 Paper III

Halland, H., Martin, P., Dalmannsdóttir, S., Sveinsson, S., Djurhuus, R., Thomsen, M., Wishart, J. and Reykdal, Ó. (2020). Transnational cooperation to develop local barley to beer value chains. Open agriculture, 5(1), 138–149. doi:10.1515/opag-2020-0014

This study evaluates the transnational and transdisciplinary nature of a three-year (2015–2018) R&D project called Northern Cereals, which aims to enhance sustainability in the form of increased self-sufficiency of cereal and cereal products in the North-Atlantic region. The project included R&D partners from four countries, along with 310 stakeholders. It utilized a transdisciplinary methodology because the broad objective of the Northern Cereals project could only be addressed by accessing knowledge and skills from many different disciplines and from various stakeholders. All of the partners had some of these knowledge and skills, while no single partner had access to all of them. Transnational cooperation allows for common issues to be effectively and innovatively solved in order to reach critical mass in this sparsely populated region.

The transnational and transdisciplinary nature of the Northern Cereals project is evaluated in this paper by reviewing the methods, outcomes, and partners/stakeholders involved in tackling the different challenges identified along the barley to beer value chain (growing, malting, brewing, marketing). Given that the shortage of grain and malt is considered the main limitation of complete value chain development, the project mainly focused on growing (farm level) and malting. However, by relying on the expertise of the microbreweries, the desired outcomes in brewing and marketing were also achieved.

The findings showed that transnational cooperation was truly an integral part of the project; partners from all regions participated to achieve the target outcomes, and all outcomes involved the efforts of multiple partners/regions. In addition, partners, stakeholders, and contexts were similar enough to make knowledge transferable, but different enough for interesting comparisons to be made. Transnational cooperation proved to be very beneficial for achieving the aims of the project and for maximizing the impact of a small pool of cereal R&D expertise spread across a large geographic region. The transdisciplinary approach also allowed the project to tackle various challenges, and the inclusion of many stakeholders ensured outcomes with practical relevance. The project concluded by stating that stakeholder involvement was the project's main strength. However, the lack of academic knowledge on marketing and innovation may have been a shortcoming.

5. Discussion and implications

The following discussion seeks to answer this thesis' research questions by analyzing Papers I–III using the theory presented in Chapter 2 (Section 5.1). From these findings, I discuss this thesis' theoretical contribution (Section 5.2), give recommendations for further research (Section 5.3), and discuss relevant limitations of the research (Section 5.4). I conclude this chapter with a section discussing the implications of the findings for policy and practice (Section 5.5).

5.1 Findings

In this section, I utilize the three papers (Papers I–III) to answer the research questions. As indicated earlier, this thesis has four sub-research questions (SRQ1–4):

SRQ1: *How can farmers' perspectives on sustainability inform the sustainability learning process in Arctic Norway?*

SRQ2: *How can sustainability assessments contribute to farmers' sustainability learning processes in Arctic Norway?*

SRQ3: *What are the characteristics of farmers' sustainability learning in Arctic Norway?*

SRQ4: *How is a participatory approach important in sustainability learning processes in Arctic Norway?*

These four SRQs aid in answering the MRQ.

MRQ: *How can farm sustainability in Arctic Norway be conceptualized as a learning process?*

This section is structured by separating each research question. First, I discuss the four SRQs (Sections 5.1.1–5.1.4, respectively) and, by drawing on the insights gained from these discussions, elaborate on the MRQ (Section 5.1.5).

5.1.1 SRQ1: *How can farmers' perspectives on sustainability inform the sustainability learning process in Arctic Norway?*

Farmers are key stakeholders in agricultural food production, and their perspectives on sustainability are of paramount importance, as they are the ones upon whom possible changes toward enhanced sustainability depend (de Olde et al., 2016). Farmers' perspectives on

sustainability contains their values that are set in the contexts in which they reside (Paper I). Contextual factors are prominent in all three papers (Papers I–III) as background for the studies and as implications of and explanations for the findings. The farmers' values are more indirectly assessed in this thesis, particularly in Papers I and II, through the qualitative analysis from in-depth interviews and workshops. Using the three papers, I will discuss the findings connected to the contexts of and values held by farmers, as well as the implications their perspectives have on the sustainability learning process.

Contextual factors and farmers' values affect farm practices (Darnhofer et al., 2010b). In Arctic Norway, we find that context affects the type of knowledge required. For instance, knowledge to overcome restraints to production due to natural conditions in Arctic Norway is needed, along with information concerning new technical equipment to ease climatic restraints on production (Papers I and II). That context influences the knowledge sought is also described in Šumane et al. (2018). In addition, it is evident that there are interdependencies between the terms: context influences values, and values, in turn, influence motivations (Hansmann, 2010). In Papers I and II, we find that farmers' values affect their motivations for conducting sustainable changes on the farm. For instance, in relation to the three dimensions of sustainability (environmental, economic, and social), we find values expressed as motivations for maintaining the farms' natural resources, for gaining positive economic results for the farms, and for attaining good working conditions on the farm (Papers I and II). In Paper II, we did not find clear motivations for holistic sustainability. However, the farmers do have values that can be viewed as more holistic sustainable values, such as values regarding continued production on the farm or those about having a good life as the basis for being a farmer. However, in Paper II, these are seldom explicitly expressed as motivations for making changes toward enhanced sustainability.

The sociopolitical context also affects the possibility of further advancing farm sustainability (Papers I and II). In Paper II, we find that societal factors impeded possibilities for farm sustainability, as the centralization of operations of large market actors increased the transport length of goods, thereby increasing farmers' economic vulnerability. However, this can also facilitate possibilities, as findings showed that attitudes toward environmental and sustainability issues are positively viewed in society and that these helps ease farmers' work for sustainability. The heightened environmental focus in society at large is also observed among the farmers, and the connection between them and their societal contexts plays a crucial role in the farmers' gradual alteration of their own values. This connection between

the values held by the farmers and the collective values held by the larger society is also described in Darnhofer et al. (2010b) and Darnhofer et al. (2012). In addition, context, such as issues related to policy, also affects the possibilities to advance farm sustainability, with findings indicating that the high documentation requirements enhanced farm sustainability (Papers I and II). On the one hand, such documentations give higher workloads to management; on the other hand, it seems that farmers recognize and value the idea that these requirements ensure that their production activities are performed in an acceptable manner. In addition, in Paper III, we found that contextual factors affected stakeholders' social learning, because cultural and historical similarities eased cooperation, whereas sufficient differences enhanced learning from this collaboration. How context affects farms is also described in, for instance, Gibson (2006) and Darnhofer et al. (2010).

Meanwhile, trade-offs and synergy discussions are essential in furthering farm sustainability (Schader et al., 2016). As in Galli et al. (2016), we found that context and values influenced such discussions. An example of such a discussion is that the use of plastic fiber covers in production eases climatic restraints in Arctic Norway agriculture; however, it also increases the amount of plastic waste (Papers I and II). Moreover, in trade-off discussions among different dimensions, values are put to a test. In Paper I, we found that farmers placed the highest focus on the environmental dimension. This is in contrast to the findings of Bertella et al. (2021), who reported that microbreweries in Arctic Norway often focused first on the economic dimension. The higher environmental focus of the farmers is explained by their high dependency on natural conditions (Paper I). However, in Paper II, we found that economic motivation served as the farmers' main motivational factor. This indicates that conflicting values are present in trade-off decisions between what is good for the environment, for the production, and what is ultimately good for the economy. Due to such trade-offs, farmers' values do not necessarily lead to immediate changes in production (Harmer and Rahman, 2014). This is also evident in our findings.

Farmers' perspectives are manifested as thoughts and beliefs (awareness) and in their practical operations on farms (Ison et al., 2000; Darnhofer et al., 2010b). Based on our findings, these two forms of manifestations do not always coincide. For instance, we found that farmers lacked a holistic awareness of the concept of sustainability, but in their farm practices, they actually worked on most aspects of sustainability (Paper I). On the contrary, we found that farmers were aware of sustainability issues, such as reducing pesticides, that they—due to practical reasons or trade-off factors—were unable to practice on their farms

(Paper II). In a study by Bonisoli et al. (2019), they did not find a deep interest in sustainability among the farmers. In comparing their findings to the results of this thesis, it might be that there is a distinction between farmers' awareness of the concept of sustainability and what they do in their actual daily practices on the farm. However, Paper II discusses that, after going through several rounds of learning (as sustainability learning is perceived as an iterative process), the values held by farmers that are not expressed in their farming practices might eventually manifest in the long run.

In summary, farmers' perspectives on sustainability inform the sustainability learning process in several ways, including what they learn, why they learn, and how they learn. A conclusion in Paper I is that understanding farmers' perspectives serves as a basis for improving farm sustainability. Furthermore, qualitatively revealing farmers' perspectives has the advantages of being context specific, that is, relating to a specific farm and based on perspectives on sustainability of a specific farmer on that farm. In addition, it facilitates more holistic discussions on farm sustainability and helps overcome some of the challenges of scale, such as enabling discussions of longer time scales (both the historical past and a more distant future) (Bond and Morrison-Saunders, 2013). However, one disadvantage of qualitative approaches is that farmers tend to talk more about the positive aspects of the farm, which are the most valued. In addition, because they are subjective, they do not necessarily adhere to globally accepted standards for sustainability. Thus, leaving the definition of sustainability only to subjective perspectives will likely be insufficient in enhancing farm sustainability. Therefore, in addition, utilizing more objective sustainability assessments may be a solution.

5.1.2 SRQ2: *How can sustainability assessments contribute to farmers' sustainability learning processes in Arctic Norway?*

Working for enhanced farm sustainability requires farmers to have a good understanding about what to work towards (Hubeau et al., 2017). As discussed in Section 5.1.1, we find that intuitively, farmers do not know what constitutes farm sustainability (Paper I). Sustainability assessments are developed to enhance awareness of what sustainability entails, thus enabling them to transform their farm practices toward enhanced sustainability (Alrøe and Noe, 2016). Using SAFA as an analytical framework in Paper I, we find that, "despite a somewhat lack of holistic focus on the concept of sustainability in the open questions, the more detailed

questions based on the SAFA framework (…), reveal that all the farmers in their everyday work are very much concerned about all parts of the sustainability concept" (p.63).

In Paper II, we performed farm sustainability assessments with the SMART-farm tool based on SAFA. A challenge in using sustainability assessments is that they are comprehensive (Jawtusch et al., 2013; Schader et al., 2014). Hence, thoroughly reviewing the complete results of the assessments with farmers or other stakeholders requires much time, expertise, and effort. For this reason, in Paper II, we focused further discussions in the stakeholder workshops on topics for which the farms had the lowest score. These are topics perceived to be areas with the most benefits to gain in terms of sustainability improvements (Paper II, Table 4). How to best inform farmers about sustainability assessment results is a research concern (Alrøe and Noe, 2016). In Paper II, we connected sustainability assessments with discussions in stakeholder workshops, which proved very valuable in this regard, as we were able to collectively translate the assessment results into concrete improvements to enhance sustainability at farms in Arctic Norway (Paper II, Table 6). Furthermore, the farmers in our study reported that they gained new insights into the content and complexities of the sustainability concept, further raising their consciousness regarding the efforts needed to increase the level of sustainability on their farms.

Another challenge in using predefined sustainability assessment tools, such as SMART-farm, is that they are constructed to be used globally. Although some adjustments can be made to better fit the context of the farmers in Arctic Norway, many of the questions raised or even the phrasing of the questions do not properly match the reality of the farmers. Thus, in the review of the assessment results, it is necessary to consciously reflect on how relevant each topic is for a specific farm in Arctic Norway. For instance, in Paper II, the farmers reflected on their feelings of being "a little small in relation to some of those topics" (p.9). However, using a globally accepted assessment tool also proved to be valuable for the farmers, as this made them aware of other issues regarding sustainability, especially those that may not be immediately relevant for their specific farms, but indirectly relevant by virtue of them being part of a global society.

Given that sustainability learning is an iterative process (Paper II) and that sustainability assessments can be used in several stages (or frequently), such assessments can also be employed as an evaluation tool in a sustainability learning process (Restrepo et al., 2018; Parry et al., 2020; Liberloo et al., 2021). Related to this, Olde et al. (2017) reported that different assessment tools can yield different results. In using this as an advantage, over time,

one can use various tools to gain an enhanced and comprehensive awareness of what farm sustainability means.

Including sustainability assessments in farmers' sustainability learning has been proven to be rewarding while also building awareness of the concept, improving understanding of what sustainability means on the specific farm, and identifying critical topics to improve. The advantage of a sustainability assessment is that it is based on globally accepted indicators of farm sustainability. Compared to qualitative approaches, sustainability assessments can, to a higher degree, point to negative effects or points that need improvement in terms of sustainability. However, in terms of disadvantages, they can be less context-specific, constrained by practical restrictions, and rarely capture long-term time scales; furthermore, it is quite challenging to reduce to indicators the complexities of sustainable food production for the purpose of quantitative calculations (Bond and Morrison-Saunders, 2011; Schader et al., 2014; Migliorini et al., 2018). In this thesis, I used both sustainability assessments (SMART-farm) and qualitative approaches to study sustainability at the farm level. The benefit of such an approach is that it can avoid disadvantages while maximizing the advantages of both approaches, utilizing both to work for enhanced farm sustainability (Galli et al., 2015; de Olde et al., 2016).

5.1.3 SRQ3: *What are the characteristics of farmers' sustainability learning in Arctic Norway?*

Learning is crucial when aiming for more sustainable practices, and the possibility of a farm to improve sustainability depends on the farmer's ability to learn (Wals, 2007; Darnhofer et al., 2010a). This SRQ is identical to the RQ in Paper II. To investigate this, we used an iterative framework (adopted from Hansmann, 2010) that addresses what is learned, why it is learned, and how it is learned (Maarleveld and Dabgbégnon, 1999); one that is framed by the context; and specifies the farmer as the learner. The framework also delineates specific learning outcomes because enhanced sustainability can only be achieved through the implementation of these outcomes (Armitage et al., 2008). Through a participatory inquiry approach, we identified several learning processes in each of the four dimensions of sustainability (as defined in SAFA). Table 10 summarizes these findings described in detail in Paper II (Halland et al., 2021b, pp.10–12).

Table 10. Overview of sustainability learning processes identified in Paper II: Main characteristics and the link to single (S)- or double (D)-loop learning.

Dimension	**What?**	**Why?**	**How?**	**Outcome**	**S and/or D**
Good Governance	Holistic sustainability Management	External and Internal	Experiential and Collaborative	Implementation of a plan and report for farm sustainability	S/D
Environmental Integrity	Agronomical Technical Local	External and Internal	Experimental Experiential and Collaborative	Improved agronomical practice	S
Economic Resilience	Management Market Relational	External and Internal	Collaborative and Experiential	Improved local procurement Secure market situation	S S/D
Social Well-Being	Relational Local	Internal (and External)	Collaborative and Experiential	Heightened focus on equity Improve quality of life Heightened competence	S/D S/(D) S/D

Various types of knowledge (what?) are important for farm sustainability, and the sources of such knowledge are both informal and formal. However, in the social dimension, informal knowledge plays a more prominent role. The farmers' motivations (why?) for making sustainability changes are diverse. Internal motivations are especially connected to the environmental and social dimensions, and external motivations are particularly connected to the economic dimensions. The farmers learn (how?) mainly through collaborative and experiential learning, and only in the environmental dimension is experimental learning prominent. Most of the learning processes are single-loop learning, resulting in incremental changes in farm practices; however, the results also show evidence of double-loop learning, changing perspectives, or more significant changes in their practices. This is most prominent in the governance and social dimensions.

The results of the in-depth analysis also show that five principal aspects characterize sustainability learning in the context of horticultural farms in Arctic Norway, and these characteristics are closely connected. The five characteristics are discussed in detail in the Discussion section of Paper II (pp.12–14) and summarized as follows (Paper II, p.15):

1. The complexity of the concept of sustainability and the immense level of conflicting issues entail that the learning process constantly negotiates on trade-offs, synergies, and long-term effects.

2. The complexities are reflected in the diversity of both internal and external motivations for sustainability learning. Economic motivations are often a main motivational factor, although seldom the sole motivational factor.

3. Building sustainability awareness can be considered as a main cause for, and often a main outcome of, sustainability learning. Raising awareness can also lead to double-loop learning where the outcome is changes in farmers' values and perceptions.

4. Sustainability learning is predominantly a social learning process, where the complexities call for transdisciplinarity, optimally combining formal and informal knowledge from a variety of different sources.

5. Sustainability learning is highly interconnected with contextual factors, and what sustainability ultimately means must be understood locally.

In viewing farm sustainability as a learning process, the Arctic Norway farmers' sustainability learning and the characteristics of this process must be incorporated and improved. This study also revealed the need to focus beyond the farm scale, as farm sustainability is linked to policy and societal developments (Lamine et al., 2014). For instance, it has been shown that, in the past, internal motivations had grown in conjunction with policy regulations. A stronger political commitment to holistic sustainability could, therefore, enhance farm sustainability. In addition, limitations that restrict the possibility of improving holistic farm sustainability have been found: there are few formal sources for holistic sustainability knowledge, there are no established learning platforms for holistic farm sustainability, and there is little evidence of internal motivations for holistic sustainability. This means that achieving holistic farm sustainability would require a long-term, transdisciplinary learning process, in learning environments that enables seeing farm sustainability holistically (Wals, 2015b).

5.1.4 SRQ4: *How is a participatory approach important in sustainability learning processes in Arctic Norway?*

The complexity of the sustainability concept and the sustainability learning process necessitates that several stakeholders must be involved in efforts to improve farm sustainability (Hansmann, 2010; Wals, 2015a; Hubeau et al., 2017). However, with reference to prior research (Section 2.2.2), several aspects concerning their participation must be considered: why should various stakeholders be included? (Schmidt et al., 2020), which practical aspects should be considered? (Wesselink et al., 2011), how is the learning environment important for the stakeholders' learning process? (Reed, 2008; Rodela, 2014), and what are the best practices for participatory approaches? (Hubeau et al., 2018). In the following, I will discuss these aspects against the context of Arctic Norway agriculture.

In all three papers (Papers I–III) in this thesis, stakeholder participation played a central role; however, there were variations in the stakeholders' objectives for participating. With reference to the four rationales for stakeholder involvement (Schmidt et al., 2020), I evaluated the various objectives. In Papers I and II, the substantive objective was a main objective, as it was important that the studies were context-specific and relevant to the involved parties. In Papers II and III, the social learning objective was a main objective, as learning through social interactions was sought. In Paper III, the implementation objective was a main objective, as stakeholder participation would ensure that the target outcomes were generated. Although not considered as a main objective in either of the three papers, the normative objective was also relevant and served as a basis for stakeholder participation in all the studies. However, it can be argued that this characterization of the rationales for participation is made by the researcher. It could be that the stakeholders themselves held other objectives for their participation (Wesselink et al., 2011). This is not investigated in this thesis. However, rationales for stakeholder participation should be considered and jointly reflected on by researchers and stakeholders at the onset of the process, particularly in a long-term sustainability learning process in Arctic Norway's agriculture. This is also emphasized as a crucial element in research (Schmidt et al., 2020).

In participatory processes, it is vital to consider practical aspects (Wesselink et al., 2011), which may vary according to context. For instance, stakeholders' time and resources are major factors determining the possibilities for successful learning processes. When and how can they participate? For Arctic Norway farmers, the short growing season makes participation challenging from May to September. At the same time, other stakeholders upstream in the food value chain or from other adjacent industries have other seasons in which such participation can be challenging. In addition, the duration of sessions, platforms for participation, costs of travel, and being absent from their companies are other issues to be considered. In Arctic Norway, the long distances between larger horticultural farmers and relevant stakeholders are a factor in this regard. In Paper II, an additional practical challenge emerged due to the COVID-19 pandemic, because physical meetings were prohibited, and all communication was performed through electronic means (i.e., MS Teams).

The learning environment plays a crucial role in the quality of a learning process, and this varies in each learning process (Reed, 2008; Rodela, 2014; Hubeau et al., 2018). For instance, in Paper III, we recognized the influence of contextual factors (Section 5.1.1). In addition, interpersonal aspects are important in building a good learning environment (Reed, 2008;

Rodela, 2014). In the Northern Cereals project (Paper III), close cooperation between researchers and stakeholders is emphasized as the project's main success factor. The stakeholders' knowledge and expertise were acknowledged, thus leading to mutual learning and joint outcome development. One reason for this can be explained by the researchers coming from applied research institutes, with prior well-developed industry links as well as good knowledge of practical challenges within the industries. Similarly, in Paper II, it is recognized that the farmers in Arctic Norway have a well-established collaborative relationship with researchers and extension services. This has nurtured respect and mutual trust among the different parties. Furthermore, trust has been found to be a characteristic feature of Arctic Norway farmers (Paper II). Restrepo et al. (2020) recognized that mutual trust and power in the process can spur stakeholders' enthusiasm for learning. However, a limitation was mentioned in Paper II: for practical reasons, homogenous groups of experts were chosen in the workshops. In comparison, more heterogeneous groups could have spurred deeper learning and generated more robust findings (Nowotny, 2003; Eksvärd, 2010).

Which methods are utilized in a participatory process depends on various elements, such as which stakeholders are participating, on practical considerations, and which challenges are addressed. In Papers I and II, collaboration served as a key feature for sustainability in Arctic Norway horticulture and was assessed as a strength of the farmers. This was reflected in the range of collaborative methods identified in Paper II, which were connected to farmers' sustainability learning, such as informal discussions, sharing experiences between farmers, various R&D collaborations, collaboration with market actors, and cooperation with various actors to facilitate work for vulnerable groups. This finding coincides with those of Darnhofer et al. (2010a) and Ingram et al. (2018), who stated that collaboration is a key trait of the learning process for farm sustainability. In Paper III, the methods were chosen to best solve the identified challenges, and all methods and activities were collaborative, either between researchers, between researchers and stakeholders, or between stakeholders. Furthermore, the flexibility in the choice of methods is stressed by Hubeau et al. (2018), and this coincides with the findings in this thesis.

In addition, the nature of the participatory process, including ways of working together, is important for the success of a sustainable learning process (Reed, 2008). In Paper III, this was considered a transdisciplinary process (Tress et al., 2005; Lang et al., 2012). The combination of various researchers and stakeholders who jointly solved the challenges identified throughout the barley-to-beer value chain and related to the co-production of new knowledge

comprised the transdisciplinary feature described in that paper. In Paper II, transdisciplinary processes were identified as the best practices for sustainability learning processes in Arctic Norway horticulture. To further advance the goal of farm sustainability in Arctic Norway, it will be important to adapt the sustainability learning process to research findings on the best practices for transdisciplinary processes, such as those described in Lang et al. (2012), Hubeau et al. (2018), and Restrepo et al., (2020).

In summary, to answer this SRQ, participatory approaches are decisive for the quality of sustainability learning processes in Arctic Norway. Ensuring such quality entails learning from prior research on participatory approaches and adapting them to the specific context and the practical and interpersonal aspects that are distinct to that context. To achieve success, it is crucial that there is flexibility in approach and process.

5.1.5 MRQ: *How can farm sustainability in Arctic Norway be conceptualized as a learning process?*

In this thesis (Section 2.2.1.3), I defined sustainability learning as "a long-term and multilevel transdisciplinary learning process aiming for enhanced sustainability." I will elaborate on this idea to conceptualize farm sustainability as a learning process by drawing on the insights gained from the four SRQs (SRQ1–4) previously discussed in this section. First, the findings show that there are three features that frame farm sustainability: it is a long-term process, a multilevel concept, and it must be embedded in the very way of farming.

The first feature indicates that working toward farm sustainability is a long-term process. For instance, farm sustainability requires long-term planning (Paper I). Looking at the themes and subthemes in SAFA (Table 2), they all have an inherent element of time connected to them. Some can be a quick-fix, like using protective gear to increase workers' health and safety, while others, like crop rotation, take many years until the positive effects can be observed. Long-term planning is crucial in gaining such positive long-term effects; however, it is difficult because to "plan for the future is challenging passing from one generation to the next, and for the farmer to plan for a distant future would be virtually impossible" (Paper I, p.63). In Paper II, a main characteristic of farmers' sustainability learning was found to be that it entails constant negotiations "on trade-offs, synergies, and long-term effects" (p.15). Knowing that the sustainability concept is filled with uncertainties and continues to evolve as new concerns and new knowledge arise (Miller, 2014; Alrøe and Noe, 2016), working for

holistic farm sustainability, in which all three sustainability dimensions "perform in a concerted action," is a never-ending process (Paper II, p.1). The long-term aspect of working for enhanced sustainability has also been described in prior research (Brunori et al. 2016; Heinrichs et al., 2016).

The second feature is that farm sustainability does not only depend on what occurs on the farm itself; rather, it can be described as a multilevel concept. Even though the farm level is the focus of this thesis, the findings show that farm sustainability develops concurrently with sociopolitical development. The sociopolitical context impedes and facilitates the possibilities for enhanced farm sustainability (Paper II). For instance, how sustainable a farm can be depends on existing policies; farmers comply with the government's rules and regulations under the assumption that complying with these ensures that their production methods are performed in a cautious way (Papers I and II). In Paper II, we also found that policy development, along with public awareness, led to heightened awareness (double-loop learning) of environmental issues. The farm is also a business, gaining much of its income from the market; therefore, producing according to market demands is imperative to ensure continued production. To enable enhanced farm sustainability, it is also crucial that the market level requires and demands a higher level of farm sustainability. However, due to the fact that Arctic Norway's agricultural sector is highly regulated, a stronger political commitment for holistic sustainability can in particular enhance farm sustainability. The multileveled feature of working for enhanced sustainability has also been described in various ways in prior research (Darnhofer et al., 2010b; Lamine et al., 2014; Darnhofer et al., 2017; Hubeau et al., 2017; Eksvärd and Marquardt, 2018).

The third feature is that farm sustainability must be embedded in the very process of farm production, as the way of practicing farming. This implies that it cannot be conceptualized as a typical three-year R&D project, as is the common way of structuring research financed, for instance, by EU funds or National Research Council funds. Due to the long-term and multilevel aspects of farm sustainability, such approaches will likely not be sufficient. For instance, the Northern Cereals project (Paper III), although perceived as successful and having gained much interest in local produce from farmers and brewers, has yet to result in increased cereal production in Arctic Norway. One reason is that there are other restraints to such increased production—ones that go beyond the scope of that project because cereal production in Arctic Norway is constrained by political and economic reasons that are decided at the national governmental level (Bunger and Tufte 2016). This process view

requires the very way of farming to be the learning environment addressed in Paper II: a learning environment that enables seeing farm sustainability holistically (Wals, 2015b).

With these three features framing farm sustainability in Arctic Norway, I will use the framework from Mascarenhas et al. (2021) to conceptualize farm sustainability (Section 2.2.2.3). The framework distinguishes the learning process through five questions, and the following is a discussion of these five questions regarding farm sustainability, which is conceptualized as a learning process in the context of Arctic Norway agriculture. The five questions distinguishing the learning process for sustainability according to Mascarenhas et al. (2021, p.2) are as follows:

i. Why learn? (the purpose of knowledge generation and sharing)
ii. Who to learn with? (the actors involved in the learning process)
iii. What to learn about? (the knowledge, insights, ideas, and perspectives involved in the learning process)
iv. How to learn? (the methods and tools used in the learning process)
v. When to learn? (the timing of different stages in the learning process)

Why learn?

Working for farm sustainability is driven by the idea that this is a better way of producing for the natural environment, for farm economies, and for the stakeholders involved in farming. The complexity of the sustainability concept and the multilevel feature of farm sustainability entail that there are multiple stakeholders involved (Who to learn with?); therefore, the motivations of all involved parties should ideally promote this purpose. This is also linked to the rationales for participation discussed in Section 5.1.4. At the farm level, the farmers' motivations for sustainability learning varied, including both internal and external motivations, and their contexts and values influenced their motivations (Papers I and II). Studies have shown that internal motivations are particularly important drivers of learning (Hansmann, 2010; Restrepo et al., 2020). However, the findings of this thesis indicate that, because a farm is a business, it therefore depends on income for continuation; hence, external motivations are also key driving forces toward farm sustainability (Paper II). Presently, there is little evidence of internal motivations for holistic sustainability (Paper II). Hence, this is a factor that should be elaborated upon and further promoted to enhance farm sustainability. If the internal motivations for the holistic sustainability of all stakeholders can be strengthened,

then, presumably, a huge leap toward enhanced farm sustainability can be achieved. In this regard, motivations are outcomes of sustainability learning, and positive outcomes spur motivations (Hansmann, 2010, Restrepo et al., 2020). Therefore, motivations for enhanced farm sustainability can evolve in the course of a sustainability learning process in Arctic Norway.

Who to learn with?

Farmers are the ones who will ultimately make the necessary changes to enhance their farms' sustainability (de Olde et al., 2016). However, the findings clearly show that farmers alone cannot bring about all the necessary changes. The sustainability concept covers a broad range of topics, and the meaning and importance of these topics depends on stakeholders' values and on contextual factors, while the multilevel character of farm sustainability necessitates that several stakeholders must learn simultaneously (Hansmann, 2010; Wals, 2015a; Hubeau et al., 2017; Roux et al., 2017). In our discussion of farmers' sustainability learning in Paper II, we included farmers, agricultural extension workers, county administrators, and researchers, all of whom are important stakeholders in the Arctic Norway agricultural context. However, several other sources of farmers' sustainability learning were mentioned, such as other farmers and industry networks, local society, providers of machinery, documentation actors, financial and market actors, consumers, and food safety and labor and welfare authorities. In Arctic Norway, all of these stakeholders will have to work together toward enhanced farm sustainability. Presently, however, a question arises as to whether all these actors see themselves as stakeholders in farm sustainability, and if they do, then their rationales for being a stakeholder in the learning process toward enhanced farm sustainability should be determined to ensure that they are all moving in the same direction (Schmidt et al., 2020; Mascarenhas et al., 2021).

What to learn about?

In a way, this question can be viewed as the essence of farm sustainability. A prerequisite for enhancing farm sustainability is knowing what to work towards (Hubeau et al., 2017). This includes the content of the knowledge that must be learned and the practices that must be improved. It also contains various perspectives on sustainability and embedded contextual factors. In Paper I, we found that the farmers did not intuitively know what constituted

holistic farm sustainability; however, in their everyday work, they exhibited that they were already engaged in work on all sustainability dimensions. In Paper I, we concluded that understanding farmers' perspectives is a basis for improving farm sustainability. Expanding this, in Paper II, we found that including sustainability assessments in farmers' sustainability learning was beneficial for building awareness of sustainability at the farm level and for identifying topics to improve, as these were used as a starting point for learning (Alrøe and Noe, 2016; de Olde et al., 2016). The combination of these approaches, sustainability assessments, and stakeholder perspectives proved valuable for translating the assessments into recommendations for context-specific measures for enhanced farm sustainability (5.1.2).

Increasing awareness of what to be learned to enhance farm sustainability also entails increasing the stakeholders' consciousness concerning trade-offs and synergies involved when working toward this target (Paper II). These trade-off discussions are, in a sense, a core aspect of the "What to learn" question, as it is through such discussions that best practice can emerge (Schader et al., 2016). Context also influences such discussions and the type of knowledge needed (Galli et al., 2016; Šumane et al., 2018). In Paper II, we found that new knowledge of special Arctic conditions is essential for enhanced farm sustainability. Therefore, a decisive factor in the "What to learn" question is that this must be determined locally. In addition, what is regarded as sustainable is constantly evolving (Miller, 2014; Alrøe and Noe, 2016). This means that there should be flexibility regarding what entails the necessary knowledge to enhance farm sustainability (Darnhofer et al., 2010a).

How to learn?

Learning through transdisciplinary processes was identified as the best practice for sustainability learning in the context of Arctic Norway agriculture (Paper II). In the sustainability learning literature review (Section 2.2.1), transdisciplinarity is proposed as the main methodology, and transdisciplinary processes are commonly utilized in the learning process for sustainability in agriculture (Hubeau et al., 2018; Restrepo et al., 2020). Transdiciplinarity ensures that the learning process toward enhanced farm sustainability is participatory, as collaborations are considered the main approach for farm sustainability (Darnhofer et al., 2010a; Ingram et al., 2018), also seen in the context of Arctic Norway farming (Section 5.1.4). The level of learning, as in single- or double-loop learning, was also studied in Paper II. The way toward enhanced farm sustainability seems to entail taking advantage of this strength for cooperation and encouraging learning that facilitates double-

loop learning. Enabling conditions for this to occur are present when utilizing transdisciplinary methodologies.

Even if transdisciplinarity, according to the characteristics discussed in Section 2.2.2.3, is considered the ideal approach toward enhanced farm sustainability, it is important to adapt the process to the context of Arctic Norway agriculture. For instance, several factors, such as time and resources available for the various stakeholders, cultures for cooperation, and limitations in possibilities for changes in institutions, can impart many hindrances for ideal multilevel, long-term transdisciplinary processes. In this regard, one advantage for Arctic Norway agriculture is that this sector is relatively small and transparent, in which trust is a characteristic feature between stakeholders, and contextual factors are rather similar. Therefore, the findings from Papers I–III indicate that the learning environment is good, as would also be the case if more stakeholders are added into the learning process. Wesselink et al. (2011) proposed that stakeholder's joint reflexivity on the process itself is vital to overcome (or bring awareness of) possible hindrances/challenges.

When to learn?

Seeing farm sustainability as a long-term, multilevel process and not a short-term project means that this question cannot be answered in a straightforward manner. In Paper II, we found several examples of sustainability learning processes originating from various sources, such as new policy implementations, customer needs, public attention, and new knowledge. It is likely that a future process for farm sustainability will follow similar paths; hence, the question of when (i.e., the timing) must be flexible (Hubeau et al., 2018). Flexibility is also important in choosing which methods to utilize (Section 5.1.4), as well as important due to the iterative nature of farmers' sustainability learning wherein learning and new knowledge spur further learning and new motivations for learning (Paper II). Therefore, the process cannot be pre-described, as it depends on prior learning outcomes. For instance, "What to learn" cannot be a static exercise, but a continuous process. To a large degree, the actual changes toward enhanced farm sustainability (sustainability outcomes) will determine whether the learning process is going in the direction of enhanced sustainability; thus, evaluating the process will be vital (Restrepo et al., 2018; Parry et al., 2020; Liberloo et al., 2021). Sustainability assessments can also be utilized as an evaluation and monitoring tool.

By utilizing the framework from Mascarenhas et al. (2021), I have conceptualized farm sustainability as a long-term and multilevel learning process. To achieve farm sustainability, several steps must be aligned: there must be a purpose for the process, various stakeholders must take part, we must know what to learn, a transdisciplinary methodology must be used, and there should be flexibility in determining the timing of when to learn sustainability. In addition, the process must be embedded in the very way of farming.

5.2 Theoretical contributions

The general theoretical contribution of this thesis is that it advances research on sustainability. Specifically, it furthers the concepts of "sustainability learning" and "farm sustainability." However, the overall contribution of the thesis is that it combines four research rationales (Section 1.1) to answer the call made by Apetrei et al. (2021): research must study how to create change to hasten the slow phase of progress toward sustainability. By utilizing present theories on the concepts of sustainability, sustainability learning, and learning processes for sustainability in agriculture, as well as by expanding such theories through three empirical studies (Paper I–III), results show the importance of combining "sustainability as a theory" and "sustainability as a practice". I propose that the key to enhancing sustainability in Arctic Norway agriculture lies in this combination. I will highlight three aspects to which this thesis theoretically contributes: first, deepening the understanding of how values and context influence farm sustainability, second, combining sustainability assessments with a learning process, and third, deepening the understanding of sustainability learning in agriculture.

First, I have deepened the understanding of how values and context influence farmers' sustainability learning and, subsequently, farm sustainability. This is done both through in-depth interviews with farmers and stakeholder discussions in workshops to reveal their perspectives on farm sustainability (Papers I and II). The findings reveal that such understandings are important in enhancing farm sustainability because contexts and values influence motivations for learning, what is being learned, and how it is learned. In these qualitative studies we also found that a limitation for enhancing farm sustainability was that "the knowledge of what, holistically, sustainable food production includes is unclear" (Paper I, p.67).

This leads to the second aspect of this thesis' theoretical contribution that I will draw attention to. In Paper II, we performed sustainability assessments and used these as a basis for

discussing farmers' sustainability learning. The importance of this combination has been emphasized in several leading sustainability assessment studies over the last decade (Binder et al., 2010; de Mey et al., 2011; Bond et al., 2012; Sala et al. 2015; Alrøe et al., 2016; de Olde et al., 2016; Whitehead et al., 2020). However, it has yet to be implemented in connection with studies on farm sustainability assessments (de Olde et al., 2018). By undertaking sustainability assessments, followed by individual farm discussions and group discussions, the results showed that this enhanced the contextualization of farm sustainability and enabled farmers and stakeholders to concretize possible sustainability improvements. In addition, this combination proved to be an effective method for raising sustainability awareness among farmers and stakeholders.

The third aspect of this thesis' theoretical contribution concerns the findings in the literature review on sustainability learning (Section 2.2.1.3), which states that none of the studies using this concept are connected to agriculture. The literature review reveals that for this concept to strengthen its impact, its usage must be expanded beyond the education for sustainability literature, which is also discussed by Hansmann (2010). Paper II adopted a framework to analyze sustainability learning in Arctic Norway horticulture, thus contributing to the expanded use of the concept of sustainability learning in the literature on agricultural sustainability. In addition, Paper II characterized the sustainability learning process in Arctic Norway agriculture. Related to this, the thesis contributes by adding knowledge of learning processes leading to sustainability changes in agriculture. This has also been presented as a research gap in Lankester (2013). Finally, the framework adopted in Paper II proved valuable for revealing the characteristics of a sustainability learning process, which may be useful to other sustainability learning studies.

5.3 Recommendations for further research

As the concept of farm sustainability is broad, complex, and filled with uncertainties, there is an endless list of new research that could add knowledge to this concept. I list a few examples connected to content and perspectives, participation and learning, outcomes, and communication, as well as a recommendation to further explore the multilevel perspective of farm sustainability.

Advancing knowledge on what is to be learned, which is the essence of sustainability learning, requires a constant focus on new knowledge of all various themes and sub-themes

included in the sustainability concept relating to farm sustainability. This includes new knowledge regarding trade-offs and synergies between themes in various contexts and how time scale effects influence both themes and trade-offs between them. In addition, SAFA itself cannot be a static tool but should be in continuous development as well as being better contextualized into various empirical research settings. When expanding the number and types of stakeholders, new perspectives on farm sustainability emerge, which can give valuable insights into the concept of farm sustainability. Given that participation and cooperation are crucial in further advancing the concept of farm sustainability, there are countless research opportunities that can help strengthen knowledge on "what works," identify the best combination of stakeholders, and determine which methods fit better, including how double-loop learning can be enhanced to speed up the learning process.

Another suggestion for further research is that learning processes for farm sustainability should further strengthen the focus on the outcomes of such processes because these will ensure that the process is going toward the direction of enhanced sustainability. Restrepo et al. (2020) found that farmers' sense of progress toward outputs that have direct effects on their production systems sustained their motivation for continuing with the learning process. Paper III also revealed that the stakeholders were particularly involved in generating concrete outcomes. In addition, one challenge in transdisciplinary processes is that socially relevant outcomes are sought for both researchers and stakeholders. Therefore, a communication challenge emerges in connection with outcome generation, as research outcomes are seldom readily available outside research communities (Miller, 2013). Hence, for such research to be socially relevant, it must be translated to a common language between researchers and other stakeholders.

The final suggestion for further research is connected to farm sustainability as a multilevel concept. As this thesis takes a farm-level view, such a multilevel perspective is not explored in full. In the review of sustainability learning literature, the results showed that more systematic or holistic approaches are prominent (Scholz et al., 2006; Tabara and Pahl-Wostl, 2007; Burns, 2015; Sandri et al., 2018). Paper II also recommends that the framework utilized in that study be incorporated into agricultural innovation systems theory (Aerni et al., 2015). This could lead to a more systematic analysis of farmers' sustainability learning and add valuable knowledge on how to embed the process to achieve enhanced farm sustainability as "the way of farming".

5.4 Limitations

The study focuses on a remote area in the northern European periphery, with relatively few active farmers. Thus, it should be understood in connection with this contextual background. In the three studies discussed in this thesis, there have also been limitations addressed in each publication. Papers I and II were limited by the relatively small number of farmers and other stakeholders involved in the studies. Paper II also had limitations in the data-gathering phase of the study. This is because restrictions related to the COVID-19 pandemic prevented physical meetings, and all data gathering had to be performed through electronic communication. Paper III had a limitation related to the project itself; in particular, Northern Cereal's lack of academic representations in the disciplines of marketing and innovation weakened the project's transdisciplinarity. Paper III could have also benefited from an evaluation of a long-term sustainability learning process of Arctic Norway farmers (Section 1.3). However, this was not possible due to time and resource limitations during this PhD period.

The suggested research need, to further the research in more systemic ways, can also be seen as a limitation in this thesis (Section 5.3). The multilevel feature is of immense importance for farm sustainability, given that the latter cannot be enhanced in isolation but only through a long-term process within and enabled by the system. Not having this focus from the onset of the PhD may have restrained the findings. However, the detailed view found in this thesis could have been more difficult to achieve if set in a broader systems perspective.

5.5 Implications for policy and practice

To the best of my knowledge, no prior research has been undertaken on holistic farm sustainability in Arctic Norway. Therefore, this thesis contributes empirically to the literature on this topic. The knowledge developed may be of high interest to stakeholders and policymakers connected to agriculture in Norway, and even to a broader Arctic agricultural context (Natcher et al., 2021). In the following section, I will list a few examples of special interest. First, there is a need for new competencies and innovations connected to specific Arctic conditions. Second, the best place to start working to achieve enhanced farm sustainability is to focus on the governance dimension. Third, there is a need for improved contextualization of sustainability. Fourth, self-sufficiency issues should be of specific

concern, and fifth, participation and cooperation are key to sustainability and should be further strengthened.

First, a finding specifically connected to the Arctic Norway context is that new competencies and innovations tailored to distinct Arctic conditions, especially climatic and natural conditions, are needed to enhance farm sustainability. Emphasis should also be placed on the most threatening challenge to humanity so far: climate change. Related to this, there is an urgent need to establish measures to mitigate emissions and adapt to upcoming changes. Good examples presently found in Arctic Norway are the development of the climate calculator for farms in Norway and new production techniques (e.g., tunnel production) to overcome climatic challenges.

Second, regarding the process of furthering holistic farm sustainability in Arctic Norway, the findings show that a good place to start is to work on the governance dimension. This dimension has been shown to create a synergistic effect on the other three dimensions (Schader et al., 2016). Therefore, to strengthen the governance dimension of the farms may improve overall farm sustainability in the region. In Norway, there is a great focus on sustainability in the area of governmental policy, and farmers are required to comply with comprehensive documentation requirements. Papers I and II revealed that this is one of the reasons for the good sustainability performance in Arctic Norway's horticultural farms. Paper II also indicated that, through all these documentation requirements, many factors are put in place to ensure good governance in terms of sustainability. However, in Norway, both policies and documentation requirements are fragmented in terms of having a holistic sustainability focus (Bardalen et al., 2020). Thus, strengthening this at the national policy level is expected to enhance farm sustainability, as farmers are enabled by the policies that guide their practices. From prior examples in Paper II, such as implementing the Environmental plan in agriculture, such implementations can also lead to double-loop learning, thus resulting in heightened awareness. A more comprehensive sustainability focus on policy and documentation requirements may lead to a heightened awareness of farm sustainability. In Paper II, such heightened awareness is seen as both a prerequisite for, and a result of sustainability learning.

Third, the findings indicate that agriculture in Norway needs an improved contextualization of sustainability. Apart from this thesis, I am aware, or am a part of several initiatives for assessing or improving sustainability in processing companies, whole value chains, industry segments, or farming communities in Norway. These initiatives share the common task of

finding ways to overcome the initial hindrance of not knowing what sustainability means in their specific contexts. As SAFA is a thoroughly established and globally accepted tool for assessing sustainability in agriculture, it could be utilized as a basis for further contextualizing it to the specificities of the Norwegian agricultural context. In undertaking such a task, each initiative does not have to repeat these same initial establishment of indicators, but rather focus on actual improvements of sustainability.

Fourth, the uncertain times we are living in have heightened interest in enhancing the self-sufficiency of the Arctic Norway agricultural sector, which is closely related to the concept of farm sustainability (Bayr, 2020). To produce in accordance with the natural conditions for production is one of the main intuitive perspectives of sustainability of the farmers in Paper I. Furthermore, self-sufficiency in procuring seeds, seedlings, soil, and food products was a common theme throughout the workshop discussions in Paper II. Paper III also highlighted the possibility of expanded cereal production in the Arctic. Cereals can be produced in the Arctic; in fact, they have been produced in the region for hundreds of years. However, they are nearly no longer grown due to economic and/or political reasons. Limiting the hindrances of economic or political character can considerably increase the degree of self-sufficiency in Arctic Norway's agricultural sector.

The fifth and final suggestion relates to the finding that collaboration plays a prominent role in enhancing farm sustainability. This is a focus area that should be strengthened in the future. Papers I and II revealed that many valuable types of collaborations, such as farmers' networks, collaborations with various industries, and R&D collaborations. However, the continuing reduction in the number of farmers, which has been happening for several decades, threatens the possibilities for collaborations (Knutsen et al., 2020). Related to this, strengthening the possibilities that would allow farmers to continue their farming activities will also strengthen sustainability. The responsibility shared by all stakeholders connected to food production is that they must bring forward the needs in this regard and spread information about the benefits that can be gained by the nation from having local food production, security, and sufficiency.

6. Conclusion

In this thesis, I combined four research rationales: stakeholders' perspectives (Section 1.1.1), sustainability assessments (Section 1.1.2), sustainability learning (Section 1.1.3), and participatory approaches (Section 1.1.4), and performed three empirical studies (Paper I-III), to answer the MRQ, *How can farm sustainability in Arctic Norway be conceptualized as a learning process?* I have discussed the findings from the three papers against theories from the sustainability literature, sustainability learning literature, and literature regarding learning processes in agriculture. To conceptualize farm sustainability as a learning process, I utilized the framework proposed by Mascarenhas et al. (2021).

The first finding is that three overarching features frame farm sustainability in Arctic Norway. First, it is a long-term process that entails constant negotiations on trade-offs, synergies, and long-term effects, in which working for enhanced farm sustainability is a never-ending process. Second, it is a multilevel concept wherein farm sustainability develops concurrently with societal, political, and market developments, which can either impede or facilitate possibilities for enhanced farm sustainability. In particular, a stronger political commitment to holistic sustainability can enhance farm sustainability in Arctic Norway. Third, farm sustainability must be embedded in the very process of farm production, wherein the process itself should be a learning environment enabling holistic farm sustainability.

By further distinguishing farm sustainability in Arctic Norway as a learning process through the five questions outlined by Mascarenhas et al. (2021), I obtained several findings, as follows:

Why learn? External motivations connected to the economy serve as key driving forces. Enhancing internal motivations for holistic sustainability can further enhance farm sustainability, which can evolve in the course of the sustainability learning process.

Who to learn with? Farmers are the ones who will ultimately make the necessary changes on their farms. However, these farmers cannot bring about these changes independently. Several stakeholders must learn with them simultaneously, all driven by the aim of achieving enhanced farm sustainability.

What to learn? Understanding stakeholders' perspectives is a fundamental aspect of the process. Furthermore, including sustainability assessments further builds awareness of farm sustainability and serves as a starting point for learning. Context influences what to learn and, through trade-off discussions, best practices will gradually emerge.

How to learn? Collaboration is a key feature of farm sustainability and is a core strength of farmers. Using transdisciplinary methods maximizes the advantage of this strength and facilitates double-loop learning.

When to learn? The timing must be flexible due to the iterative nature of farmers' sustainability learning. Therefore, the process cannot be pre-described, as it depends on prior learning outcomes.

Theoretically, the main contribution of this thesis is that it adds knowledge on how to induce changes toward enhanced farm sustainability. Studies on this topic are lacking, according to Apetrei et al. (2021). Thus, the main novelty of this thesis is that it utilized present theories and expanded them by applying them in the three empirical studies (Papers I–III) discussed in this work, thus demonstrating the importance of combining "sustainability as a theory" and "sustainability as a practice." In particular, this thesis deepens academic understanding on how values and context influence farmers' sustainability learning, thereby indicating their importance in enhancing farm sustainability, especially given that contexts and values influence motivations for learning, what is being learned, and how it is learned. Furthermore, by combining sustainability assessments with a learning process—an idea that has yet to be implemented in connection to farm sustainability (de Olde et al., 2018)—this thesis reveals that such a combination enhanced the contextualization of farm sustainability and enabled farmers and stakeholders to concretize possible sustainability improvements. Finally, this thesis contributes to the literature by deepening the understanding of sustainability learning by utilizing the concept of sustainability learning in agriculture where it has not yet been utilized (Section 2.2.1.3), and by adding knowledge of learning processes leading to sustainability changes in agriculture, which is a research gap presented in Lankester (2013).

Recommendations for further research is diverse since there is a need to keep a constant focus on new knowledge on all the various themes and subthemes included in the sustainability concept related to farm sustainability, including new knowledge regarding trade-off effects. Adding to this is that SAFA itself cannot be a static tool but should undergo continuous development as well as being better contextualized into various empirical research settings. Another recommendation is to further strengthen research on the outcomes of such processes because these will indicate whether the process is going toward the intended direction of enhanced farm sustainability. In addition, to enhance farm sustainability in Arctic Norway, research should strengthen the multilevel aspects of the learning process, as this could lead to more systematic analyses of farmers' sustainability learning. In particular, this could add

valuable knowledge on how to embed the process to achieve enhanced farm sustainability as "the way of farming".

Given that no prior research has been undertaken on holistic farm sustainability in Arctic Norway, this thesis also makes an empirical contribution. First, there is a need for new competencies and innovations connected to special Arctic conditions, especially climatic and natural conditions. Second, the best place to start working toward enhanced farm sustainability is to focus on the governance dimension. This entails working toward a more comprehensive sustainability focus on national policy and documentation requirements, as farmers are enabled by the policies that guide their practices. Third, the agricultural sector in Norway requires the improved contextualization of sustainability, and SAFA is suggested as a base for this work (Bardalen et al., 2020). Fourth, the uncertain times we live in have led to a heightened interest in enhancing self-sufficiency in Arctic Norway agriculture, which is closely connected to farm sustainability (Bayr, 2020). To produce in accordance with the natural conditions for producing is one of the farmers' main perspectives of sustainability in Paper I. Thus, limiting hindrances of economic or political character can considerably increase the degree of self-sufficiency. Fifth, the reduction in the number of farmers is a threat to the possibilities for collaboration (Knutsen et al., 2020). Therefore, strengthening farmers' possibilities for further farming activities will strengthen sustainability.

A main message from this study is that to talk about sustainability, one must see it holistically. This is inherent in the definition of the concept (WCED, 1987; UN, 2015). Furthermore, seeing "relationships, interdependencies and [the] whole" has been proposed as the solution to the notion that sustainability is a "wicked" problem (Wals, 2015a, p.28). In this regard, the issue of time is, perhaps, the most challenging aspect of sustainability. Learning processes and most democratic participatory processes take time (Wesselink et al., 2011). The problem is that in urgent matters, such as climate change and loss of biodiversity, we do not have the privilege of time. This is also related to the notion that sustainability learning should lead to radical or paradigmatic change (Section 2.2.1). Although we already know and acknowledge the severity of the many challenges connected to sustainability (e.g., climate change), regarding the sustainability of farms in Arctic Norway, it remains difficult to see how this can radically change at present. First, farming is based on traditions, on connections to the land, and on long-term natural processes. Second, the idea of farmers working toward sustainability changes implies long-term commitment to, for example, making investments for improved infrastructure or better agronomical practices, such as crop rotation and grafting.

Third, farm sustainability is highly dependent on policy and market requirements. Because of this, I believe farm sustainability will mainly appear as gradual change. Nevertheless, the findings in Paper II have shown that, due to double-loop learning, larger changes do occur, especially if observed over a longer time period.

Looking back at the history of Arctic Norway farming, paradigmatic changes have also occurred. The dramatic changes in agriculture, starting in the first half of the 20th century, with its technical and agronomical advancements, occurred in parallel with radical economic, political, and social changes (Ladstein og Skoglund, 2008; Brox, 2016; Knutsen et al., 2021). As policy, societal, and market factors influence how sustainable a farm can be (Darnhofer et al., 2012; Darnhofer et al., 2017), farm sustainability could only emerge as a radical or paradigmatic change if it is aligned with radical changes toward enhanced sustainability in society at large.

7. References

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8. Appendix

Appendix 1. Summary of the reviewed publications in the sustainability learning literature review found in 2.2.1.

Reference	**Main content of the study informing the literature review**
Scholz et al., (2006)	Transdisciplinarity is suggested as the main mode for sustainability learning, as a process of mutual learning and joint real-world problem solving.
Tàbara and Pahl-Wostl, (2007)	Sustainability learning in an integrated complex systems perspective, where social learning, enables "*a completely new way of thinking and a radical change in values*".
Sipos et al., (2008)	Connecting sustainability education and transformative learning into the concept of transformative sustainability learning with the 'head', 'hands' and 'heart' principles.
Thomsen, (2008)	Empirical study monitoring and improving a local community through sustainability learning in a combination of experiential learning, social learning and action.
Hansmann et al., (2009)	Empirical study of sustainability learning in a transdisciplinary case study in a higher educational setting.
Hansmann, (2010)	An introduction to the definition, origin and content of sustainability learning, with special focus on motivational aspects.
Polk, (2011)	Empirical study on capacity building in urban planning through sustainability learning that is connected to systems thinking, double loop learning and participation.
Wolf et al., (2011)	An interdisciplinary case study connected to the concept of sustainable universities where sustainability learning entails mutual learning.
Fabricatore and López, (2012)	Studying sustainability learning through gaming, finding that it should be designed with complexity, promoting complex systems thinking concerning sustainability issues.
Tàbara and Chabay, (2013)	Sustainability learning feedback loops between Human Information and Knowledge Systems and social–ecological systems require a change in worldviews.
Stakhanov et al., (2013)	Sustainability learning studied as social learning within a system, in conservation and development projects.
Bull, (2013)	Since it is vital to use transformative sustainability learning also in non-formal ESD settings, this study uses this concept in an forestry case study.
Heras and Tàbara, (2014)	Sustainability learning by transformative learning to foster social reflexivity through theater.
Marcus et al., (2015)	Describing a university's sustainability learning pathway enabling holistic systems thinking, sustainability knowledge, awareness and integration and acting for change.
Wiek and Kay, (2015)	Sustainability learning in real-world settings through solution-oriented programs that are competencies-based and experiential, allowing 'learning while transforming.'
Vilsmaier and Lang, (2015)	Sustainability learning through students' transdisciplinary work with boundaries (*as demarcations of differences*), where the goal (not method/theory) define the research.
Burns, (2015)	Show how sustainability pedagogy as a tool for transformational sustainability learning influences learning and its impact.
Heras and Tàbara, (2016)	Sustainability learning depends on participatory processes including diverse perspectives with new forms of interaction to implement collective decisions.
Heras et al., (2016)	Sustainability learning requires competence for the co-construction of transformative visions of the future, linked to action.
Barrett et al., (2017)	Transformative sustainability learning involving a deep structural shift, including many levels of learning and unlearning, within systems thinking.

Harmin et al., (2017)	Sustainability learning through transformative learning enabling critical reflection on frames of reference by engaging in Bateson's third order of learning.
Duarte, (2017)	Empirically finding that sustainability learning requires systems thinking, informed discussions among managers and employees, and a sound leadership.
Ofei-Manu and Didham, (2018)	Characteristics that support effective sustainability learning (in higher education) performance towards the UN sustainable development goals.
Lavrysh, (2018)	Implementation of transformative sustainability learning involve changes in the content of a curricula as well as in the paradigm of teaching and knowledge acquisition.
Hill and Wang, (2018)	Utilizing a transformative sustainability framework an outcomes-based curriculum for sustainability was created.
O'Neil, (2018)	A performative transformative learning process for sustainability where learning is "doing-in-action or "*in essence, it is living*".
Sandri et al., (2018)	Study on how to measure sustainability learning outcomes in higher education that develops students' abilities to respond to, and act on, sustainability challenges.
Wang and Teng, (2019)	Promoting transformative sustainability learning to foster students' transformative abilities for sustainability.
Probst et al., (2019)	Analyze if transformative learning with a transdisciplinary learning design can contribute to developing sustainability attitudes, skills and agency.
Emblen-Perry, (2019)	Sustainability learning combining experiential, active, participatory and reflexive learning embedded in real-world businesses to promote sustainable futures.
Greig and Priddle, (2019)	Both cognitive and non-cognitive dimensions are present in transformative sustainability learning with the goal of creating a sustainable future.
Trott, (2019)	Collaboration with children in a transformative sustainability learning model facilitating personal experience for participants.
Wilson and Pretorius, (2020)	Sustainability learning through exposure to real-world issues and contexts for building strategic knowledge, practical knowledge and collaborative efforts.
Edwards et al., (2020)	Developing sustainability learning curricula necessitating interdisciplinarity where participatory inquiry and practice can generate change.
Natkin and Hill, (2020)	Sustainability is interdisciplinary, and, ought to be taught across the curriculum, with a flexibility in the learning-outcome based sustainability requirement.
Orr et al., (2020)	Learning through sports: transformative sustainability learning designed to include critical thinking, kinetic experience and reflections on psychological connections.
Pereira et al., (2020)	Sustainability learning in companies is long-term actions in a holistic approach through learning loops resulting from experiences when implementing sustainability initiatives.
Aboytes and Barth, (2020)	Transformative learning is widely used in the field of sustainability, and it shares common elements with both experiential and social transformative learning.
Koh and The, (2020)	University community partnership as a key to sustainability, where a university should deliver sustainability learning outcomes to students and to serve the society.
Goldman et al., (2021)	Empirically studying sustainability learning at a waste treatment facility, by implementing the "heads, hands and heart" of transformative sustainability learning.
Hermelingmeier and von Wirth, (2021)	Sustainability learning for business transformations, triggering change through deutero learning scope, societal learning scope and cooperative advantage objective.
Noy et al. (2021)	An educational framework for teaching sustainability in an interdisciplinary context through systems thinking and transformative sustainability learning.
Pretorius et al., (2021)	Empirical study of e-learning, since sustainability learning requires alternative pedagogies to engage students through participation, critical thinking and reflection.

9. Papers

Papers I-III

9.1 Paper I. Sustainable value: the perspective of horticultural producers in Arctic Norway

Halland, H., Bertella G., and Kvalvik I. (2021a). Sustainable value: the perspective of horticultural producers in Arctic Norway. International Food and Agribusiness Management Review: 24 (1), 51–70.

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Sustainable value: the perspective of horticultural producers in Arctic Norway

RESEARCH ARTICLE

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Abstract

Aiming for sustainable development of food value chains several assessment methods are developed, however it seems challenging to go from assessment to actual change. A solution proposed is increased stakeholder involvement also in the assessment phase. The perspective on sustainability varies depending on several variables, among which the geographical context where the producers are located. The perspective of the latter is of paramount importance as these are the actors on who, ultimately, possible changes towards sustainability depend. In this article, we applied a qualitative approach to investigate the farmers' perspective on sustainability, in the horticultural production in Arctic Norway. We found that many of the premises for sustainable food production are present. The main challenges are lack of long-term planning, dependency of rented land as well as fluctuating yield and income. Producer's network is essential for development as well as introduction of technical improvements. The study shows the importance of contextualisation of sustainability, as well as pointing at concerns about trade-offs between sustainability dimensions and themes in the proposed model. The research contributes to method development by demonstrating how a qualitative approach is a fruitful method to unravel the complexities of sustainability in food production.

Keywords: sustainable food production, SAFA, farmers' perspective, horticulture, arctic food
JEL code: Q01

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1. Introduction

Although a debated term (Mooney and Hunt, 2009), 'sustainability' is said to be a 'consensus frame' (Brunori *et al.*, 2016), meaning that it is something that we all find to be true and good, and kept in general terms, it is something that everyone can agree on. A plan for sustainable development includes both a timeframe and a broad focus covering the three dimensions 'economic growth', 'social inclusion', and 'environmental protection' (first defined in Brundtland, 1987). For food production the United Nations sustainability goal number two states that, 'it is time to rethink how we grow, share and consume our food' (UN, 2015). The same document stresses that the success of its implementation will depend on countries' own sustainable development policies, plans and programmes, and that all stakeholders are expected to contribute.

Food value chains are complex interconnected systems – no part of the food chain acts in isolation. Any decision at any level has a wider impact (Albajes *et al.*, 2013). With the aim to drive food value chains (as defined in FAO, 2014a: 6) towards sustainability several assessment methods have been developed; however, these assessments have not yet spurred changes that contribute to improved sustainability in the food value chains (FAO, 2014b). To ensure positive impact, improved stakeholder involvement as well as to utilise context-specific approaches is suggested (Alrøe *et al.*, 2016). Farmers are key stakeholders in agricultural value chains and their perspectives on sustainability may serve as a bottleneck to develop the value chain in a sustainable manner, being a core actor to take action to improve farm sustainability (De Olde *et al.*, 2016).

The complexities of food production and the food value chain can be challenging to reduce to indicators for quantitative calculations (Migliorini *et al.*, 2018). Galli *et al.* (2016) therefore claim that it is useful to evaluate sustainability as stakeholder perceptions. To unravel the farmers' perspectives, qualitative methods give a rich material to analyse, and Galli *et al.* (2015) concluded that this methodology can: 'help identify issues to deal with and critical gaps, thus representing a starting point for further empirical research'. To understand the perspectives of the key stakeholders in the value chain, with their hands-on practical and theoretical knowledge, will provide a good basis to look at strengths and shortcomings on the road leading to a more sustainable production.

In this article, we contextualise the farmers' perspective of sustainability in relation to horticultural production in Arctic Norway that includes the three counties Nordland, Troms, and Finnmark. Farming in Arctic Norway is challenged due to a short and cool summer season, however climatic change is predicted to give longer growing season but worsening the harvesting conditions due to increased autumn precipitation (Uleberg *et al.*, 2014). Other challenges are long distances to market, their dependence of rented land, small areas due to topographic features that make large scale farming challenging. However, the technical developments have been considerable, and a determinant for further expansion in a high-cost and climatically challenged area like Arctic Norway.

The research question is: What is the horticultural farmers' perspective on sustainability in Arctic Norway? In this paper 'perspective' describe how a person in his or her particular context understands the world. To be able to investigate the research question we used the Sustainability Assessment of Food and Agriculture systems (SAFA) guidelines (FAO, 2014b) as a starting point, and conducted semi-structured interviews, where the questions were broad and open, and the interviewee to a large extend could define the content. With the new knowledge gained, we aim at identifying the most important challenges for improved sustainability of horticulture production in this specific context, as well as looking at the interrelations between the dimensions and issues. Based on this we will provide policy and practitioner's recommendations for improved sustainability of horticulture production in Arctic Norway. In addition to these empirical aspirations, the article contributes to method development by using a qualitative approach to unravel the farmers' perspectives where the qualitative analysis contributes by contextualising the SAFA themes.

The rest of the article is organised as follows, in part two we clarify our theoretical framework that will make the basis for later discussions. Part three comprises the method section where we also include a section

on the empirical context. Part four includes our findings from interviews with farmers, and discussion and conclusion are found in the last two parts.

2. Theoretical framework

2.1 Sustainability in food production

To try to answer what constitutes sustainable food production, there have been a considerable emphasis on developing sustainability assessments, with an implicit goal to assess the gap between the existing situation of food production and the desired situation (Brunori and Galli, 2016). Gaspartos *et al.* (2008) claim that a sustainability assessment ought to integrate all three dimensions of sustainability, consider future consequences and uncertainties of actions, and engage the public to insure impact. This complexity implies that there is not one single method that can give the complete answer (Alrøe and Noe, 2016; Alrøe *et al.*, 2016; Brunori *et al.*, 2016; Gaspartos *et al.*, 2008). Food production is especially complex due to its dependence on environmental conditions, like the quality of their soil and on climatic conditions. Socioeconomic factors are also broad since food production and its value chain affect, and is affected by, rural communities and government, and contain value-adding activities towards the consumers (Alonso, 2015).

A timeframe is implicitly built into the definition of sustainability and is therefore also an important part of sustainability assessments. This factor is however not unproblematic and is discussed in research. Bond and Morrison-Saunders (2011) found this as the most problematic issue concerning sustainability assessments, since 'there is no consensus on what appropriate timescales should be'. In sustainable agricultural production the notion of the timeframe is crucial, for instance a destructed topsoil takes thousands of years to regenerate, surplus CO_2 emitted only accumulates in the atmosphere continuing to cause global heating basically infinitely and plastics basically never disappears since it only will break down in smaller pieces. Aiming for a sustainable production can therefore never be a short-term project.

What sustainable food production is, depends on the context, both geographical as well as on socio-cultural factors. In assessments, the choice of indicators and the weight put on each indicator will depend on local conditions (Alrøe *et al.*, 2016). Therefore, according to Schmitt *et al.* (2016) when performing an assessment, it is important to have knowledge about all flows and actors in the chain, geographical factors as well as economical and socioeconomical factors. With an extensive knowledge of the context the researcher can understand how the context effects the performance in the value chain (Schmitt *et al.*, 2016). Coteur *et al.* (2016) find that each individual agricultural sector operates in different contexts, depending on 'the farm type, the attitude and skills of a farmer or advisor', and their analysis shows that context plays a major role when conducting sustainability assessments of farms.

In addition, as research progresses and we gain more knowledge, as well as when new concerns emerge in society, the thought of what sustainability is, is changing (Alrøe and Noe, 2016). A quote from Brunori *et al.* (2016): 'sustainability is not a status to achieve, but a never-ending process' summarises this challenging task.

2.2 SAFA in research assessing the sustainability in food production

The Food and Agricultural Organisation (FAO) has developed a comprehensive framework and indicator-based tool called Sustainability Assessment of Food and Agriculture systems (SAFA) (FAO, 2014b). This tool includes a guideline and a thorough book of indicators with descriptions including relevance, unit of measurement, how to measure it, rating and its limitation. SAFA uses a widely accepted language for sustainability for it to be globally applicable. SAFA also includes a fourth sustainability dimension: governance. In addition, governance is seen as a horizontal dimension that relates to the other three dimensions since management is very important for ensuring adequate sustainability performance in farms/companies (Schader *et al.*, 2019).

Because of its comprehensiveness, data to assess the various indicators can be limited, or might take considerable time and resources to obtain (Jawtusch *et al.*, 2013). Jawtusch *et al.* (2013) stress the importance of the expertise of those who conduct the assessments and interpret their results.

SAFA is however widely utilised and Boinisoli *et al.* (2019) made an overview of studies that implement SAFA methodology. They found that SAFA was utilised in various ways, from complete sustainability assessments to sustainability assessments using some of the indicators. They also noted that both qualitative and quantitative methods were utilised in these studies, and that the results were mainly visualised in a spider web graph where the chosen sub-themes were graded according to its level of sustainability performance.

One of the steps in SAFA is 'contextualising the particular study'. This is done in different ways in empirical studies. In a large EU-project GLAMUR (EU, 2016), (Brunori *et al.*, 2016) they chose to change and expand the number of dimensions to five; 'Economic', 'Social', 'Environmental', 'Health' and 'Ethical', identifying 24 sustainability attributes connected to these dimensions. In each case-study (in total 39 value-chains) between 4 and 9 of these attributes were investigated further through both qualitative and quantitative measures. Theurl *et al.* (2017) identified 13 factors characterising winter harvest systems in Austria, and Al Shamsi *et al.* (2018) used 7 themes divided into a total of 20 indicators to assess the food sovereignty in Sicily and United Arab Emirates. The SAFA framework thus allows the selection of relevant themes and indicators from an extensive list. This way the assessment will be tailored made for each study.

2.3 Stakeholders in assessments – values and involvement

Much research emphasize that assessments fundamentally are based on values (Alrøe and Noe, 2016; Gaspartos and Scolobig, 2012; Thorsøe *et al.*, 2014). A challenge in assessing sustainability in food value chains is stakeholders' different values and different thoughts about what constitutes sustainable food production and a sustainable food value chain. Some of these differences are due to the stakeholders' different interests. Some stakeholders are involved in producing raw material or processing foods, some are involved in transport, we are all consumers, and most of us are influenced to varying degrees of different effects in the life cycle of food (Alrøe *et al.*, 2016). If the underlying values in the assessment are unknown, overlooked or where values are incompatible, two main problems arise: wrong measurements, and no impact on the transition towards sustainability due to failed policy being adopted. The environmental researcher Donella Meadows, goes as far as warning that choosing wrong indicators to measure sustainability by can cause serious errors (Meadows, 1998). This can happen for instance if policy makers are making plans for sustainable development based on distorted results leading to for instance unsustainable food production, or according to Gaspartos (2010) might lead to both political cost and economic loss. A challenge can also be that the assessments are not measured in a way that is understandable to end users (Gaspartos, 2010).

To make sustainability assessment reach their potential, sustainability assessments should consider the values of the different stakeholders (Gaspartos *et al.*, 2008). Stakeholders are defined as 'those who will bear the consequences and carry out actions for change' (Alrøe and Noe, 2016). The range of stakeholders are particularly varied when environmental issues are concerned (Govindian, 2017). Stakeholder involvement ensures that 'the 'right problem' gets addressed in 'the right way'' (Maasen and Lieven, 2006). Involvement is considered especially important in issues concerning sustainability since this in its nature is context bound and needs to be translated as well as implemented by a variety of stakeholders for change to occur (Triste *et al.*, 2014). Triste *et al.* (2014) list four advantages stemming from stakeholder involvement: increased awareness of problems and possible solutions from the actors that will need to implement the changes, more accurate holistic outcomes when including several viewpoints, increasing support for the assessment results, as well as learning opportunities.

2.4 Farmers' perspectives on sustainability

In an agricultural food value chain, a key stakeholder would be the farmer. The farmer will to a high degree affect how sustainable the other actors in the value chain will be able to perform or how consumers will value the food products. The farmer will also bear the consequences of an unsustainable practice, both in a short and long term. Coteur *et al.* (2016) writes that farms' aim for sustainable farm practices is the premise for improved sustainability in the food value chain. In addition, the farm level is a main driver for sustainable rural development (Schader *et al.*, 2016).

If the farmers do not know what constitutes a sustainable production, i.e. a consciousness of the combined effects of economic, social and environmental factors, this hampers the world-wide strive towards sustainable food production. Bonisoli *et al.* (2019) in their study did not find a deep interest amongst the producers about sustainability of the local agriculture. Also, Schader *et al.* (2016) stresses that 'in order to enable farmers to make sound decisions, all dimensions of sustainability need to be considered'. Knowledge about what comprises a holistic sustainable production then needs to be present.

Schader *et al.* (2014) claim that there are two prevalent perspectives on the term sustainability in food and agricultural research; the business or farm perspective that describes 'whether the farm is able to sustain itself for an extended period of time', or the societal perspective that describes 'whether a farm contributes to a sustainable development of society' (Schader *et al.*, 2014). However, investigating various assessment methods Schader *et al.* (2014) found that the different methods tended not to have a clear distinction between the two perspectives. But, in their studies on farm sustainability, Coteur *et al.* (2016) find that the importance of using assessments that focus on farm development is emphasized by farmers

Qualitative methods have the advantage of giving a rich material to analyse, which allow the researcher to unravel the farmers' perspectives on sustainable food production. Such studies can reveal very valuable knowledge about how actors view sustainability and can be important for understanding how to ensure impacts from assessment results, as well as to identify critical issues and trade-offs (Brunori *et al.*, 2016). In addition, the social dimension seems difficult to capture in a quantitative way (Brunori and Galli, 2016; Röös *et al.*, 2019). De Olde *et al.* (2017) find that different assessments cause different results, and when selecting an existing tool, indicators and procedures are predefined. With semi-structured interviews the questions are broad and open, and the interviewee can, to a large extend, define the content. When choosing a more participatory process, semi-structured interviews can ensure that misinterpretations of the results is avoided (Schmitt *et al.*, 2016).

3. Methods

The empirical part of this study concerns the horticultural farmers in Arctic Norway. This case is chosen since little research is conducted on the sustainability of Arctic horticulture, and due to governmental focus on increasing this production. The main author's 20-year experience as a project leader in this field as well as on her educational background in horticulture, provides a good understanding of the context and the related peculiarities. Positioning herself as a competent and concerned researcher has enabled her to establish and further develop good trusty relations with the farmers and local food producers contacted for this study. Her involvement in the field responds also to the call for inquiry methods where action and engagement are viewed as particularly valuable for transition towards sustainability (Eksvärd, 2010).

3.1 Case studies with in-depth interviews with key stakeholders

This study takes a qualitative approach to gather a rich insight into the research topic and context. The method chosen to understand our cases is in-depth interviews with farmers about their perspectives on sustainability. In this study, semi-structured interviews were chosen, meaning that the topics and main questions is defined before the interview session, but leaving room for deviating from the interviewer's

guide to pursue interesting topics that may arise in the interview situation (Justesen and Mik-Meyer, 2010). As a background for developing the interview guide, the SAFA guidelines (FAO, 2014b) were utilised. Here the concept of sustainability is divided into four dimensions: 'good governance', 'economic resilience', 'social well-being', and 'environmental integrity' (Figure 1). And, divided into 21 themes and 58 sub-themes.

The themes used in the currents study were selected after an initial mapping of the value chain, utilising agricultural statistics, national policy documents, reading various project reports, as well as using our extensive knowledge about the value chain in question. The result from contextualising the horticultural production in Arctic Norway was that we kept the four dimensions in SAFA, including having the 'good governance' dimension as a horizontal principle especially important for the performance in the other dimensions. We initially selected 15 themes (Table 1) that we considered relevant, and used this as a base for the interview guide. We chose not to include themes in SAFA that we considered more relevant to companies than farms, for example 'accountability', 'corporate ethics' and 'rule of law', as well as themes not considered relevant for the Norwegian context or in horticulture such as 'cultural diversity', 'fair trading practices' and 'animal welfare'. 'Initially participation' was put in the 'social well-being' dimension, since we regarded it primarily as farm interaction with society. Other themes were included, or rewritten from Figure 1, for instance the themes 'future prospects' and 'local society'.

To get a representative selection for the interviews we turned to the statistics from the Norwegian Agriculture Agency's list of subsidies receivers related to land use in 2017. We selected farms that had production volumes estimated to give a significant portion of an annual salary for one person, and found 58 horticultural producers that produced either more than 2 hectares potatoes, 1 hectare vegetables or 0.5 hectares berries/fruits. We also wanted to interview farmers from all three production systems; berries, vegetables, and potatoes, as well as having a geographical distribution in the Arctic region, and a variety of end-markets

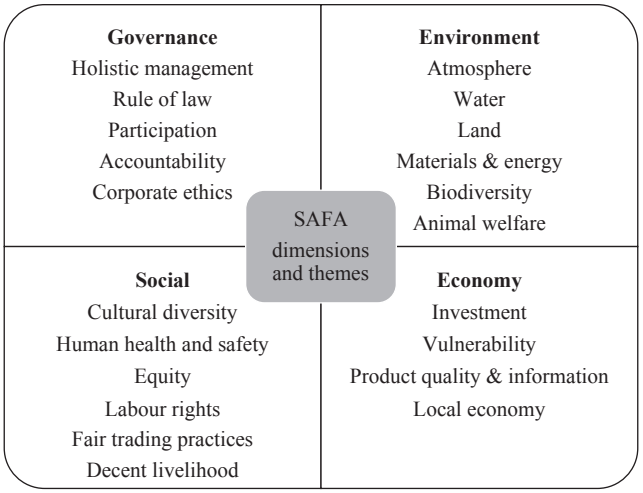

Figure 1. SAFA dimensions and themes.

Table 1. SAFA dimensions with themes contextualised for this study.

Good governance	Economic resilience	Social well-being	Environmental integrity
holistic management	local economy	local society	energy
future prospects	vulnerability	participation and network	waste and recycling
	long-term profitability	labour condition	soil
	product quality	health and safety	water
			biodiversity

for their products ranging from sales based on customer 'self-harvest' to selling through a wholesaler. In addition, we interviewed only conventional producers since only 5 of these 58 producers were certified for ecological production. Considering this, we selected ten farms for the interviews (Table 2).

Geographically the farms were located in Nordland and Troms County. The ten interviewed farmers produced about 40% of the total potato area in Arctic Norway and about 20% of the total area utilised for berries and vegetables (Table 3). In addition to interviewing the farmers we also had an initial interview with the regional wholesaler. The interviews were conducted from June-September 2019.

Apart from one interview, which was made by telephone, all interviews were conducted in person by the main author. The interviews were recorded and later transcribed, and the anonymity of each interviewee was sought by leaving out names or places that could identify the specific farm. The interviews were set to last about one hour, and the interview guide was divided into three parts. Each interview started with initial talks about the general background of the farm/company. The producers were then asked what sustainability means to them, and how questions pertaining to sustainability affect the production on the farm/in the company. Finally, more detailed questions concerning the selected themes from the SAFA guidelines were discussed. This third part took about 2/3 of the time allocated to the interview. The transcribed interviews were coded in NVivio 12 (QSR International, Burlington, MA, USA). The analysis was focused on content analysis were both the content (farmers' perspectives on the various themes) as well as the context were analysed. The analysis also focused on identifying interactions between the perspectives on the various themes and dimensions, as well as on drawing implications from these analysis on policy development for the specific context.

Table 2. Interviewees main product(s) and age.

Company / Farm	Potatoes	Vegetables	Berries	Other income	Interviewee	Age
C1	wholesaler				C1a	35-55
					C1b	35-55
F2		x	x	external work	F2	<35
F3		x		livestock	F3	<35
F4	x			livestock	F4	>55
F5		x		livestock	F5	>55
F6			x	livestock	F6	>55
F7	x			livestock	F7a	>55
F7					F7b	35-55
F8			x	external work	F8a	>55
F8					F8b	35-55
F9			x	tourism	F9	>55
F10	x	x		processing	F10	35-55
F11	x			external work	F11	35-55

Table 3. Production on the interviewed farms compared to the total number of horticultural farms in Arctic Norway.[1]

	Potatoes	Vegetables	Strawberries	Other berries
Total production in Arctic Norway	428 ha	46 ha	15 ha	9 ha
The 10 interviewed farms – production	82 ha	18 ha	3 ha	2 ha

[1] Data from 2018, production-subsidies for agricultural companies. Available at: https://data.norge.no

3.2 The context – the horticultural value chain in Arctic Norway

Since 2001 there has been an increased focus on developing the local food value chains in Norway. Increased value creation locally was the aim in the beginning of this period, but later governmental documents focus increasingly on sustainable production. The White Paper 11 (Norwegian Ministry of Agriculture and Food, 2017) emphasizes that increased agricultural production should be based on Norwegian resources, and the White Paper 39 (Norwegian Ministry of Agriculture and Food, 2009) states that Norwegian agriculture and food production shall be conducted in a climate-friendly manner. Since the Agricultural negotiations in 2012 the government earmarked has funds to support development of 'Arctic agriculture', and in the agricultural negotiations in 2019 there was an agreement to nationally establish a special focus on the horticultural sector to increase production and demand for Norwegian-produced horticultural goods.

Plant production in Arctic Norway is challenged due to a short growing period and cool summer temperatures, however the 24-hour light period in the summer compensates for some of the lack of warmth in the growth period. Due to climatic change a prolonged growing season is expected due to higher average temperatures, however increased precipitation in the autumn worsening harvesting conditions is also expected (Uleberg *et al.*, 2014). Artic Norway is geographically a region characterised by long distances where transport and logistics are a considerable cost for the producers. One of the main traits is that the farmers are dependent on land rental, since the ownership structure is such that there are many landowners, few farmers, and small land units (Kvalvik *et al.*, 2011). Due to this, in addition to topographical factors where only 3.6% of Arctic Norway area is arable, large-scale volume production is challenging. Another challenge is that there is only one wholesaler receiving potatoes and vegetables left in the region. Table 3 shows the total production area in 2018.

The technical developments have been considerable, and a determinant for further expansion in a high-cost and climatically challenged area like Arctic Norway. Improved plant material and planting procedures have also altered the possibilities for production in this region. A challenge is that specialised production puts great demand on the competence of the producer as well as on the need for larger investments in greenhouses, production tunnels for berries, and specialised equipment for agronomical operations, sowing and harvesting.

In general, the agricultural sector in Norway is strongly regulated by law in issues concerning worker rights and wages, health and safety, accounting and audits, etc. The specific issues concerning quality control in agricultural production is found in the 'Quality system for the Agriculture'[1] where every farmer must submit annual self-audits and where demands for documentation is high.

4. Findings

4.1 Farmers perspective on the concept of sustainability

To get information about the initial and intuitive perspective, the farmers were asked about their understanding of the concept of sustainability and how they relate this understanding to how they run their farm. This was done to gain insights into how farmers relate to this societal goal for food production in general, what dimensions of sustainability they were concerned about and how this affected their production.

The main impression is that the term is not something that they use much in their everyday life and work, however a common acknowledgement is that: 'the word itself, you don't hear it every day, you do it automatically' (F2). Several of the farmers also point to the concept as being very wide, and something that can be misused: 'it becomes an empty phrase, such as politicians use' (F9). In addition, one farmer mentions a frustration among farmers since: 'for many farmers it is difficult to understand, to be defined as a 'climate-bad-guy', because it is so far from what one feels like engaging in food production' (F7b). When asked what

[1] Kvalitetssystem i Landbruket, available at: www.matmerk.no/no/ksl/om-ksl

they would include in the concept sustainability responses from all the ten farms included the 'environmental' dimension, seven included the 'economic' dimension and five included the 'social' dimension. Four of the interviews included all three dimensions. In the 'economic' dimension the farmers focus on gaining a positive economic result for their farm as well as discussing socio-economic factors. In the 'social' dimension the farmers talk about buying local goods and services, using local resources and discusses the social benefits of their production. Then, in the 'environmental' dimension the farmers focus on issues related to maintaining the natural resources, especially in connection to agronomic practices, and to produce what they have the best natural conditions for producing. Having a long-term focus is also mentioned here.

All farmers relate their understanding of the concept 'sustainability' to the management of their farm. Sustainability is mainly related to economic and environmental issues and often these issues are set up against each other as a balancing compromise: 'it should sustain my economy, that can be superior, but it should also be seen in relation to the environment and that part' (F4).

4.2 Contextualising sustainability in horticultural production in Arctic Norway using SAFA

After the general discussions about the concept 'sustainability', the questions based on the SAFA framework were discussed. The main findings in each dimension are presented in the following sections.

■ *Good governance*

Good governance relates to farm management. Two themes were considered relevant in the context of horticulture production in Arctic Norway: 'holistic management' and 'future prospects', and our findings show that both themes are considered important for the overall sustainability on the farm, and that there are potential for improvements in both.

All the farmers interviewed wanted continued production on the farm, but several factors challenge this wish. We also find age differences, where older farmers are concerned since continued production relies on new farmers taking over the production when the farmer wants to retire. Traditionally, the children continued farm production after their parents, but were the children do not want to take over an extra concern for the future production is present. This kind of uncertainty put strains on the possibilities to plan long-term and for leading the farm in a direction suitable for the ones who will take over: 'it is a bit difficult now when it is getting so close to the finish line (…) is it sustainable to invest in a tractor for two years, or in a seed drill, should I rent that service until things are more clear? Then it becomes even more difficult for the person who is considering taking over, to make that choice' (F5). Dependency on rented land can also be a challenge on the ability for long tern planning, and is a special concern for one of the farmers: 'this year the plan was to only have turnip and some root swede, but then I got hold of more land, and then I had more. But next year, what do I get then?' (F2). On one of the farms, another uncertainty about continuation is that there is only one wholesaler left in the region, leading to very long transportation of their potatoes, and they are questioning the sustainability in that.

A second point important for the 'governance' dimension is how the farms are run, plans made and followed up. From the ten interviewed farmers we perceive a lack of long-term planning, especially plans that are more formalised in writing**.** However, this seems to work since as one farmer says jokingly: 'well, mainly it is just myself in the management, so it works well' (F10). However, when it comes to the economical part more written plans are made, and, especially when larger investments are needed**.** In addition, the high requirements for rule of law documentation also leads to an enforcement for planning.

■ *Economic resilience*

Economic resilience relates to economic issues on the farm. Four themes were considered relevant in the context of horticulture production in Arctic Norway, 'local economy', 'vulnerability', 'long-term profitability', and 'product quality'. For the 'local economy' we find that this theme is closely related to 'local society' under the 'social well-being' dimension. Our findings show that 'vulnerability' and 'long-term profitability' are highly related, and one of the main focuses for the farm practices and for the farms ability to work on overall sustainability. The theme 'product quality' is a continuous work for the farmers and for the wholesaler, but can also be included in the theme 'long-term profitability'.

The farmers seem to agree that there is quite good money to be earned from horticultural production in Arctic Norway: 'I would never produce potatoes if it wasn't money to be earned from it' (F7b). However, horticultural production in Arctic Norway can be a risky business and the yield and the revenue fluctuates**.** The production subsidies are area based and for horticultural crops, in addition, based on yield. Since the area is small for many of the producers, especially in berry production, if the yield is low there is very little security in the governmental subsidies. The fluctuating yearly income means fluctuating taxation and one of the farmers suggest the horticultural industry should consider: 'to put some in a fund (…) for the bad years, as in forestry, they have five years average income tax returns' (F10).

The horticultural farmers are closer to the market than producers of meat and milk**.** Of the interviewed farmers, six sell the main part of their produce to the wholesaler. Selling to a wholesaler reduces some of the risks, and the work with selling and processing their production: 'if we didn´t have the guarantee of market access through the agreements with (the wholesaler) then we would never have taken such risks on our own' (F7b). These farmers make only one-year detailed production plans with the wholesaler, and this could lead to some uncertainty. However, since there is a potato deficit in Arctic Norway this is not a big concern for the potato producers. For the vegetable producers selling to the wholesaler the market situation has been more unpredictable. The produce that is not sold through the wholesaler is sold directly from the farm either to shops, horeca or directly to the customers. This is how all the berries are sold, where two of the producers rely for a large part on 'self-harvest'. One challenge mentioned is selling their products to the supermarket when they at the same time has price dumping on horticultural produce selling berries, potatoes or vegetables for a very low price to attract customers. For the produce sold directly to the customers, it seems that price is of less importance. Some of the vegetables produced is sold at direct markets and this can give a much higher income per weight, however, the work load can be high.

Much of the business models are chosen with the aim of reducing the risks from horticultural production and securing long-term economic surplus for the farm. All the farmers practice various ways for the farmers to secure income. On five of the farms horticulture production is combined with livestock: 'milk and meat production are the base, the stable, and then the other is gambling, like a 'Lofot-fishery', you can do well and you can do badly' (F7a). Having a combination with livestock especially, is crucial for being able to employ year-round full-time workers on the farm. Four of the interviewed farmers also rely on income from external jobs**.**

Product quality and improved processing is an important issue in the economical dimension, to ensure that as much of the produce as possible can be sold for human consumption and as high-value products. For products that are only utilised fresh, as the local turnip, the percentage wastage is high, but for products that can be processed, such as root swede that is peeled and processed the percentage wastage is lower. For field-grown berries, the weather conditions to a high degree, determines how much berries are wasted**.** When selling through a wholesaler the quality criteria for fresh saleable products are strict, and the producers that sell directly to the customers are more flexible for setting their own quality criteria.

■ *Social well-being*

Social well-being relates to how the farm interacts with society. Four themes were considered relevant in the context of horticulture production in Arctic Norway, 'local society', 'participation and network', 'labour conditions', and 'health and safety'. Our findings show that the farmers consider that they have a positive impact on the theme 'local society' and that 'labour conditions' and 'health and safety' aspects are good. The theme 'participation and network' is found to be a key element for sustainable development on the farm.

Having a tight producer's network seems to be one of the most important factors for farm development and job satisfaction. The farmers also recognise it as an opportunity to buy better equipment, for efficiency as well as being positive for the social aspect. Farmers situated far from the wholesaler can feel that they lack a network of horticultural farmers. Many of the farmers participate in various development projects that gives them added network regionally and nationally, in addition to being active in farmers associations. A few are also involved in local chamber of commerce, although one farmer recognises that it should be a stronger focus for farmers to interact with other industries.

Most of the farmers say that they feel they have a very positive impact on the local society and that the local society appreciate their work. For one of the berry farms that sells the berries directly from the farm, this generate customers for the local shop as well as other activities in the village. There is however a difference in how agriculture is perceived in their local commune, farms in typical industry or fisheries communes feel less appreciated. All the farmers who are selling produce directly to the customers are saying that they get much positive attention and appreciation from customers for producing local produce**.** One of the farmers who is selling his produce to the wholesaler is saying that he feels his largest contribution to society is: 'it is more that one contributes in the larger scale regionally, in northern Norwegian scale, by keeping up the production, and contributing to locally produced food' (F11). Most of the farmers are saying that they are very conscious about buying local goods and services.

In addition, the farms provide job opportunities. Except one, all farms rely on full time or short-term hired employees. Combined the ten farms has approximately 16 full time employees, 10 that are employed part time for a large portion of the year, as well as estimated about 40-50 seasonal workers. Farms are therefore, for this region, a quite large employer. A challenge is to get local workers, and two of the farmers are talking about how the countryside has changed: 'we no longer have access to workers from the village, we have to get seasonal workers from abroad' (F11). Most of the workers are from Eastern Europe, but some of them have moved to Arctic Norway with their families. Many of the farms also rely on help from their families and by working long days themselves in the high seasons**.**

All the farmers say that health and safety is a focus for them, and in particular when hiring people**.** It seems that there is a focus on training for new workers and that some, more complicated operations are only done by the farmer. Some has also visits from their local health and safety adviser through the farmers Agricultural Services Organisation, and two of the farmers say that they have had visits from the labour inspection: 'it is also a good experience (...) it is very good that they also are concerned about agriculture' (F7b).

■ *Environmental integrity*

The environmental integrity dimension relates to the farm's impact on nature. Five themes were considered relevant in the context of horticultural production in Arctic Norway, 'energy', 'waste and recycling', 'soil', 'water' and 'biodiversity'. Our findings show that the farmers are working consciously on all these themes, also due to the high rule of law requirements for documentation.

For the horticultural farmers diesel for the tractor is the main on-farm source of energy. The land structure is such that each farmer has many small fields, and the fields can be many kilometres apart and lead to much transport. The farmers are aware of this and some say they use 'land-exchange' with neighbours to reduce

tractor driving and to get more suitable land for crop rotation. Energy saving is also an issue while working the land, minimising driving distance by doing many operations simultaneously. Transportation in distribution in the value chain is also an issue, one of the farmers who has a long distance to the wholesaler is considering the sustainability aspect of producing potatoes when: 'I risk that my potatoes are being transported between 1,500-2,000 km from they are produced until they come to the store' (F11). The decentralised settlements are a concern selling berries through 'self-harvest' directly from the farm, where each customer drive long distances.

The two main sources of waste in horticultural production is plastic and biological material. The increased used of fibercovers to improve the microclimate and to reduce the risk of pest damage has increased the problem with plastic waste in horticultural production. Even though this is considered a one-year-cover they try to use it two-three years. However, all say that the local waste management companies have good routines for recycling**.** For the biological waste most of the rotten berries are thrown away in natural compost, the damaged vegetables not harvested, and leafs are mainly ploughed down. In table top production the growth medium is a concern, utilising either turf or far-travelled coco waste. Some of the farmers are also discussing possibilities to utilise biological waste as an alternative source of energy.

In general, the farms in Arctic Norway are small and agricultural land only a small percentage of the total land area: 'even though a large part of the river delta is cultivated, there is still forest left in the delta and it is surrounded by high mountains and forests, so I think that in that area agriculture has relatively little impact on nature' (F11). Still, how the agricultural production affects the soil and water sources locally is of great concern. It is also highly regulated. The farmers are imposed by law to test their soil quality at least every 5 years and to have yearly plans for fertilisation. Taking care of their soil is essential for future productivity and is considered when working in the fields: 'thinking about which machines to use, how big they are and tire width and stuff (...) and as little driving as possible to take care of the soil that will be cultivated later, it is of course important' (F10). Fertilising methods are considered, to fertilise directly were it is needed and in the right amounts. The agricultural impact from runoff to water sources, like river, groundwater and lakes is also regulated by law: 'if you adhere to the laws I think you should be a good and 'clean' production company' (F5). It is noted from many that because of the cool climate less pesticides is needed. However, all the farmers use chemical pest and weed management to some degree. In general, the farmers are cautious about using chemical pesticides, and integrated management such as crop rotation, fibercovers for physically closing out the insects or biological pest control in tunnel production is widely used. Crop rotation is an important part of the agronomic planning for all the farmers, but the lack of suitable land for horticultural production is a limitation for this for most farmers. For potato producers buying clean seed potato is one solution.

Climatic factors challenge production in Arctic Norway, and methods for improving the microclimate is widely utilised. Tunnel production with production-ready-plants is introduced in berry production: 'you can say that with table top and raspberries in pot production, we have ruled out winter problems' (F6). It is also mentioned that new production systems for other crops can give new opportunities to this high-cost and climatically challenged area for plant production. Another issue is to obtain suitable varieties for these conditions where earliness is one of the main features sought. Projects with breeding and selection is done in the network around the wholesaler: ''cause we need adapted varieties, most varieties are developed very far south from us' (C1b).

5. Discussion

The findings presented in Section 4 are discussed in the next section in relation to the farmers' perspective and the implication for the horticultural production in Arctic Norway. Based on such discussion, two tables are elaborated, Table 4 summarises the findings and their implications for sustainability and Table 5 shows the themes our analyses suggest to utilise for future studies of sustainability in this production. This section closes commenting on the qualitative approach used in this study and its contribution to investigate the complex phenomenon of sustainability and sustainability perspectives.

5.1 Farmers' perspective on sustainability

The findings suggest that sustainability is not a term the farmers use in everyday conversation. However, our findings show that the horticultural farmers in Arctic Norway have their own perspectives on sustainability, and that they all relate this to how they run the farm. The interviews reveal that the highest focus is on the environmental dimension. This in contrast to the findings in Bertella *et al.* (2020), where companies often focus first on the 'economic' dimension. The high environmental focus of the farmers might however be explained by their high dependence on environmental conditions. Some also highlights the interconnectedness of the different dimensions of sustainability, especially between the 'environmental' and the 'economic' dimension, both the inherent tension and the synergic aspects. Analysis show a somewhat weaker connection towards the social dimension, although half of the interviews contain issues connected to this dimension. One weakness might be that only four of the ten farmers mention all three sustainability dimensions; 'economy', 'society', and 'environment'. Since sustainable food production is a governmental aim competence building about what constitutes a complete sustainable production system could make the farmers even more conscious about the holistic efforts needed to increase the level of sustainability at the farm.

Schader *et al.* (2014) distinguish between the business or farm perspective and the societal perspective in sustainability analysis. We find that mainly the farmers took the farm perspective although some of the comments have a wider approach that can be viewed close to the societal perspective. From our findings it seems however, that the distinction made by Schader *et al.* (2014), although intuitively comprehensible, maybe is not so easy to distinguish in practice. The farmers seem to conceive both perspectives interchangeable, not explicitly distinguishing between the two perspectives.

5.2 Implications for sustainability in Arctic Norway

Despite a somewhat lack of holistic focus on the concept of sustainability in the open questions, the more detailed questions based on the SAFA framework on the four sustainability dimensions and related themes, reveal that all the farmers in their everyday work are very much concerned about all parts of the sustainability concept. As is pointed out by the wholesaler: 'I can't say that (the word sustainability) is used much talking to the producers, but that's really what we're working on all the time' (C1a). The need to specifically look at all the various sustainability themes is there for imperative to understand the farmers' perspective of the concept. Table 4 systematises the main findings in our study and their implications for sustainability.

The findings as systematised in Table 4 suggest that the farmers are working on all aspects of sustainability. One important reason for the good performance is due to the high level of public documentation requirements imposed on the farmers. This is also found in Kiełbasa *et al.* (2018) where external pressure from national and EU regulations is the most important factor determining farmers' perspective and practices in the environmental dimension. In Norway, where the documentation requirements are high also in the 'economical' and the 'social' dimension, for example in connection to health and safety, auditing and employment, this might hold true also for these dimensions. The implications for sustainability (Table 4) are discussed below.

The findings relative to the 'good governance' dimension show that there are challenges in the possibilities for long-term planning. Agriculture is a long-term project were many of the operations like crop rotation, making new land and trenching will have effects well into the future. Investments in machines, storages, etc. must also be based on planning for the future. Bond and Morrison-Saunders (2011) found the timeframe as the most problematic issue concerning sustainability assessments, and considering the possible long-term effects of agricultural production, for instance with issues related to top-soil, CO_2 or plastics, time-frame aspects are definitely important. Our findings suggest that the ability to plan for the future is challenging passing from one generation to the next, and for the farmer to plan for a distant future would be virtually impossible. From the ten interviewed farmers we also find a lack of plans formalised in written documents. This can be a shortcoming for producing sustainably over a longer period, possible affecting both economic and environmental performance. However, the documentation requirements from the government forces the

Table 4. The main findings and implications for sustainable production.

Dimension and theme	Findings	Implications for sustainability
Good governance		
Holistic management	Limited formalised planning	Challenge for best practice
	High in rule of law documentation	Leads to a general high level of sustainability
Future prospects	Challenge for long-term planning especially due to generational shifts	Challenging for innovations and investments for improved sustainable production systems
Economic resilience		
Vulnerability	Yield fluctuations leading to income fluctuations	Trade-off between the economical and the environmental dimension
Long-term profitability	Low in economic security	New policy and subside practices needed
	Reasonable income	Innovation and competence
Product quality	Risk reduction production	Prolonged market contracts
	Technical and processing improvements	New products, new markets needed
Social well-being		
Local society	Feel appreciated	Job satisfaction
	Buying local goods and services	Connected to societies also through the economic dimension
Participation and network	To varying degree	
Labour condition	Dependent on foreign workers	Critical for increased/improved sustainable production
Health and safety	High focus	Challenging for sustainability
Environmental integrity		
Energy	Diesel for tractors, focus on reduction	Potential to look at new energy sources
	High distribution mileage	More infrastructure needed
Waste and recycling	High use of plastics, but a good recycling system	Potential for new value streams for today's waste
Land use		
Biodiversity	Highly regulated fertilisation regimes	Trade-off between land use and productivity (e.g. crop rotation)
	Small plots, less pesticides	Improved focus on biodiversity
	Climatic adaptations	Technical innovations and adapted plant varieties

producers to document and plan many aspects of production. The 'governance' dimension can be perceived as a horizontal dimension affecting the performance in the other dimensions (Schader *et al.*, 2019). A similar finding is reported by Schader *et al.* (2016) who conclude that farms optimising the governance dimension can improve the overall sustainability performance. Improving the long-term planning and improving routines for more formalised plans can improve the sustainability in the economic, social and environmental dimension of the horticultural production in Arctic Norway.

With regard to the 'economic resilience' dimension, to secure income is an important feature for all the producers, and it is important to note that all the investigated farmers rely on income other than from horticultural production alone. Half of the farms combine horticultural production with livestock. This is also commented by Al Shamsi *et al.* (2018) as a best-practice reducing off-farm input and increasing product range. The producers say however that there is good money to be earned from horticultural production. Findings from Migliorini *et al.* (2018) in regards to horticultural production, showed that one of the main reasons for the high level of sustainability found, is due to positive economic indicators. Our findings show that new policy and subsidies practices should be considered since there is little security in todays practice. For instance, it is mentioned that changes in the taxation systems can decrease the effects of income fluctuations.

There are also trade-offs between the 'environmental' and the 'economical' dimension concerning factors affecting yield levels set against the income levels. In a high-cost country like Norway, where especially the wage-level is high, the focus will be on high-value quality crops rather than on volume. New innovation connected to a high competence level can lead to risk reduction since climatic challenges are reduced as well increased effectiveness in production leading to less manual labour. We also find that market issues such as prolonged market contracts for instance with the wholesaler could improve security, in this context this is especially important for the vegetable producers. A heightened attention to alternative processing to increase the value of the products that do not comply with the quality criteria, is also considered important.

In the 'social well-being' dimension, the farmers feel appreciated for the work they do and that they contribute to their local communities. In a Swedish study Röös *et al.* (2019), 'finding one's work meaningful' was found to be highly important to the farmers, and although not investigated explicitly in this study, the impression from the analysis is that the farmers find their work meaningful much due to their contribution to the local community. The theme 'local economy' found in the economic dimension has a large impact on how the farmers relate to the local communities, through buying locally and producing local food. Most important for the farmer in this dimension, is however to have a good network of producers. Especially for the network around the wholesaler, many new young producers are enthusiastic and ready to learn new production techniques. In the increased production of strawberries in tunnel we find that also network over longer distances can work utilising skype and other electronic channels to keep in touch regularly. Al Shamsi *et al.* (2018) also comment on networks as an important premise for sustainable production. One challenge in this dimension is to get seasonal workers locally. The farmers using foreign workers are satisfied with their work capacity. However, it can be vulnerable for local communities to be so dependent on outside workforce to maintain production, possible also leading to less connectivity to the local society.

In relation to the 'environmental integrity' dimension, one main feature is that much of the agricultural practices and possibilities for land use are regulated by law, and it is mentioned by farmers that, when complying with these regulations, the effect on the soil, water and atmosphere from production will be positive. However, one of the biggest challenge for good environmental production is found to be the dependency of rented land. Farmers say that land-exchange is usual in many areas, and this can be a solution for some to get access to more land suitable for horticultural production as well as decreasing the driving distances between the different fields. A lack of land is also a reason for less than recommended crop rotation, which can lead to an increased need for pesticides and increased fertilisation levels. In active agricultural areas this is a challenge**.** Ssebunya *et al.* (2019) found in their studies several trade-offs between the environmental dimension and other dimension. This can also be found in our study exemplified with the less than optimal crop rotation, since not utilising suitable land for yearly production will reduce yield and consequently reduce income, i.e. a trade-off between the 'environmental' and the 'economical' dimension. Waste is another issue. The use of plastic covers in production increases yield and therefore income, but at the same time increases the amount of plastic waste. Using waste streams for bioenergy can also be possible, but probably this must be done in collaboration with other industry locally to get the volume of waste necessary to reach economic viability. Transportation mileage in the value chain is high, both due to the geography, few farmers and little infrastructure. Theurl *et al.* (2017) found that, contrary to common belief, local food distribution does not involve less transportation, especially when individual shopping trips are considered.

Since in Arctic Norway only 0.83% of the land area is utilised for agricultural production, and the farms and fields are small, it is mentioned by the farmers, that their horticultural production effects the natural environment to a small degree. Due to new research and development there is continuous improvement in for example use of pesticides and fertilisation practices that can further improve biodiversity. Findings from Migliorini *et al.* (2018) show that a high level of sustainability stemmed from a high focus on land-use and biodiversity. Even though the overall environmental sustainability is considered good in Norway, many farmers mentioned the need to implement technical improvements on tractors, equipment, and precision agriculture. In a high-cost country with small field sizes the farmers must rely on quality yield rather than quantity, and then such technical innovations will be crucial.

5.3 Further considerations for sustainability in horticultural production in Arctic Norway

The findings suggest that dividing the sustainability concept in four dimensions provides a good a useful conceptual tool for studying the sustainability of horticulture producers in Arctic Norway. However, our analysis suggests a more elaborate and a somewhat different structure to the sustainability themes, than the one this study has initially chosen (Table 1). In particular, there are two themes important for the sustainability of horticultural production in Arctic Norway that were not included initially: the importance of technical improvements and innovation in both production methods and in product development, as well as the importance of competence level to be able to implement sustainable practices. New innovations can give new opportunities to a high-cost and climatically challenged area for plant production. In general, the competence level is considered high among the farmers, however, the technological development in the horticultural sector is rapid, and new competence must follow this development simultaneously. In Kiełbasa *et al.* (2018), similar findings are presented, with the farmers' level of knowledge of environmental issues having an impact on the natural world.

Another theme that has emerged as particularly important in the context we have investigated is the concern about and importance of land rental on the performance in the environmental dimension, as well as the important implications climate and climate change has on this dimension. Although climate change is not broadly mentioned by the farmers this is a feature from the context that is, and in the future will be even more, important for production. We therefore suggest 'land rental' and 'climate' as additional themes to be studied in this specific context.

As discussed, the study show that 'participation and network' is a key factor for improved and increased horticultural production. This theme was initially categorised among the factors of the 'social' dimension. Considering the effect 'participation and network' have on all the dimensions, we suggest that this theme might be better placed in the more overarching 'good governance' dimension, as it initially was also in SAFA (Figure 1). In addition, as described above the high rule of law requirements, pertaining to topics in all dimensions leads us to, as it is in SAFA (Figure 1), to include it as a separate theme in the 'governance' dimension. Table 5 shows the suggestions our analysis reveals for themes relevant for studying the horticultural production in Arctic Norway.

Another finding from our analysis is the numerous interrelations among the various dimensions and themes. The 'governance' dimension overlaps with the 'environmental' dimension, especially for the themes 'future prospect' and 'holistic management', as well as with the theme 'holistic management' and the 'social' dimension theme 'local society'. Between the 'environmental' and the 'economical' dimension, we find overlap in most themes. The 'social' dimension overlaps with the 'environmental' dimension in the theme 'local society', and with all the themes in the 'economical' dimension. It is important to recognise these overlaps to understand the complexity of sustainability assessments as well as their limitations in depicting real-world-issues in neat tables. Overlapping issues can also lead to trade-offs when working on improving a value chain since actions taken in one theme can negatively affect another theme.

Table 5. Sustainability dimensions with relevant themes for the horticultural value chain in Arctic Norway.

Good governance	Economic resilience	Social well-being	Environmental integrity
holistic management	profit and economic security	local society	energy
future prospects	economic vulnerability	local economy	waste and recycling
participation and network	long-term profitability	local food	land use and biodiversity
innovation and competence	product quality	labour condition	land rental
rule of law		health and safety	climate

5.4 The contribution from qualitative methods on sustainability

This study uses a qualitative method to identify the farmers' perspectives. We find that a qualitative method gives a rich material to analyse and that it is especially useful for discovering possibilities and challenges for a more sustainable production and to uncover new concerns in relation to sustainable production. A concern raised in Jawtusch *et al.* (2013) is that the comprehensiveness of the SAFA objectives may require much time and resources to obtain good data, and that the quality of the assessment depend on the expertise of the person performing the assessment. This address both the challenge and strengths of such a qualitative approach, where we found that a good contextual understanding is paramount for understanding farmers' perspectives and the strategies available for improving sustainable agriculture in a given context. In-depth interviews provide thick descriptions and give the possibility to identify a broad set of interacting factors that influence on the farmers perspectives that further connects and diversifies the context and the findings.

In relation to this, Migliorini *et al.* (2018) reflect on the concern that the complexities of food production challenges the possibilities to reduce sustainability issues into indicators for quantitative calculations. Qualitative methods might not be as suited for generalisation of sustainability nor for comparing sustainability levels between various production methods. Using only farmers' perspective as the only measurement will not be suited for the sole assessment of the state of the sustainability of the horticultural production in Arctic Norway. The findings unravel the perspectives of key stakeholders in the value chain. The farmers, with their combined practical and theoretical knowledge about critical factors for a successful horticultural farm provide valuable insight to challenges and conditions for improved sustainability that can inform policy. Our view on this choice of method much conclude in the same way as Galli *et al.* (2015) saying that qualitative methods: 'can help identify issues to deal with and critical gaps, thus representing a starting point for further empirical research'. However, in addition to this, we find that qualitative methods utilised to uncover the farmer's perspective on sustainability can be of paramount importance since the farmers are the main stakeholders to ensure possible changes towards sustainability. And, as such this qualitative study very much emerge as a complete work on its own.

6. Conclusions

In this study, we use a qualitative method to explore the perspective on sustainability of horticultural farmers in Arctic Norway. We find that many of the premises for fulfilling the UN SDG 2 are present in Arctic Norway horticultural production. Horticulture provides healthy food and the farmers interviewed generate decent income and are positive contributors to their local communities. The main challenge in Arctic Norway is probably to be able to produce more food. The production today is small in relation to the consumption. However, the government has a special focus on increasing the horticultural production and consumption. To achieve a higher production level of sustainable produced horticultural products in Arctic Norway, there should be more horticultural farmers and more available land suited for this production, as well as increased infrastructure that today lacks due to that it is only one remaining wholesaler in Arctic Norway. The producer's network is identified as a critical factor for development. A paradox is that the producers themselves say that there is good money to be earned from horticultural production, but still the production is low. Reducing the vulnerability due to fluctuating yields and income, as well as innovation that makes this traditionally physically hard laborious production more production efficient and technical, can help increase production.

A concern in R&D is to go from assessments to an actual transformation towards sustainability. Our findings suggest that one limitation to such transformation can be that the knowledge of what, holistically, sustainable food production includes is unclear. Farmers, as key stakeholders in the agricultural food value chain, need to play an active role in assessments for change to occur. Contextualisation of what is important to assess to consider sustainability for the specific value chain is shown to be important, and is a prerequisite for a good assessment and for the assessment to fit the real-world.

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9.2 Paper II. Learning for sustainability in horticultural production in Arctic Norway

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Learning for Sustainability in Horticultural Production in Arctic Norway

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Sustainability learning is gaining popularity as an important field within sustainability research, where farm sustainability can be understood as a learning process. In this study, we seek to reveal the sustainability learning process of farmers, utilizing a framework distinguishing contextual factors (where? and when?), knowledge (what?), motivation (why?), and process (how?). The article presents a participatory inquiry mixed-methods approach, utilizing results from sustainability assessments on five farms with the SMART-farm tool as a unifying starting point for further discussions on sustainability learning in farmers' interviews and stakeholder workshops. Empirically the study is set in the horticultural production in Arctic Norway, where few studies on sustainability have been undertaken. The study shows how both the complexity of the concept of farm sustainability and contextual factors influence the sustainability learning process, for instance by giving rise to a vast number of conflicting issues while working toward farm sustainability. The sustainability learning process is found to be predominantly a social learning process. The theoretic contribution of the study lies in its novel framework that can be used to reveal important aspects of the sustainability learning process, as well as to contribute to the literature on how to proceed from sustainability assessments to implementation. A key finding from the study is that farmers will require continuous assistance in their processes toward farm sustainability, but for this to be possible, knowledge, sources of knowledge, and learning platforms for holistic sustainability need to be established.

Keywords: sustainability learning, double-loop learning, SMART-farm, arctic horticulture, participatory approach

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INTRODUCTION

Sustainable farming, both as a vision and as a practice, is placed high on the political agenda, although the idea of sustainability, at the farm level remains contested in terms of its nature (what is a sustainable farm?) and its prospects (is it possible for a farm to be sustainable?) [FAO (Food Agriculture Organization)., 2014; Brunori et al., 2016; Bardalen et al., 2020; COM (European Commission)., 2020]. Sustainability challenges are sometimes described as "wicked" since they can be complex, with conflicting interpretations and uncertain outcomes (Rittel and Webber, 1973; Glass et al., 2012; Wals, 2015). The concept of sustainability rest on three pillars: environmental protection, economic resilience, and social inclusion [WECD (World Commission on Environment and Development), 1987], and for a holistic sustainable development these pillars need to perform in a concerted action.

Darnhofer et al. (2010) find that a farm's ability to become sustainable depends on several factors; key among them is the farmer's ability to learn, a process that can be understood as "the human response to tackle issues that require change" (Blackmore et al., 2012, p. 162). Understanding how to learn sustainability—i.e., learning to "*achieve and support sustainable development*" (Hansmann, 2010, p. 2877), is crucial in moving toward sustainable practices (Wals, 2007). Tàbara and Pahl-Wostl (2007, p. 1) emphasize that discussions on sustainability have "*shifted from being goal oriented to understanding sustainability as a learning process*" and numerous learning theories have been developed, each focusing on a different sustainability aspect (Blackmore, 2007; Illeris, 2018). Argyris and Schön (1978) juxtaposed learning with change, and this approach becomes the core of our theoretical framework that further draws insights from the sustainability learning literature (Hansmann, 2010), double-loop learning (Argyris and Schön, 1978), and social learning (Blackmore, 2007; Wals, 2007) to help us understand learning for sustainability at the farm level.

The purpose of this article is to address the following research question: What are the characteristics of sustainability learning in the context of horticultural farms in Arctic Norway? The article utilizes a mixed methods approach in a participatory case study of horticultural family farms in the region. More specifically, the study uses sustainability assessments to contextualize sustainability and as a starting point for a learning process toward farm sustainability (de Olde et al., 2016). Theoretically, this study enhances our understanding of how learning processes can lead to increased farm sustainability (Lankester, 2013), while empirically, it brings new evidence on farm sustainability and the underlying processes for how new knowledge becomes action regarding farm sustainability (Restrepo et al., 2018). We further suggest a way to advance from sustainability assessments to a sustainability learning process for actual change. Methodologically, this study contributes to the growing body of participatory research literature that utilizes mixed methods in a case study approach.

THEORETICAL BACKGROUND

The theoretical background draws insights from several areas: sustainability learning, social learning, loop-learning theories, and learning for sustainability at the farm level, including sustainability assessment literature.

Sustainability Learning for Change

Sustainability learning, which "aims to achieve and support sustainable development" (Hansmann, 2010, p. 2877), is a multi-level concept (learning at the individual and societal levels), in which a transdisciplinary effort (Tress et al., 2005) is fundamental (Hansmann, 2010). Changes in complex matters such as sustainability do not occur in isolation but within a system through multi-stakeholder interactions [Tilbury, 2011; Klerkx et al., 2012; Aerni et al., 2015; TAP (Tropical Agriculture Platform)., 2016]. Tilbury (2011) identifies collaboration as a key process in sustainability learning, and sustainability learning is typically associated with social learning [UNESCO (United Nations Educational, Scientific and Cultural Organization), 2002; Tàbara and Pahl-Wostl, 2007; Wals, 2007, p. 7], i.e., learning that is occurring through social interactions that also changes the understanding of participants (Folke et al., 2005; Glass et al., 2012; Beers et al., 2014). New understanding can arise from discussing existing ideas in a different social context (Beers et al., 2014). Sustainable solutions from social learning rely on processes that are flexible and iterative, encouraging learners' reflection on various perspectives (Glass et al., 2012) and thus enabling participants to understand the "*cultural, professional and personal complexities surrounding sustainable development*" (Tilbury, 2011). The complexities of sustainability learning necessitate involvement of multiple stakeholders, having different values and beliefs, and therefore "*demand[s] not just individual learning but social learning*" (Blackmore, 2007, p. 514).

Learning is a process [Ison et al., 2000; UNESCO (United Nations Educational, Scientific and Cultural Organization), 2002; Tàbara and Chabay, 2013, p. 7] leading to change (Bateson, 1972; Argyris and Schön, 1978). Change may refer to a cognitive change in the learner, which may or may not result in practical changes (Leeuwis and Van den Ban, 2008). Although the process toward sustainable development gains more momentum worldwide, it is slow-paced, especially when considering the immense and immediate challenges facing the environment and societies [UN (United Nations)., 2019]. A way to speed up the learning process for sustainability is through double-loop learning (Argyris and Schön, 1978).

The learning process begins when observing the result of an action (Argyris and Schön, 1978) and then engaging in self-reflection that then leads to either single or double-loop learning (Restrepo et al., 2018). Our approach adopts double-loop learning as described in Tàbara and Pahl-Wostl (2007), "*in which the learner becomes aware of the assumptions and values that he or she holds, and is capable of major shifts*," which is distinctly opposed to single-loop learning where the aim is to perform routine processes in a more efficient or better way (Argyris, 1992). Changes in double-loop learning further involve altering the governing variables, including changing norms and values (Argyris, 1992). In situations where more transformative changes are needed, as is the case for sustainability learning, one has to question the underlying norms and assumptions and therefore proceed through a double-loop learning approach. Double-loop learning is crucial for the long-term survival of a company, especially when faced with uncertainties, something that is also the case for the farm businesses we examine (Argyris, 1992). The literature also suggests the possibility for triple-loop learning (Eksvärd, 2010; Armitage et al., 2011; Restrepo et al., 2018), referring to reflections leading to learning about the learning process itself (Groot and Maarleveld, 2000); however, this approach is beyond the focus of this study.

Figure 1 illustrates our underlying theoretical framework which builds on a model by Hansmann (2010, p. 2879). In Hansmann's model, learning is an iterative process in which motivations and knowledge serve as first inputs, leading to both affective and cognitive outcomes, which can lead to new learning. Our framework contains aspects that affect the learning process,

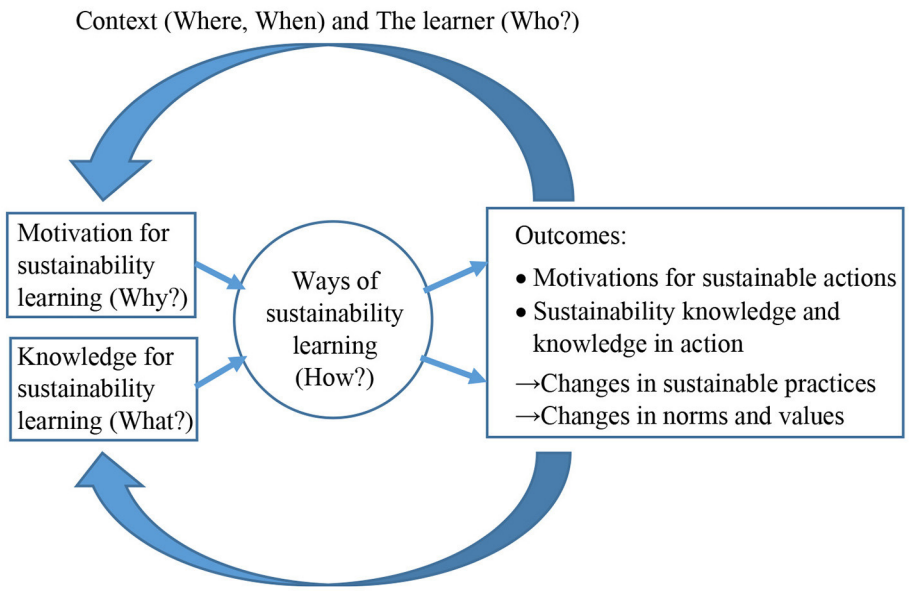

FIGURE 1 | Framework for analyzing sustainability learning.

addressing what is learned, why is it learned, and how is it learned (a notion adapted from Maarleveld and Dabgbégnon, 1999). Specifying learning outcome is also essential (Armitage et al., 2008). The complete process is framed within its context, addressing *where* and *when* is it learned, in addition to *who* learns?

The framework serves as a guide for empirically investigating the entire learning process needed to improve farms' sustainability level. *Where* and *when* refer to context, defined by time, place, and culture (Bond and Morrison-Saunders, 2013). Related to this is the notion of *who* learns. Organizations do not learn (Argyris and Schön, 1978), but rather people learn, so specifying who is learning becomes essential. *What* is the sustainability knowledge, including knowledge in action (Tilbury, 2011), and *why* refers to the motivations for learning and making changes, stemming from both internal (e.g., own curiosity and interest) and external (e.g., learning process as a means to an end) factors (Ryan and Deci, 2000; Hansmann, 2010). Finally, *how* accounts for the main process of learning, distinguishing between collaborative (learning in cooperation with others), experiential (building experience between theory and practice) and experimental (through practical experiments) (Thompson and Scoones, 1994; Darnhofer et al., 2010; Restrepo et al., 2018). The framework also includes the outcomes of the learning process, as change in sustainable practices as well as change in norms and values. Sustainability learning is the essence of this framework where single and double-loop learning (Argyris and Schön, 1978) are used to describe the level of change involved in the process of action and reflection leading to learning. This framework becomes iterative when new sustainability knowledge and new motivations for sustainable actions lead to further sustainability learning in a continuous process.

Learning for Sustainability at the Farm Level

Ever since the Brundtland commission defined sustainable development [WECD (World Commission on Environment and Development), 1987], sustainability has been studied at the farm level as a learning process (Tàbara and Pahl-Wostl, 2007; Darnhofer et al., 2010; Brunori et al., 2016). Learning has been studied at the farm level both in general and in relation to sustainability, and there is a wide range of literature studies that relates to the components of our framework (**Figure 1**).

Scholars argue that learning at the farm level must be understood as contextual (Jarvis, 1992; Blackmore et al., 2012), where the three dimensions of sustainability (social, economic, and environmental) are interconnected and affect one another differently, depending on the context. On farm level, for instance, a lot of knowledge develops daily as the farmer practices farming (Folke et al., 2005). This type of knowledge is context-dependent, and farmers can be considered experts on their own farms. This local and experiential knowledge is particularly valued among farmers and is considered especially important for farm sustainability since it is addressing local systems as a whole, considering "*the complexity of the realities in which farms operate*" (Šumane et al., 2018, p. 238). Triste et al. (2018) find that farmers' motivations also are context dependent.

A key difficulty in delimiting sustainability learning is to define the content of what is to be learned (Tàbara and Pahl-Wostl, 2007). An extensive literature on sustainability assessments has been developed to address what sustainability is at the

farm level (de Olde et al., 2018), and undertaking such an assessment is seen as "*a starting point for discussion, reflection and learning*" (de Olde et al., 2016, p. 398). A recent literature review of sustainability assessment studies at the farm level reveals that only one of the 67 examined studies discussed the implementation phase and how such assessments contribute to change (de Olde et al., 2018). A key reason for the lack of farmers' support for working toward improvement strategies is of a practical nature: it can be a time and resource consuming process for both assessor/adviser and farmer, and in addition, not all farmers are interested in interactions with other farmers or experts having to share both knowledge and farm data (Coteur et al., 2020). It is however recognized that a way for assessments to lead to more sustainable practices is to be followed by a learning process (de Mey et al., 2011; Whitehead et al., 2020).

Several studies about learning at farm level investigate the farmers' motivation for learning. According to de Olde et al. (2018), farmers' motivation to improve their sustainability practice on their farm is a prerequisite for the implementation of new sustainable practices. Triste et al. (2018, p. 121) studied farmers' motivations for participating in sustainable farming initiatives and conclude that the "*motives are diverse, manifold and directed by a diversity of underlying motivational processes*." Darnhofer et al. (2010, p. 549) find that motivations for learning are affected by the farmers' "*personality, preferences and competences*," and Ingram (2010, p. 197) in the same manner identifies that "*individual willingness to experiment, problem solve and 'trust [their] own judgement"* is evident in motivated farmers. In particular, the values held by the farmer influences what they change and what and how they learn (Blackmore et al., 2012; Darnhofer et al., 2012; Lamine et al., 2014). Darnhofer et al. (2010, p. 549) also find that farmers are motivated by "*external structures such as the social norms, technologies and the natural environment.*" Learning can be triggered by crises, such as experiencing financial or climatic hardships (Sutherland et al., 2012; Lankester, 2013).

The literature addresses how to learn sustainability, both by examining the sources of learning as well as the process of learning at farm level. Regarding sources of learning, studies indicate that the main sources for farmers' learning are: through own experience, through peer learning, and through external sources or institutions. Lankester (2013) and Restrepo et al. (2018) find that farmers value learning stemming from own experience and practice. This adheres to Darnhofer et al. (2010) who emphasize experimenting with outcome monitoring as an important source of farmers' learning. The main source of farmers' learning seems to be learning from other farmers, where concepts such as peer-learning, peer-exchange, and farmer-to-farmer learning are used (Leeuwis and Van den Ban, 2008; Cooreman et al., 2018; Kouchner et al., 2019). Lankester (2013) and Restrepo et al. (2018) highlight both active participation and observation, as well as discussions and sharing experiences and results with other farmers. In this regard, farmers consider successful colleagues as experts (Šumane et al., 2018). Farmers also use external sources or institutions in learning, such as information networks, extension services, public administration agencies, and regulatory institutions (Šumane et al., 2018; Kouchner et al., 2019). Agricultural research institutions are also important, particularly if the farm utilizes more advanced technologies (Šumane et al., 2018). Mixing various sources of knowledge is beneficial for learning (Darnhofer et al., 2010), involving both formal, knowledge from academia and industry, and informal, local and farmers' knowledge (Šumane et al., 2018).

The learning process is often represented as a combination of experiential, experimental, and collaborative learning. Restrepo et al. (2018) evaluate a collaborative learning process for sustainability among smallholder dairy farmers in Kenya, where they highlight the importance of experiential learning in a co-production process in which a learning loop model is applied. Darnhofer et al. (2010) emphasize learning through experimenting and monitoring the outcome, and Ingram (2010, p. 183) discusses that experimental learning on the farm is "*accompanied and enhanced by a process of social learning*." The learning process is continuous and reflective, where farmers "*review and reaffirm their decisions*" (Ingram, 2010, p. 197). Lankester (2013) finds that organized collective learning is important in helping farmers develop the farm in a sustainable mode. Much learning takes place in discussions with other farmers, especially when dealing with a broad concept such as sustainability, and farmers' learning benefits from discussions with various stakeholders (Darnhofer et al., 2010; Šumane et al., 2018). Oreszczyn et al. (2010) highlight how farmers' learning takes place in complex social learning systems.

Double-loop learning and single-loop learning are empirically distinguished according to the level of action and the level of reflection. Restrepo et al. (2018, p. 1267) identify single-loop learning processes, at the farm level, as processes that involve *identifying short-term solutions for specific problems* and *task-oriented problem solving* and double-loop learning processes as those processes that involve *reflecting on the problem and how aims can be achieved* and *transforming old ways of understanding*. Armitage et al. (2011) include rethinking management goals as a result of double-loop learning, while Eksvärd (2010, p. 266) introduces double-loop learning through the question "*Are we doing the right things?*," therefore implying that this process can also lead to changes in the very production system or business model of a farm. Darnhofer et al. (2017) point to the challenge of implementing changes on a farm stemming from double-loop learning because this may require a transformation in governance structures outside of the farm's sphere.

METHODS

This article adopts a participatory inquiry approach, where stakeholder involvement is central. Participatory approaches are particularly well-suited in studying complex matters such as sustainable agriculture (Eshuis and Stuiver, 2005; Bruges and Smith, 2008; Eksvärd, 2010). Stakeholders are "*those who will bear the consequences and carry out actions for change*" (Alrøe and Noe, 2016), and their involvement ensures an outcome that is more accurate, holistic, and relevant to the context (Triste et al., 2014).

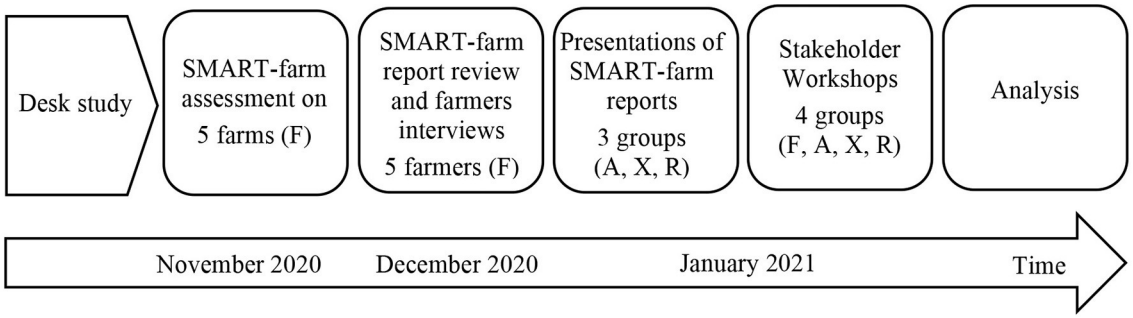

FIGURE 2 | Methods utilized and timeframe.

The study focuses on the horticultural production in Arctic Norway, where despite the governmental aims of sustainable agricultural practices and increased horticultural production, little relevant research has been conducted. The first author's extensive work experience in the local industry, in addition to a M.Sc. in horticulture, allowed for a thorough understanding of the context as well as enabled a trusting relationship with the stakeholders, the latter including farmers (F), county governor administrators (A), extension workers (X), and horticultural researchers (R). We adopt a mixed-methods approach, utilizing both semi-quantitative and qualitative methods (Keahey, 2020). The methods were applied successively over the span of 3 months, allowing rounds of reflection in-between (**Figure 2**). It should be noted that this study is a continuation of a previous study in the region where the focus was on the horticultural farmers' perspectives on sustainability (Halland et al., 2021).

To gain a clear understanding of the concept of farm sustainability in the specific context, we first conducted a desk study of sustainability in Arctic Norway horticulture (section Gaining Insights Into the Empirical Context and Farm Selection) and performed sustainability assessments on five farms (section Assessing Sustainability at Farm Level Using SMART-Farm Tool). Next, we held a SMART-farm report review session with the farmers from the assessed farms. In this review session, the five farmers were interviewed about changes made on the farm that they perceived to have improved its sustainability (section In-Depth interviews With Farmers: Changes That Lead to Sustainability Actions). Finally, four stakeholder workshops took place (section Workshops With Stakeholders: Learning for a Sustainable Future), where co-production of knowledge involving various stakeholder groups allowed multiple values and perceptions to be taken into account (Moriggi, 2020). Section Analyzing the Data describes the analysis of the findings. Throughout the phases of the process, the main author kept a diary for continuous and immediate self-reflections. The participants were informed about and consented to the terms of the research: ensured anonymity, a secure time-limited data storage, and the possibility to withdraw from the study. Due to restrictions caused by the COVID-19 pandemic, all interactions with stakeholders—including assessments, interviews, presentations, and the workshops—were conducted using the Microsoft Teams online platform. The interviews and workshops were recorded and transcribed for later analysis.

Gaining Insights Into the Empirical Context and Farm Selection

The desk study covered several sources, including: governmental documents (e.g., White Papers, Propositions, and official reports), statistics from Statistics Norway on agricultural development and from the Norwegian Agriculture Agency on production subsidies, R&D reports on farm sustainability in Norway, and relevant media coverage.

For the purpose of the study, we recruited five farmers that operate farms that produce berries, vegetables, and/or potatoes (**Table 1**). These farmers were well-known to the lead author as they were also participants in a prior study in 2019 (Halland et al., 2021). Combined, these farms represent 15% of all the land utilized for producing potatoes in Arctic Norway, 13% of the vegetable producing area, and 14% of the berry producing area. All participating farmers have long experience in farming (>10 years) and are actively involved in several initiatives concerning Arctic Norway horticulture. When undertaking sustainability assessments, it is important to note that the entire farm was assessed, and not only the part involved in horticultural production.

Assessing Sustainability at Farm Level Using the SMART-Farm Tool

The SMART-farm tool was employed in November 2020 to gain a clear understanding of the selected farms' sustainability (Schader et al., 2019). The tool is based on FAO's Sustainability Assessment of Food and Agriculture Systems (SAFA) methodology [FAO (Food Agriculture Organization)., 2014] and has a 2-fold purpose: (i) generate a sustainability report that can be used to increase the farmers' awareness and knowledge about sustainability on their own farms, and (ii) become a starting point for learning. The SMART-farm tool is developed by the Swiss agricultural research institution FiBL and registered in the Resource Identification Initiative under RRID:SCR_018197 (Bandrowski et al., 2016).

The tool assesses the farms' sustainability based on a scoring system on the environmental, economic, and social dimensions, as well as on the governance dimension (Schader

TABLE 1 | Characteristics of the participating farms.

Farm	Potatoes	Vegetables	Berries	Main market	Other income
F1	43			Wholesaler	Livestock
F2			2	Farm sales	Livestock
F3			1	Farm sales	Tourism
F4	10	6		Grocery stores	Processing
F5	9			Wholesaler	External work

Cultivated area in hectares.

TABLE 2 | SAFA dimensions and themes [FAO (Food Agriculture Organization)., 2014].

Good governance	Environmental integrity	Social well-being	Economic resilience
Holistic Management	Atmosphere	Cultural diversity	Investment
Rule of law	Water	Human health and safety	Vulnerability
Participation	Land	Equity	Product quality and Information
Accountability	Materials and Energy	Labor rights	Local economy
Corporate Ethics	Biodiversity	Fair trading practices	
	Animal welfare	Decent livelihood	

et al., 2019). SMART-farm measures the percentage of goal achievement, covering 21 sustainability themes, 58 sustainability sub-themes, and 118 default indicators (**Table 2**) [FAO (Food Agriculture Organization)., 2013]. Several tradeoffs and synergies are recognized in the assessments; the prominent ones are the tradeoffs between the performance in the Environmental Integrity and the Economic Resilience dimensions, as well as the synergies between the Good Governance dimension and the three other dimensions: Environmental Integrity, Economic Resilience, and Social Well-being (Schader et al., 2016). The assessments were conducted by the lead author, who is qualified through practical and theoretical training as a SMART-farm assessor.

The survey automatically generates a report, with pre-set objectives for each theme and sub-theme. The results are shown as the farm's percentage of goal achievement. In addition, the report further highlights aspects that have an especially positive and/or negative impact on the rating. The report is shared with the farmer (section In-Depth Interviews With Farmers: Changes That Lead to Sustainability Actions), thus aiming toward an enhanced understanding and increasing the probability that the assessment will lead to further learning. To facilitate this learning process, the SMART-farm report was translated into Norwegian in order to ensure the farmers' full understanding.

In-Depth Interviews With Farmers: Changes That Lead to Sustainability Actions

The SMART-farm report review session with the farmers included short in-depth semi structured interviews. Each interview was structured according to the four sustainability dimensions and followed directly after the discussion of the results in each particular dimension, therefore enabling relating sustainability status (as reported by SMART-farm) to previous changes made on the farm. In the interviews, we focused on the *what*, *why*, and *how* aspects of learning from our analytical framework (**Figure 1**). Each review session lasted ∼1 h. One shortcoming of the findings from these interviews is that the number of participating farmers is limited.

Workshops With Stakeholders: Learning for a Sustainable Future

The third part of the empirical investigation was four stakeholder workshops aimed at knowledge co-production and joint reflection. In total, 14 participants attended the workshops: 4 horticultural researchers, 3 county governor administrators, 3 agricultural extension workers, and 4 farmers. The study relied on selective sampling where participants had good knowledge of the context and a long work experience with horticulture and/or agricultural development in the region. Participating stakeholders had different responsibilities toward farmers, thus allowing different perspectives on farmers' learning. The four workshops contained participants from the same stakeholder group. However, acknowledging that this can be a shortcoming of the study, we chose homogenous divisions to ensure good discussions on a digital platform, allowing for freer speech and avoiding possible power imbalance between stakeholder groups. Having the farmers in a separate workshop also ensured anonymity for the farmers who had their farms assessed.

Each workshop contained two sessions (except the farmers, with whom we held individual assessment review sessions). The first session lasted 45 min, where a presentation was given of the overall findings from the five SMART-farm sustainability assessments, leaving room for questions and general discussions. The second session was a 2–2.5 h group discussions (**Table 3**). Contrary to the interviews (where the focus was on past changes), the main focus in the workshops was to provoke reflections on how to enhance existing sustainability levels. The lead author delivered the presentations and facilitated the group discussions. To ensure that the stakeholders' genuine opinions were obtained,

TABLE 3 | Overview of the workshops' implementation.

Date and time	Session	Stakeholder group	Number of participants
January 7, 2021, 11:30–12:15	Presentation	Horticultural researchers located in the region	4
January 11, 2021, 9:30–11:30	Group discussions		
January 13, 2021, 9:00–9:45	Presentation	County governor administrators from the Agricultural and Food Department	3
January 14, 2021, 9:00–11:00	Group discussions		
January 21, 2021, 1:00–1:45	Presentation	Agricultural extension workers with a special focus on horticulture in the region	3
January 22, 2021, 9:00–11:00	Group discussions		
January 27, 2021, 8:30–11:00	Group discussions	Farmers assessed with SMART-farm tool	4*

One of the farmers was unable to attend.

TABLE 4 | Common challenges from the SMART-farm reports discussed in the workshops.

Good governance	Environmental integrity
The farm does not have a plan for future improvements in its sustainability. The farm has neither carried out nor published a sustainability report within the past 5 years **(F), (X), (A), (R)**. No sales products are certified by a third-party certifier to carry an eco-label or a social label **(X), (A), (R)**. It cannot be ruled out that farm inputs come from countries where problematic social conditions exists **(F)**.	A large part of the agricultural area receives chemical herbicide applications, and comparatively many different active ingredients are used **(R)**. The crop rotation only consists of few elements and land is not maintained with a green cover during autumn and winter **(F), (X), (A)**.
Economic resilience	**Social well-being**
A relatively low proportion of the farm inputs are purchased or produced locally **(F)**. Alternative markets do not exist for all products if buyers drop out, and in general the farm sells its products to only a few customers/buyers **(X), (A), (R)**.	Only a few employees had access to external training in the past 5 years **(A)**. The farm does not take measures to prevent discrimination against women, minorities and other vulnerable groups. The farm doesn't provide extra support to disadvantaged groups **(F)**. The average working time of the farm owner is high **(X), (R)**.

the facilitator did not actively engage in the discussions, but only had a timekeeping and a subject-boundary keeping function.

The first session ended with the presentation of the upcoming tasks for the second session, and each participant had to prepare for the tasks individually beforehand. These tasks consisted of four exercises, one for each sustainability dimension. The exercises addressed common challenges from the SMART-farm assessment reports. In each workshop the participants selected one or two challenge(s) that they perceived demanding for sustainability in this context (**Table 4**). The task was then to answer the questions *what to learn, why learn*, and *how to learn* (**Figure 1**) to be able to change and improve the selected topic.

Analyzing the Data

Thematic analysis, described by Saunders et al. (2019, p. 651) as involving coding of data to distinguish themes or patterns related to the research question, was conducted in NVivo 12, where the data were divided according to stakeholder groups and sustainability dimension. Our methodological framework (**Figure 1**) served as the basis for the initial coding scheme and the data were coded for contextual factors in *when* and *where is it learned? When* (time) as in trajectory of changes (past, present, future) and *where* reflecting on the learning environment: place, policy, and societal implications. The learning process was coded for *what is learned?* (distinguishing sustainability knowledge, knowledge in action, and sustainability knowledge providers), *why is it learned?* (distinguishing between internal and external motivations), and *how is it learned?* (distinguishing sources of learning, ways of learning, and processes involved).

After the coding was completed, the analysis focused on addressing the research question through correlations between contextual factors and the *what*, *why*, and *how* of sustainability learning. Ways of learning were distinguished between individual and social learning, including social processes involved. In the last step we focused on sustainability learning processes and how the various parts of the framework were expressed. Here we also distinguished single and/or double-loop processes involved; to reveal the latter, we particularly looked for shifts in underlying thoughts, values, or assumptions.

FINDINGS

Background—The Horticultural Industry in Arctic Norway

Arctic Norway is the area in the two northernmost counties in Norway (Troms and Finnmark, and Nordland) stretching from 65°N to 71°N. Plant production is challenged by a short and cool growing season. The total area utilized for agricultural production is only 0.83% of the region's total land area, much due to the topography with its many fjords and mountains (Nøstvold et al., 2019). The horticultural

sector in the area is small. In 2019, of the total of 3,091 farms applying for subsidies, 138 farms produced either potatoes, vegetables and/or berries, with a total of 419 hectares potatoes, 50 hectares vegetables, and 24 hectares berries (Norwegian Digitalization Agency, 2019). All the farms are family farms with few external, mainly seasonal, employees. Horticultural yield is fluctuating due to annual climatic variation, and therefore, multifunctional farms with more than one production system—a condition that reduces vulnerability—is the most common way of farming. For instance, 75% of farms with horticultural production also practice husbandry. The last decade has been characterized by technical developments in horticulture production systems that are enhancing possibilities for improved production.

Norwegian national agricultural policy promotes sustainable farming (White Paper 11, 2016–2017) and aims toward the increase of horticultural production (Prop. 120 S, 2018–2019; Grøntsektoren mot 2035, 2020). Local actors with formal expertise are present in the region, for instance through the Agricultural Extension Service, and horticultural producers are actively engaging in R&D projects with regional research partners. The few large producers mainly sell through the only wholesaler that is present in the region, while smaller producers mainly sell through various farmers' markets or directly on-farm, although a few of them have on-farm processing facilities for their own produce. Local sales are stimulated by the increased consumer focus on local food over the last decade (Stiftelsen NorskMat, 2021). The agricultural industry in Norway remains highly regulated (e.g., in terms of wages and working conditions, health and safety, accounting and audits, etc.) and specific requirements related to quality control in agricultural production are found in the Quality System for Agriculture (KSL), a self-reporting system where every farmer must submit annual self-audits.

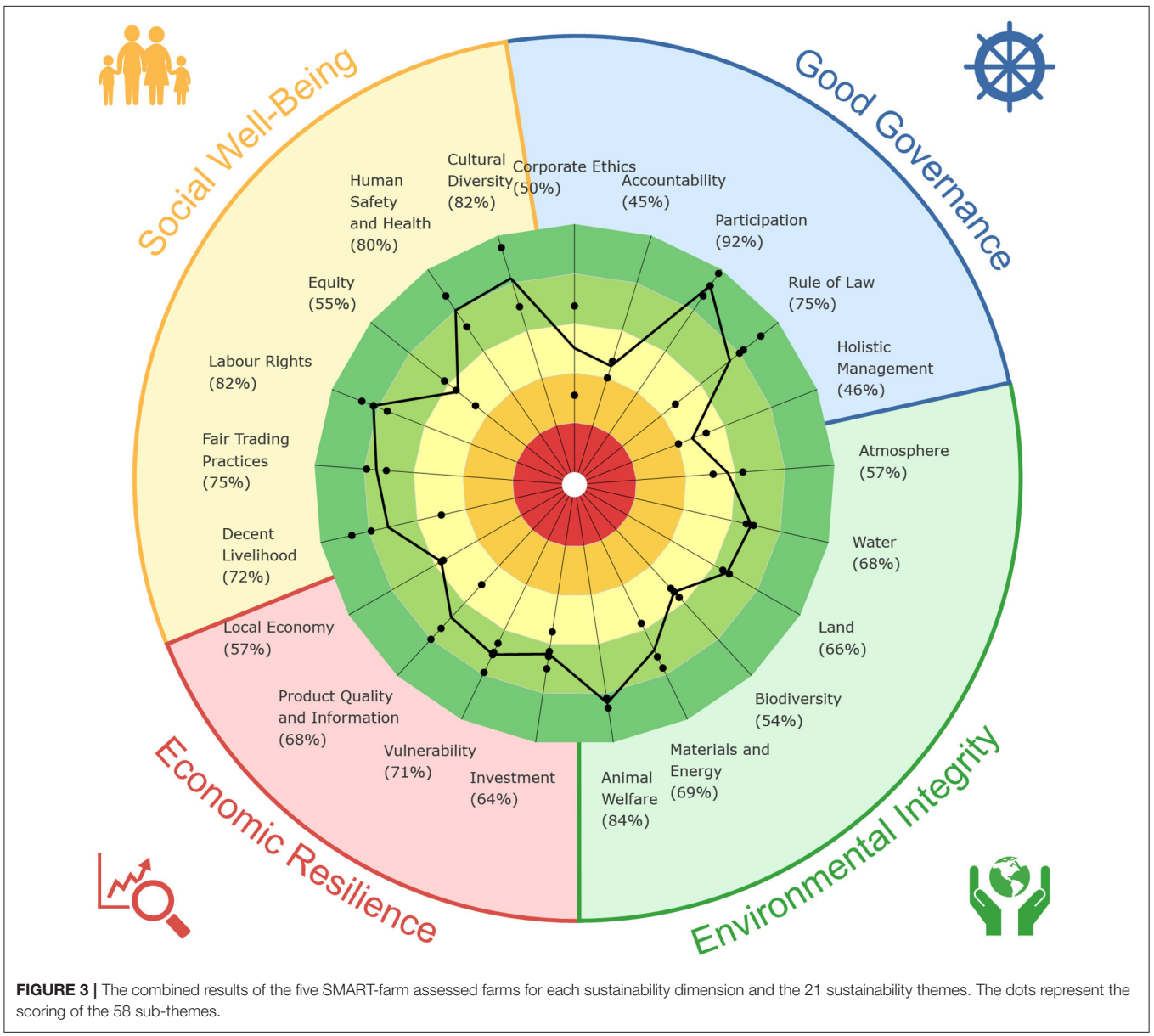

FIGURE 3 | The combined results of the five SMART-farm assessed farms for each sustainability dimension and the 21 sustainability themes. The dots represent the scoring of the 58 sub-themes.

Sustainability Assessment as the Starting Point for Discussions

Figure 3 illustrates the combined SMART-farm results of the five farms. In general, scores in the green areas (above 60%) are considered good [SMART (Sustainability Monitoring Assessment RouTine)., 2016], and it can be advisable to start the focus for improving sustainability on the themes scoring below this cutoff (in the yellow, orange, and red sectors). Although there are differences, resulting for instance from type of production (tunnel production of berries or open field potato production), availability of input locally or availability of written management plans, the trends of the different themes and sub-themes are rather consistent among the farms. Discussing these trends with the involved farmers revealed a general understanding among farmers that such trends reflected contextual conditions.

The themes with consistent lower scores might be areas that are either not so relevant in this context or are challenging for sustainability. Of the 58 sub-themes, 19 had scores of <60%-−7 in the Good Governance dimension, 5 in the Environmental Integrity dimension, 4 in the Economic Resilience dimension, and 3 in the Social Well-Being dimension. The combined results overall give an indication of the sustainability situation on horticulturally producing farms in Arctic Norway and serve as a starting point for further learning.

Findings From Farmers' Interviews and the Stakeholder Workshops: Learning for a Sustainable Future

The findings from the interviews with the farmers and the workshops are structured using the framework in **Figure 1**. Findings related to each question are presented in the following sections.

Where Is It Learned?

In the workshops, horticulture production is said to be knowledge intensive, and the horticultural farmers are perceived as: "*very interested in new knowledge and innovation, they are very forward-thinking*" (R). This perception stems from there being relatively fewer subsidies and financial innovation support schemes available, recent introduction of more technical production systems, and the necessity of risk-reduction strategies to minimize yearly yield fluctuations (mainly climate-related). The size of the farm also affects sustainability learning—for instance discussing themes in the Social Well-Being dimension one participant reflected that "*I feel that we may be a little small in relation to some of those topics, with support to vulnerable people and such*" (F). Most farms are dependent on seasonal workers but have experienced difficulties finding local workforce and are therefore increasingly dependent on foreign labor.

R&D projects including researchers, extension, and farmers are mentioned as important for sustainability learning where knowledge production for the special arctic conditions is essential. One such project was recognized as successfully expanding the table-top production of strawberries in tunnels: "*especially in such a small market as we have in northern Norway, such a project is very important, having several producers working on the same challenges* (and) *it becomes as natural to talk about economic challenges as challenges with insects, agronomy or production*" (R). Differences in size and challenges in transportation and logistics, are key factors discussed in the Economic Resilience dimension, and the local wholesaler is a decisive factor for production volume. Another feature characterizing Norwegian farmers is "trust," for example that large national input providers know the origin of their input: "*it is a lot about trust, I assume that most farmers buy from serious companies in Norway, so we think they have good control*" (F), although healthy skepticism exists. In addition, it is recognized that an agricultural policy that facilitates agriculture throughout the country, is crucial for sustained Arctic agriculture.

Many knowledge suppliers are mentioned in the workshops and interviews (**Table 5**). To further the farm in a sustainable direction, a more holistic insight on farm development is required, and one prominent feature is that there are few, if any, established learning platforms for this today: "*but where to find this knowledge (…) it is not so easy for a farmer just to call the extension service and say that I want to be better at sustainability?*" (A).

When Is It Learned?

The effect of time, both in the sense of the *actual time period of the study* and of *passing time* (changes to improve sustainability may well be seen in the future), affect sustainability learning. For instance, this study was performed during the COVID-19 pandemic which gives new perspectives on sustainability. In the workshops it was discussed how the pandemic made consumers more aware of how dependent the country is on global farm input production and distribution, and on the importance of self-sufficiency and buying local produce. This was also linked to sustainability being a valid argument for continued arctic agricultural production: "*that we should engage in agriculture in northern Norway, even though it might have been cheapest to get all the food from* (abroad)" (X). Self-sufficiency on terms of a local seasonal workforce was also discussed.

Sustainability learning as a long-term process is also evident in the discussions. One aspect is the trade-offs and economic concerns related to changing to a more sustainable production: "*In the long run sustainability will be positive for the economy, but in the short-term they go against each other in many ways*" (X). Another aspect is that: "*the time has worked*" (X), referring to that they have seen a development in farmers' attitudes. This development is closely connected to the wider public discourse on sustainability: "*we all have a long way to go, we are not there, we are consumers, the last 50 years we are raised to buy and throw away, and changing that, the whole mindset, that takes time*" (X).

Who Learns?

In this study the farmer is considered the learner. However, the farms in Arctic Norway working with horticulture are almost solely relatively small family farms, where farming is described more as a lifestyle, with high work-loads in season that to a large degree are affecting the whole family: "*it is more of a lifestyle, and you can forget about summer holidays*" (X). Often there are many family members working in close collaboration in production, as

TABLE 5 | Sources of learning, and main deliveries per sustainability dimension.

Sources	Good governance	Environmental integrity	Economic resilience	Social well-being
Individual farmer	Reports and media coverage.	Policy, reports, and media coverage. Experiments.	Monitoring decisions and market options.	Personality based
Extension	Operational planning	Experiments, monitoring, and advise in production	Economic concerns of production practices	Facilitate training
R&D	Sustainability assessments	New production systems or practical topics	Economic features related to production	
Farmer to farmer	Informal discussions, mentors	Share experience, practical collaborations, mentors	Sharing experience, mentors	Sharing work-force
Network	Branding, political force	Sharing production specific experiences	Market options, sharing resources and experience	Sharing work-force
Family	Informal discussions, strategic decisions	Younger generation with a stronger focus on environment	Economic decisions	Work/leisure, work safety, a good life
Local society	Informal discussions	Input concerning resource utilization	Arranging local markets	Local work-force, local contributions
Other	Documentation actors	Organic farming, machine-providers, documentation actors	Financial and market actors, consumers, Food Safety Authority	Labor and welfare authorities, documentation actors

TABLE 6 | Sustainability knowledge.

Knowledge	Examples
Knowledge about holistic farm sustainability	Knowledge to take sustainable choices, given the inherent complexities, trade-offs, and synergies
Agronomic knowledge	Knowledge concerning: plant protection, crop rotation, biodiversity, soil, clean seeds, fertilizing etc.
Knowledge for good management	Knowledge for good planning, managing diversity in production, making sustainable decisions etc.
Local knowledge	Agronomic knowledge for local condition including natural conditions Local and practical—tacit knowledge
Technical knowledge	Knowledge for precision agriculture and other technical advances in streamlining and easing production
Market knowledge	Knowledge for market access—e.g., sales and marketing
Relational knowledge	Personal competence for cooperation and empathy

TABLE 7 | Internal motivations for sustainability learning.

Internal factors	Example	Why does this motivate?
Knowledge seeking	Curiosity and interest in the field	Deep understanding of production and implications
Environmental consciousness	Reduce impact of production	Produce in a more environmentally friendly way
Social responsibility	Facilitate work, educate workers	Value their workers and contribute to local society
To have a good life	Plan and reduce workload	Improving quality of life and have a good family life
Improve chances of generational shift	Taking over a sustainable farm	Knowing the farm will have continued production, and making long-term planning feel worthwhile

well as in planning. Therefore, learning which aims to make the farm more sustainable needs to be distributed within the family, and, where appropriate, include employees and the seasonal workforce. In addition, in the workshops, much of the focus was on the Arctic Norway horticultural farmers, collectively.

What Is Learned?

Knowledge (including knowledge in practice) is both inputs and outputs of a sustainability learning process. **Table 6** presents the various types of knowledge found to be important for farm sustainability.

These types of knowledge are found to be varying in nature, linked to the source of knowledge, from informal (local, coming from farmers) to formal (academia, industry). Only informal knowledge is found in Local knowledge and Relational knowledge, and mainly formal knowledge is found in Technical knowledge. In all the other types of knowledge in **Table 6** we find a combination of both formal and informal knowledge.

Why Is It Learned?

The main finding is that, as the concept of sustainability is complex, the farmers' motivations for making sustainability changes at farm level are diverse. **Table 7** summarizes the main internal motivations stemming from the farmers' curiosity and interest in learning. Internal motivations are found in all the sustainability dimensions, although they are especially connected to the Environmental Integrity and Social Well-Being dimensions.

TABLE 8 | External motivations for sustainability learning.

External factors	Example	Why does this motivate?
Farm management and production	Improve product quality and decrease waste	Improve economy, quality, and reduce waste
Natural conditions	Possibilities for production	Improve economy and reduce transport
Politics and policy	Political commitment to Arctic agriculture	Enhanced potential, reduce economic risk
Society and market	Market differentiation	Freedom of choice of market solutions
Cooperation	Strong local actor securing deliveries	Reduce risk in market and production
Technology	Technology that streamlines operations	Improve efficiency, reduce resources

Table 8 summarizes the main external motivations. These are motivations where the outcome of a learning process is expected to be a means to an end. We find external motivations in all the sustainability dimensions, although only a few in the Social Well-Being dimension. The large majority of the external motivations are connected to improving the farm economy and risk reduction.

How Is It Learned?

The farmers learn in various ways, explained by one farmer as: "*talk to advisers, own experience, trial and error*" (F). **Table 9** shows the findings for ways of learning, collaborative, experiential, and experimental, in the four sustainability dimensions. The main ways of learning are collaborative and experiential. Only in the Environmental Integrity dimension is experimental learning prominent; however, this learning is sometimes also connected to experimental learning in the Economic resilience dimension. In the Social Well-Being dimension collaborative learning dominates.

Learning As a Process

The findings show several examples of sustainability learning processes, in all four sustainability dimensions. Most of the learning processes are single-loop learning, but we also find evidence of double-loop learning.

In the Good Governance dimension all four workshops (F, R, X, A) discussed the implementation of a written plan and a subsequent report for farm sustainability. There was a consensus that sustainability planning and reporting at farm level should be implemented gradually by utilizing and expanding existing documentation demands (e.g., KSL). It should also be a long-term process: "*this can be a long-term work, there seems to be an acceptance for that, as long as you (..) develop in a good direction*" (A). Learning can then have a snowball effect, where accumulating learning leads to improvements in all dimensions. It was suggested that learning can arise from adopting best practices from abroad or learning from pioneering farmers. Raising awareness is thought to be a main driver for this development: "*a massive lift in competence is needed, to change our way of thinking, because it is our way of thinking that needs to be changed first and foremost*" (X). A change in agricultural sustainability has to go hand-in-hand with the wider public discourse on sustainability. A similar implementation process has been described; in 2003 the "Environmental plan in agriculture" was introduced in Norway, the topic was very new and challenging to comprehend, causing much aggravation among farmers. Today, however there has been a significant increase in awareness: "*now everyone knows the importance of taking care of the environment* (recycling) *waste, and we register climatic change etc., so this has in a way become daily language today*" (X). This is a double-loop learning process, and it can be expected that implementing a plan and reporting on sustainability in the future will follow a similar sustainability learning path. It is also noticeable that in the Good Governance dimension, today, there are few if any formal sources of knowledge available providing a holistic focus on sustainability knowledge to the farmers.

In the Environmental Integrity dimension, the discussions were on agronomical features, improved crop rotation (F, X, A), and reducing chemical plant protection (R). The farmers' motivations are 2-fold—improved profitability: "*the main motivation, we just have to admit that, is an economic driver (..) reducing production costs and increasing yield and quality*" (F), but also curiosity and a genuine interest in the field. The ways of learning are often based on monitoring and evaluation of practical changes in production, with reflections regarding the sustainability connected to these changes. One farmer reflected on the work with reduced chemical plant protection: "*I have a focus on reducing chemical plant protection, but as it is now I can't avoid it, but I haven't used insecticides in maybe 10–15 years because I use traps, nets or covers, but covers are a plastic product, produced in* (far away), *so really, maybe it is not such a great improvement in sustainability after all*" (F). Often learning is closely related to trade-off discussions with the Economic Resilience dimension. All the processes described in this dimension could be characterized as single-loop learning processes. However, even though the focus is on efficiency and incremental changes, taking a long-term perspective, we see that small annual changes may result in larger changes.

In the Economic Resilience dimension, the discussions revolved around increased local procurement (F), securing self-sufficiency in soil, seeds/seedlings and fertilizers, and secure market conditions (X, A, R), including freedom of choice regarding market options. Many of the learning processes are based on different forms of cooperation, between farmers and extension, or more specialized cooperation like machine collaboration or sales networks to strengthen production possibilities, ease investment loads and enable better market access. In this dimension the learning processes are found to be mainly single-loop, and learning is often connected to various trade-off discussions with the Environmental Integrity dimension. Trade-off discussions can also lead to reflections resulting in double-loop learning. One farmer was concerned

TABLE 9 | Findings concerning the ways of learning in the four sustainability dimensions.

	Good governance	Environmental integrity	Economic resilience	Social well-being
Collaborative	Informal discussions, inspiring others, collaborative actions on sustainability.	Sharing experience and practical collaboration between farmers. Collaboration with research, extension etc.	Sharing experience between farmers. Collaborations between farms, market actors, customers or industries.	Farmers' cooperation, planning within family, collaboration with various external actors.
Experiential	Building sustainability awareness: assess, plan, implement, monitor, and report.	Monitoring and reflection on production efficiency, possibilities and impact.	Monitoring efficiency, thorough economic and market considerations.	Operational planning and monitoring. Social awareness and contribution.
Experimental		R&D projects, extension, and farmers' experiments.	Economic focus on agronomic experiments. Trial and error in new business models.	

with mileage, since direct sales on a remotely situated farm lead to long transportations, asking: "*is it at all sustainable to produce berries in our region?*" (F). This spurred discussions among the farmers about the farm's effects on the local economy and local society as well as on the availability of fresh quality products and added value for the customers.

In the Social Well-Being dimension the discussions focused on non-discrimination and support to disadvantaged groups (F), high average working hours (X, R), and access to training (A). Many of the motivational factors are internal, such as taking a heightened social responsibility and for the farm-family and workers to have a good life: "*we are a family business focusing on that everybody should have a good life, it's probably more about how you are as a person* (..) *it is more about personality than business thinking*" (F). Learning occurs within the family, with neighboring farms, with the local community, but also with institutions outside agriculture like the Labor and Welfare Administration (NAV). Learning based on planning, monitoring or reflecting on social concerns is also prominent. Discussions revolved around the issue of whether agriculture as a whole should take a greater social responsibility. Farming is often perceived more as a way of life rather than a career, and without awareness and good planning of working-time it is easy to be trapped in heavy work-loads: "*I think that farmers often think that time is not money, it's just a requirement that they have to work all the time*" (R). The learning processes are mainly through single-loop learning, however, double-loop learning is also present, especially through reflections revolving planning.

DISCUSSION

The following discussion seeks to answer this study's research question: What are the characteristics of sustainability learning in the context of horticultural farms in Arctic Norway? The findings show five overarching characteristics discussed in the following sections. Although separating these five characteristics, we also acknowledge that they are closely connected.

Complexity and Conflicting Issues

For holistic farm sustainability, the complexity of the concept (including the many, sometimes conflicting, issues involved) becomes central in the learning process. The interconnectedness of the farming system (Eksvärd and Marquardt, 2018) and the very nature of sustainability as a "wicked problem" (Rittel and Webber, 1973; Glass et al., 2012; Wals, 2015) adds to the level of complexity. Tàbara and Pahl-Wostl (2007), describe sustainability learning as a search for a "collective truth" that nevertheless, can also cause setbacks, if for instance policy and needs for sustainability changes are incompatible (Darnhofer et al., 2017; Eksvärd and Marquardt, 2018). In our results we find such contradictory needs, for instance between on the one hand, farmers aiming at sustainability through reduced economic vulnerability, market stability, and lower emission from transport, and on the other hand, large market actors aiming toward increased efficiency through centralization of storage and distribution hubs.

The findings reveal that the learning process, to a large degree, involves taking into account considerations for trade-offs, synergies, and long-term effects. Well-known are the trade-offs between the environmental and the economic dimensions (Schader et al., 2016). Trade-offs within dimensions are also common, such as reducing pesticides vs. using plastic fiber covers, and trade-offs between other dimensions, such as facilitating work for vulnerable groups vs. efficient use of farmers' working time. Schader et al. (2016) find synergies between the Good Governance dimension and the three other dimensions, Environmental Integrity, Economic resilience and Social Well-Being. As the SMART-farm results (**Figure 3**) show relatively low scores in several of the themes in the Good Governance dimension, this will therefore be a good point to start the sustainability learning process for the Arctic Norway horticultural farmers. Nevertheless, **Figure 3** also shows relatively high scores in most themes in the other three dimensions, and this may relate to the high policy documentation requirements already present.

Time-scale aspects remain a challenge when working for sustainability, knowing that changes need to be made in the present, while results may only be seen later, often far into

the future. This is especially challenging when planning for farm sustainability (Halland et al., 2021). In the workshops it was revealed that working for holistic farm sustainability was perceived to be better for the production and for the economy in the long run, even though in the short run it might be conflicting. One example was in improving the crop rotation system as opposed to annual efficient use of all the available land for horticultural production, as in the long-run, land can be higher yielding and less disease prone if crops are rotated. Working for sustainability is a continuous process (Brunori et al., 2016); in the long-term, periods of stability crisis, and new opportunities will fluctuate (Havet et al., 2014). Going through several rounds of learning, the farmer gains the necessary knowledge to address various conditions—knowledge that is vital for achieving long-term sustainability on the farm.

Combination of Internal and External Motivations

Darnhofer et al. (2010) acknowledge the crucial role of the farmer in farm development, and how farmers' motivation is essential for making changes toward sustainability on the farm (de Olde et al., 2018). In our findings, we see that the complexity of the concept of sustainability is reflected in the diversity of motivations for sustainability learning. Such diversity is also found in Triste et al. (2018). Hansmann (2010) stresses the motivational factor for sustainability learning, including both internal and external motivation, although he finds internal motivation particularly important since "[it] *might also support the development of pro-sustainability motivations for changing behavioral patterns in everyday life*" (Hansmann, 2010, p. 2881). In all dimensions we find both external and internal motivations, although internal or personal motivations, are mostly prominent in the Social Well-Being dimension. A farm is a business, a workplace that is generating the income for the farmer, and often also for the family and workers. Therefore, economic motivations are often either a main motivational factor or found in combination with essentially all the other external motivational factors. Although intrinsically important, economic motivations, perhaps with the exception of the Economic Resilience dimension, are seldom the sole motivational factors.

The findings also suggest that even in topics were there are strong policy regulations, especially connected to the Environmental Integrity dimension and Social Well-Being dimension, internal motivations are prominent. This result may appear to be contrary to Stock and Forney's (2014) finding that "*externally imposed legislative regulations (e.g. environmental regulations) can undermine farmers' experiences of autonomy*". Some examples relate for instance to health and safety, labor rights, and environmental impact on soil, water, and atmosphere. It is however difficult to say what came first, regulations or internal motivations. However, Hansmann (2010) stresses that also motivations for making new sustainability changes are an important outcome of sustainability learning. Thus, it might be that they work in concert, evolving as awareness and motivational outcome from a learning process. Internal motivations for holistic sustainability are not explicitly found in our study; however, it might be that they will evolve as a motivational outcome from a sustainability learning process if policy regulations concerning holistic sustainability planning and reporting are introduced. This is an issue that needs to be properly addressed in further research.

Building Awareness as a Main Cause and a Main Outcome of Sustainability Learning

Raising awareness of the concept of sustainability can be considered a main cause, and often a main outcome, of sustainability learning. The findings show that, especially for the Good Governance dimension, the process of planning for sustainability followed by subsequent monitoring, evaluation, and reporting of farm sustainability, is thought to lead to awareness of farm sustainability. Changes in policy and documentation demands, as for instance the 2020 implementation of a waste reporting requirement, may spur awareness, leading to farmers gaining new knowledge specific to their farm that may lead to farmers' active engagement in waste-reduction. In addition, although only briefly mentioned in the workshops, other studies have shown that organic farming is a source of inspiration, raising awareness about more sustainable farming practices (Lamine et al., 2014). Farmers' awareness can also be raised by external pressure from society; one example is how negative media coverage of working conditions for horticultural seasonal workers in Norway spurred actions to be taken by both the agricultural industry and governmental bodies. Crises can also act as trigger events (Sutherland et al., 2012).

In the workshops it was discussed how raising awareness could be personally quite demanding, since it will involve a mental process. Cooreman et al. (2018, p. 95) describe how this can lead to deeper learning: "*after experiencing a 'cognitive conflict,' a learner can feel stimulated to think critically about his way of looking at reality.*" Such processes can lead to double-loop learning, changing the values and the norms in the learner (Tàbara and Pahl-Wostl, 2007). Knowing how to facilitate for double-loop learning can therefore be essential in speeding up the process of sustainability learning. Eksvärd (2010) finds that the ability to ask probing questions is important for double-loop learning, and through this she concluded that: "*the first steps in transition toward more sustainable farming practice clearly involve 'un-learning' as much as 'learning'*" (Eksvärd, 2010, p. 278). Probing questions were asked in the workshops, for instance when one farmer questioned if farming practices were at all sustainable. Raising awareness might however not be directly linked to actual sustainability changes, as is for instance shown in relation to climate change adaptation (Harmer and Rahman, 2014), especially considering trade-off discussions with uncertainties of the actual sustainability of an expected outcome (as discussed in section Complexity and Conflicting Issues). Ison et al. (2000) describe change processes as moving from double- to single-loop processes, or the reverse, the outcome may express itself in either changed values or changed practices, over time.

A Social, Transdisciplinary, Learning Process

The complexity of the sustainability concept, described in section Complexity and Conflicting Issues, necessitates knowledge from numerous disciplines, in addition to local knowledge and relational knowledge, and this knowledge needs to be acquired by a variety of actors (Hubert et al., 2000). Due to these inherent complexities, sustainability learning demands a transdisciplinary process (Hansmann, 2010; Restrepo et al., 2018) where participants from different academic disciplines together with non-academic participants are working together toward the common goal (Tress et al., 2005) of producing "socially robust knowledge" and knowledge that is contextualized (Hessels and van Lente, 2008).

The findings reveal numerous examples of social learning processes in all dimensions. Social learning processes are considered essential for sustainability learning (Tàbara and Pahl-Wostl, 2007; Hansmann, 2010). The findings are consistent with the literature, where collaboration arises as a key feature of the learning process for farm sustainability (Darnhofer et al., 2010; Ingram et al., 2018). Restrepo et al. (2018) find that collaborative learning processes challenge farmers' assumptions and beliefs, and enable farmers to find relevant solutions for sustainability challenges on their farms (i.e., important in raising awareness as discussed in section Building Awareness as a Main Cause and a Main Outcome of Sustainability Learning). In Halland et al. (2021) both participation and networks were key factors for sustainability in Arctic Norway horticulture. In the SMART-farm assessment the farms also showed a very high score, 92%, on the theme Participation (**Figure 3**). Overall findings from workshops and interviews show that collaboration is important for learning, and the SMART-farm results further indicate that this is something the farmers are good at.

Optimally combining knowledge from various sources, informal and formal, is found to promote farm sustainability (Darnhofer et al., 2010; Šumane et al., 2018). Lankester (2013) argues that the famers' main source of learning is informal, and in our study we find informal farmers' networks as well as local community social networks to be important in sustainability learning, through enabling discussions concerning sustainability to be an integral part of the daily language. These findings are consistent with Cooreman et al. (2018) and Lankester (2013) showing that learning from other farmers was important for sustainability learning, for example by having "pioneer farmers," as good examples as well as contributors, especially when it comes to practical and detailed knowledge of production. The findings are also in agreement with the findings in Havet et al. (2014) where the strong integration between crops and livestock has a positive effect on farm sustainability. Moschitz and Home (2014) emphasize the importance of co-production of knowledge between research and extension with various stakeholders. The farmers in our study actively engage in R&D projects and have a well-developed collaboration with the extension service. This has been especially fruitful for new knowledge and expertise relating to arctic conditions and specialized knowledge for relevant new technologies. The findings therefore show that the Arctic Norwegian farmers have a range of formal and informal sources for the knowledge necessary to work on sustainability in the three dimensions Environmental Integrity, Economic Resilience, and Social Well-Being. However, there seems to be a lack of sources, especially formal, for knowledge in the Good Governance dimension. It could even be argued that the lack of holistic sustainability learning platforms and knowledge providers is one of the main hindrances for a sustainable farm development.

Sustainability Learning Is Context Dependent

One main characteristic of the sustainability learning process of horticultural farmers in Arctic Norway, evident in the discussions above, is how intertwined it is with contextual factors. Hansmann (2010, p. 2888) suggests that "*the ongoing, multilayered inquiries and discourses, which strive for an understanding of what sustainability ultimately means*," is the very process of sustainability learning. As there is not one fixed prescription for what sustainable farming actually is, sustainability needs to be contextualized. The importance of context becomes more evident when dealing with the interplay between special conditions; climatic, topographic, land, demographic, policy and market, where all must be understood locally. For instance, knowledge specific to special Arctic conditions was found to be lacking, and a combination of farmers' and extension experiments could remedy this situation. Restrepo et al. (2018) find that farmers value learning that is context specific and stems from practice. Also, local knowledge often contains a more holistic view of local systems (Šumane et al., 2018). It is evident that farmers' learning and transition toward sustainability needs a focus beyond the farm scale (Lamine et al., 2014), and that the learning processes of farmers and society are linked, and to a large degree bounded by policy and societal developments. One example from our findings is that attitudes toward both environmental and sustainability issues are perceived positively, both among farmers and the general public, and this makes it easier to plan for farm sustainability.

Natural conditions for food production differ, knowledge providers and actors in the value chain vary, policy and societal factors differ and, in a trajectory of time periods the situation varies, and the farmers' values and preferences differ. Subsequently, the sustainability learning process will vary according to context. Eshuis and Stuiver (2005) use the phrase "learning in context" to highlight the contextual nature of learning.

CONCLUSIONS

The article presents a mixed methods participatory inquiry approach to investigate the characteristics of sustainability learning in the context of horticultural farms in Arctic Norway. We draw on insights from sustainability learning, loop learning, social learning and learning for sustainability at the farm level. Our framework enables us to analyze important parts of the learning process (who learns, where is it learned, when is it learned, what is learned, why is it learned, and how is it learned) to understand sustainability learning at the farm level. We find that five principal aspects characterize sustainability learning in

the context of horticultural farms in Arctic Norway; however, we also acknowledge that these are closely connected:

1. The complexity of the concept of sustainability and the immense level of conflicting issues entail that the learning process constantly negotiates on trade-offs, synergies, and long-term effects.
2. The complexities are reflected in the diversity of both internal and external motivations for sustainability learning. Economic motivations are often a main motivational factor, although seldom the sole motivational factor.
3. Building sustainability awareness can be considered as a main cause for, and often a main outcome of, sustainability learning. Raising awareness can also lead to double-loop learning where the outcome is changes in farmers' values and perceptions.
4. Sustainability learning is predominantly a social learning process, where the complexities call for transdisciplinarity, optimally combining formal and informal knowledge from a variety of different sources.
5. Sustainability learning is highly interconnected with contextual factors, and what sustainability ultimately means must be understood locally.

The empirical findings raise some considerations on holistic sustainability learning. The findings reveal that knowledge required to gain a holistic insight on farm sustainability is insufficient, and few formal sources of such knowledge are available for the farmers. Nor are there any established networks or social learning platforms for holistic farm sustainability, while we also find little evidence of internal motivations for holistic sustainability. It therefore seems that there is a lack of a holistic focus for sustainability, an outcome that is consistent with Halland et al. (2021, p. 67) where a "*limitation to such (sustainable) transformation can be that the knowledge of what, holistically, sustainable food production includes is unclear.*" It could be asked if the traditional agricultural extension services and other advisors or researchers today have sufficient expertise to support farmers' learning for a holistic change toward sustainable production. In any case, it raises the question whether additional support systems or a broadened focus area for the traditional extension service is needed. From the previous discussion on motivational aspects we contend that past experiences have shown that internal motivations have grown alongside policy regulations. A stronger political commitment and subsequent policy regulation for holistic sustainability can therefore be part of the solution. Furthermore, our results illustrate that an efficient and effective holistic learning sustainability process, is a gradual transdisciplinary process, where farmers' active involvement is crucial.

Theoretically, this study contributes to filling gaps in the literature related to understanding learning processes leading to sustainability changes (Lankester, 2013). The value of the framework adopted for this study is that it emphasizes the importance of viewing sustainability learning as a continuous process in which both knowing what to learn as well as being motivated for learning are essential. This framework has proven useful in revealing characteristics of the sustainability learning process. For future studies, the framework could be incorporated with theory from Agricultural Innovation Systems (Aerni et al., 2015) to register the findings in a systemic analysis. Sustainability learning at farm level does not occur in isolation but is dependent on the complete agricultural systems. In addition, for longitudinal studies it could prove useful to better incorporate the theories of loop-learning (Argyris and Schön, 1978; Tàbara and Pahl-Wostl, 2007) or transformative learning (Moyer and Sinclair, 2020) to study real-time changes.

This study further addresses the lack of empirical studies focusing on how to go from farm sustainability assessments to sustainability implementation (de Olde et al., 2018; Coteur et al., 2020). We show how undertaking a sustainability assessment, followed by an individual discussion and a group discussion, can be a valuable way to contextualize sustainability at farm level, enabling the farmer to work on concrete sustainability improvements. This has also been proven as an effective process for raising farmers' sustainability awareness. Nevertheless, the typical farmer will need more continuous support to secure actual sustainability implementations, and therefore different sources, knowledge, and learning platforms for holistic sustainability need to be established. Knowing the complexity of the sustainability concept, establishing networks or social learning platforms for holistic farm sustainability would require new collaborations with actors working across all the sustainability dimensions. The latter relates to what Wals (2015) calls *sustainability didactics*, what is needed is then learning environments that enable learners to see the world more holistically.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available in order to preserve the anonymity of the participants who consented to take part in the study under this condition. Requests to access the datasets should be directed to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by NSD - Norwegian Centre for research data. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

All authors have participated in developing the study content and direction, and throughout the working period of the study, from January 2020 to March 2021 we had common meetings to discuss the progress. HH has been the executing part throughout the writing of the manuscript, the practical implementation of the methods as well as for the analysis. GB, LL, and IK have been actively reviewing the progress of the manuscript throughout the study's period and have delivered valuable proposals especially for theory, concept, and methods development.

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9.3 Paper III. Transnational cooperation to develop local barley to beer value chains

Halland, H., Martin, P., Dalmannsdóttir, S., Sveinsson, S., Djurhuus, R., Thomsen, M., Wishart, J. and Reykdal, Ó. (2020). Transnational cooperation to develop local barley to beer value chains. Open agriculture, 5(1), 138–149. doi:10.1515/opag-2020-0014

Research Article

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Transnational cooperation to develop local barley to beer value chains

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Abstract: Transnational cooperation is a common strategy for addressing research and development (R&D) issues resulting from similar challenges that cut across administrative borders. Value chains for food and drinks are complex, and transdisciplinary work is recognised as a method for solving complex issues. The Northern Cereals project ran from 2015 to 2018, and its goal was to increase cereal production and the value of grain products in four regions in the Northern Periphery programme area. The project included both R&D, but the main emphasis was on development, and was carried out by transdisciplinary cooperation between R&D partners and small and medium-sized enterprises (SMEs). By reviewing the project's methods, outcomes and composition, we discuss if a framework of transnational and transdisciplinary cooperation can help to develop the value chain from local barley to beer. We found that transnational cooperation was achieved successfully, that stakeholder involvement was crucial, but that academic disciplines such as marketing and innovation could have been included. In addition, we recognised that much work remains to further increase cereal production and the use of local grain in the Northern Periphery region, but believe that this project has laid a good foundation for further progress.

Keywords: Northern Periphery region, transnational, transdisciplinary, value chain barley to beer

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1 Introduction

Transnational cooperation is one of the main strategies in many research and development (R&D) projects because it is recognised that many common issues can be more effectively and innovatively solved by collaboration than by isolated national initiatives (Dühr and Nadin 2007). Achieving added value is a goal for such cooperation (Colomb 2007). Food and drink value chains are complex, stretching from primary production, through processing, marketing, consumption, waste and recycling. Although food and drink value chains have become increasingly globalised, in recent decades a local food movement has arisen as a reaction to this, and "local" has frequently been associated with "sustainable and healthy production and consumption patterns" (Brunori et al. 2016). It is recognised that new ways of generating knowledge, apart from traditional academic discipline-based approaches, are needed to solve complex challenges. Transdisciplinary is recognised as a suitable method for solving complex issues, where researchers from different disciplines work together with stakeholders (Maasen and Lieven 2006) to develop knowledge that is integrated between science and society (Tress et al. 2005).

The Northern Cereals project ran from 2015 to 2018, and its aim was to increase cereal production and the value of grain and grain products in the Northern Periphery region (as defined by the Northern Periphery and Arctic Programme). The project adopted a value chain perspective and included R&D partners from four countries in the Programme area as well as a total number of 310 stakeholders. The region shares several common features such as low population density, long distances to the larger markets, challenging growing conditions and a large impact from climate change (Natcher et al. 2019). One focus was on the barley to beer value chain and here there were large national differences in the extent of its development. The project acknowledged these differences by allowing each partner to concentrate on the aspects that were considered locally most important. In all activities, there were two or more partners

collaborating, creating many opportunities for mutually beneficial exchanges of knowledge and experience.

The value chain from barley to beer in the Northern Periphery region has multiple challenges. One of the most basic, however, is the barley production in which the lack of knowledge, experienced producers, machinery and equipment, as well as locally adapted barley varieties, are limiting the expansion of the crop. However, market trends favouring local or high-provenance products, more plant-based food and sustainable production are making northern food and drink products more attractive to consumers (Martin et al. 2016a). One significant result of this has been an expansion in microbreweries in remote regions where they can benefit from a unique locational identity (Withers 2017). Microbreweries usually have an important positive effect on the local economy and tourism (O'Connor 2018), and as product differentiation and provenance are important, some microbreweries have a particular interest in using local cereals (Danson et al. 2015) as a means of linking their products to a locality and heritage.

The development of the complete value chain requires access to a wide range of knowledge and skills. Knowledge from various disciplines such as agronomy, plant physiology, chemistry, food science, innovation, marketing and economics must align to achieve success. In addition, when concrete results such as increased barley production, improved drying, improved malt quality and higher value beer products are sought, it is necessary to work closely with the practitioners. Therefore, the project used a transdisciplinary approach where challenges were addressed in close cooperation with associate partners and other stakeholders.

The research question of this article is as follows: Can a framework of transnational and transdisciplinary cooperation promote development in local barley to beer value chains? Empirically, the study focuses on work carried out in the Northern Cereals project in the Northern Periphery region. A summary of the methods utilised, outcomes, and partners and stakeholders involved in the project is presented to evaluate the cooperation and transdisciplinary effects. The study concludes with suggestions, both for further development of this value chain and for transnational cooperation.

2 Transnational and transdisciplinary cooperation in R&D

The Northern Cereals Project was funded by the EU's Northern Periphery and Arctic Programme in which both transnational and transdisciplinary cooperation are key driving forces. The programme emphasises the use of the individual strengths of the partners, and transnational cooperation facilitates a joint approach for tackling common issues. According to Pisani and Burighel (2014), transnational cooperation projects create an opportunity "to exchange fruitful information, contextual expertise and local knowledge, thus enhancing the opportunities for innovation and economic benefits". Ray (2001) explained the rationale behind the benefits stemming from transnational cooperation as "to take advantage of similarity", "to take advantage of complementarity" and "to reach critical mass". However, it has also been recognised that successful (policy) transfer depends on the nature and quality of the cooperation (Colomb 2007). Cooperation in the Northern Periphery region aiming to improve the barley to beer value chain is well suited to this rationale. Similarities between the areas include geography, climatic conditions and cultural background, which make cooperation easy as participants feel a natural connectivity. In addition, using each participant's strengths improves the result and, in a region that is sparsely populated, there are considerable advantages in linking together SMEs from the whole region through knowledge exchange and networking activities. Such cooperation is not easy, however, and although transnational collaboration is expanding, good examples of working across administrative borders are exceptions (Dühr and Nadin 2007).

The academic division into narrow disciplines has fostered specialisation into increasingly more focused areas. Many of today's complex issues, such as climate change, food security or poverty reduction, cannot be resolved within single discipline. As a reaction to this, transdisciplinary methodologies have been proposed as a solution, where researchers from different disciplines work together towards a common goal where theory and knowledge between the various disciplines are integrated, and where non-academic participants are included in the work (Tress et al. 2005). Scholz and Steiner (2015) conceived transdisciplinarity as a mutual learning process between science and society to attain knowledge about a specific real-world issue. Moreover, it facilitates bringing societal concerns into scientific research (Maasen et al. 2006). This type of R&D must be contextualised to the specific study area, and the aim of the outcome is to produce "socially robust knowledge".

According to Nowotny (2003), such "robustness" is more likely to be achieved through the involvement of a heterogeneous group of "experts". Stakeholder involvement is a crucial part of transdisciplinary research and ensures that "the 'right problem' gets addressed in

'the right way'" (Maasen and Lieven 2006). Triste et al. (2014) also included increased learning opportunities as an advantage stemming from stakeholder involvement, which is also considered to ensure impact, as in real life changes (Gasparatos et al. 2008). However, there are many definitions of what a stakeholder is. Alrøe and Noe (2016) wrote that stakeholders are "those who will bear the consequences and carry out actions for change". Key stakeholders or primary stakeholders are also used as concepts for stakeholders more directly connected to (in this case) the value chain from barley to beer (Alrøe and Noe 2016). Tress et al. (2005) also emphasised that the level of stakeholder participation – the extent to which they are informed, consulted, involved or in control – determines their influence on the work. For a project, it is therefore important to define the role of the stakeholders, especially to fulfil the expectations the involved parties have about the project.

3 Methods

The objectives of the Northern Cereals project were very broad and could only be addressed by accessing knowledge and experience from many different disciplines. All the partners had some of these skills or knowledge, but no single partner had access to all of them. The project, therefore, provided a mechanism for pooling this expertise for the benefit of all partner regions. Although the project included both R&D, the emphasis was on the latter and the partners spent most of their time working with farmers and SMEs in very practical situations and under diverse "northern" conditions.

Simplified, the barley to beer value chain consists of the following four distinct parts: growing the barley, malting, brewing and marketing. All of them are connected, and each depends on the quality of the output from earlier steps of the chain to perform well. Figure 1 shows these four parts and the various challenges along the value chain.

The activities in the Northern Cereals project were structured under work packages (WPs), coordinated by an overarching Management WP led by Matis, Iceland. Each WP was led by an individual researcher with skills that were relevant to the WP, and the WP leaders were responsible for coordinating WP activities with participating researchers in all the other countries. All researchers then liaised with stakeholders in each WP to ensure that the WP activities were implemented. Project WPs addressed the challenges identified in Figure 1 through five main areas of activity summarised in the following sections.

3.1 Test production of barley

To develop the complete value chain, it is necessary to start with well-adapted varieties of barley. This was the main task in the Northern Cereals preliminary project (Reykdal et al. 2016), but several trials (Table 1) were also established during the main project period, and these were also used for demonstration purposes. Data collected from trial plots included characteristics such as grain and straw yield, grain moisture at harvest, thousand grain weight, the occurrence of diseases and lodging and rainfall and temperature data over the growing season. There was a special emphasis on the identification of early maturing varieties because of the importance, throughout the region, of early harvesting. Data from the trials were analysed by the researchers responsible for them and were summarised for the other project partners. Grain from trials and demonstrations was used for other project activities, especially product development. Both in the Faroe Islands and in Northern Norway, the introduction

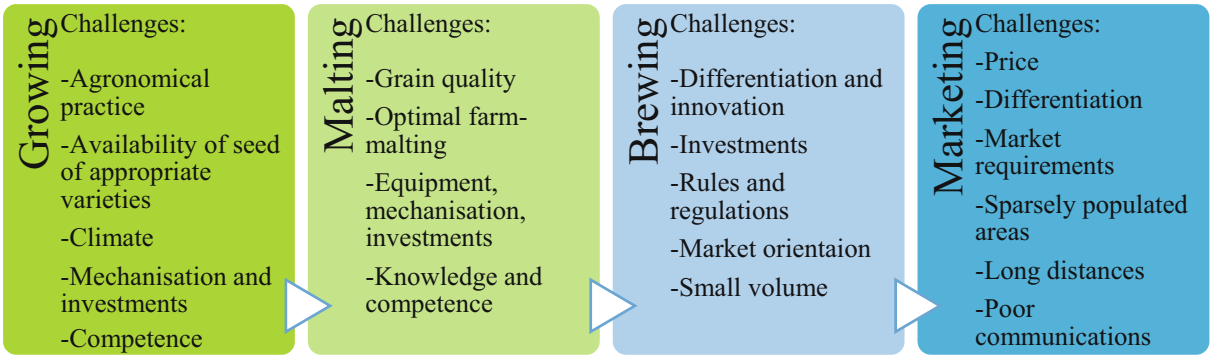

Figure 1: Challenges in each step of the value chain from barley to beer.

Table 1: Number of trials in test production of barley and small-scale malting

Country/region	NO	FO	OR	IS
Number of cereal trials/demonstration plots	8	3	5	1
Number of small-scale malting trials	4	2	3	2

FO = Faroes Islands, IS = Iceland, NO = Norway, OR = Orkney.

of appropriate machinery was also an important issue for potential cereal farmers. Guidelines and handbooks for farmers were developed in all the partner languages to aid the production of good quality grain. In the Northern Periphery region, post-harvest drying of grain is essential for safe storage, and case studies and guidelines concerning drying were developed in Iceland.

3.2 Malt quality experiments and case studies

Several small-scale malting trials (Table 1) were carried out during the project period in Scotland, Iceland and Norway, and guidelines summarising quality criteria for malting barley and case studies of floor malting methods were prepared. Two experimental malting trials were performed using test malting facilities at The Norwegian University of Life Sciences. The colour, moisture, extract, nitrogen content, friability, homogeneity and diastatic power of malt produced during the project typically were analysed. Although the brewers need to take all of these factors into account while brewing, the extract is especially important as it is a measure of the amount of sugar obtained from the malt after mashing, which is important for alcohol yield. Data from the samples malted during the project were summarised and included in reports stored on the project website which made them available to all partners.

3.3 Product development

Product development was performed by the breweries themselves, and several new products were taken to the market, including beer made from locally grown and malted barley. However, most of these products were test products or produced in limited quantities because of the shortage of local malt. The acceptability of products was assessed by the companies themselves based on in-house testing and feedback from their own client base, sometimes using social media or web-based sites.

3.4 Market knowledge

The marketing segment of the barley to beer value chain was mainly handled by the brewery stakeholders through their normal marketing channels. However, the R&D project partners also carried out a review of the market situation for barley and malt in the region. This also included global trends in the cereal food and beverage markets.

3.5 Knowledge transfer

Knowledge transfer between the project's associate partners (mostly SMEs) and the R&D partners in the different countries was the key to the project's success. Important mechanisms for doing this were the project meetings and the four conferences. They were held in four of the participating countries, with invited presenters and stakeholders, and included field trips and study visits to farms, malting facilities and breweries in addition to social activities. These facilitated the development of new networks and cooperation as well as knowledge transfer. In addition, all regions held local knowledge transfer events throughout the project period. The project also offered 4-day training placements for participants interested in starting their own malting, at a floor malting facility in Orkney, Scotland. In total, 310 stakeholders participated in the project in various ways (Table 2).

Table 2: Total number of stakeholders

Stakeholders	IS	NO	OR	FO	Total
SME	143	75	61	7	286
Business support organisations	5	10	9	0	24
Total	148	85	70	7	310

FO = Faroes Islands, IS = Iceland, NO = Norway, OR = Orkney.

4 The context – the value chain from barley to beer in the Northern Periphery area

The region shares several common features such as low population density, long distances to the larger markets,

challenging growing conditions (especially, poor soils, large variations in rainfall and temperature during the short growing season, and difficult harvesting conditions) and a large impact from climate change (principally increased temperatures in both summer and winter). Recent warming in the northern regions has helped to increase the potential for barley production (Martin et al. 2017), and this may help to offset the decreased agricultural production predicted in some more southern areas as a result of climate change (Muller et al. 2010). Nevertheless, in some years, other weather-related factors, such as high rainfall, drought, gales and late or early frosts, continue to make growing barley risky in parts of the region.

Barley has been grown in Norway and northern Scotland since ancient times, and production was introduced to both the Faroe Islands and Iceland in the ninth century. However, it is only in Orkney and Northern Norway that the cultivation has been continuous, although in Northern Norway there was a marked decline after the 1940s, due to both economic and political reasons (Halland et al. 2018). In Iceland, cultivation started again in 1923 and has been continuous since then with considerably increased production over the last few decades. In the Faroe Islands, barley was recently re-introduced. In Orkney, barley is an important established crop that is cultivated with a high level of mechanisation.

Barley is well-suited for the cool climates of the Northern Periphery region where the growing season is short and strong winds and frost can be expected. However, grain is often harvested at a high moisture content, which means that it needs to be dried for food uses although there is always an option to process the grain as wet feed for animals.

An important potential market for local barley is to supply malt for brewing. This results from the recent expansion of northern tourism, the increased demand for high provenance drink products and the growth of microbreweries or craft breweries. For example, in Iceland, the number of tourists has quadrupled from 4,89,000 in 2010 to 22,25,000 in 2017 (Icelandic Tourist Board 2018) and since the first independent craft brewery opened in 2006, there are now about 20 which are associated with the Independent Craft Brewers of Iceland on the organisation's Facebook page.

In peripheral northern areas, there are, however, some major constraints on using local barley to produce beer, especially the availability of grain of a suitable quality and quantity, and a lack of local facilities for using this to make malt. Grain quality issues stem mainly from a lack of specific malting varieties adapted to northern areas. As a result, non-malting varieties tend to be used which are likely to give malt with lower extract yields than imported malt made from the recognised malting varieties. Challenging harvesting conditions may also make it difficult to obtain grain of good quality with a high germination percentage for malting. Brewing within the region is therefore mainly carried out with malt imported from a small number of very large malting companies in Germany or the United Kingdom (Nordic Innovation Centre 2009).

Most of the partner regions have considerable potential for expanding the area of barley cultivated. In Iceland, for example, it has been estimated (Ministry of Industries and Innovation 2011) that annual production of cereals (barley) could be increased from about 16,000 t to 40,000–50,000 t per year. With the current increase in microbreweries across the region, part of this increased barley production could also be utilised to make local malt and beer. The region, therefore, has opportunities for increased self-sufficiency and sustainability by increasing domestic cereal production for feed, food and drinks.

5 Results – review of outcomes

From a value chain perspective, we review the main findings and work done in the Northern Cereals project on the barley to beer value chain. These findings are contextualised to the Northern Periphery region. However, areas with similar production constraints, where improved local malting is needed, or there is a market demand for local beer with special qualities, will also find much relevant information in this review.

5.1 New possibilities for growing, drying and storing high-quality barley

The growing season in northern areas is becoming longer, and further lengthening is expected due to higher average temperatures (Uleberg et al. 2014). However, it is also expected that there will be more rainfall in the autumn, especially in coastal areas. This is one of the main challenges for cereal production in the Northern Periphery region, and the project produced several country-specific reports (Martin et al. 2018a, 2018b, 2018c) and a peer-reviewed paper (Martin et al. 2017) on this topic. In Martin et al. (2017), the temperature and rainfall trends during

the barley growing season were investigated across the project area from 1975 to 2015. They found that a trend towards warmer growing seasons is favouring barley production and has probably been particularly beneficial in Iceland, but excessive or inadequate rainfall constrain production in many areas. They also found that "both monthly temperature and rainfall show high variability from year to year across the region, which can result in very variable growing seasons". Such yearly variations have a high impact on production as the proportion of years with bad harvests will determine the economic viability of barley production. Another important factor for cereal production and possible expansion in the area is the availability of arable land. Arable land (here defined as the land suitable for barley cultivation) was found to be a limiting factor in many regions (Sveinsson and Dalmannsdóttir 2016). The project investigated the proportion of arable land relative to total land area and found that it is unevenly distributed throughout the Northern Periphery region, with Northern Norway having the lowest proportion (0.8%) and Orkney having the highest (15%) (Sveinsson 2017). Although Iceland had only 3% arable land, Sveinsson (2017) concluded that this area had the largest potential for increased barley production, due to the proportion of available arable land.

Well-adapted cultivars are crucial for the successful barley production in northern regions, and early maturity is a key factor due to the short growing season. Some old landraces and varieties bred in the early 1900s are still grown, and prominent among these is Bere, an ancient Scottish landrace, which has a long tradition of cultivation in Orkney. Also, in Northern Norway, four old barley varieties are preserved in addition to the landrace Dønnes (Halland et al. 2018). In the Faroes, there are two surviving landraces, Sigurd and Tampar. For the value chain from barley to beer a special emphasis was put on old varieties and landraces both because of their earliness and local adaptations (Schmidt et al. 2019), as well as their potential for telling stories about food and drink through both new and traditional barley products (Martin et al. 2009). Seed multiplication of the northern Norwegian and Faroese varieties is enabling farmers to start growing these varieties and so there is now real potential for using them for future product development. In the last 40 years, there has only been one breeding programme for adapted varieties for the region, in Iceland. The Agricultural University of Iceland has run a barley-breeding programme, which has released four commercially available cultivars (Hilmarsson et al. 2017). Among these is Iskria, which has been grown successfully in countries within the Northern Periphery region. In the Northern Cereals preliminary project, a project supported by the North Atlantic cooperation, promising cultivars were compared in five countries (Reykdal et al. 2016). Icelandic varieties were also used in the Northern Cereals project for product development in northern Scotland, Northern Norway and the Faroe Islands.

Growing cereals in the project region requires specific agronomic knowledge. The project paid special attention to knowledge transfer and capacity building through handbooks and guidelines, which were made available in four of the region's languages. In addition, knowledge transfer events were important tasks for all project partners. The basis for the guidelines is the review by Sveinsson and Hermannsson (2017), which relates barley physiology to the factors necessary for successfully growing the crop in northern areas. They noted that barley is the hardiest cereal species with the lowest heat requirement for growth, and that early varieties require about 1300 growing degree days (with a base temperature of 0°C) to reach maturity. Barley seeds tolerate mild frost during germination and, in this region, it is imperative for successful production that sowing should be done as early as possible. In most of the region (especially the Faroes, Northern Norway and Iceland), grain is harvested when it is physiologically mature, although at a high moisture content (i.e. usually more than 22%). This has implications for obtaining good quality malt and makes it difficult to consistently produce malting barley with the same quality criteria used by large malting companies in more southern barley growing areas (Martin 2015). In addition, as grain is usually harvested at high moisture contents, it needs to be dried to 12–14% moisture for safe storage (Reykdal 2017). This adds energy costs to the production, and it is imperative for economic viability that this is done as inexpensively as possible.

The project also investigated economic and environmental aspects of sustainability, including local production, best practices for high-quality grain and malt, and added value through new products based on place-based information and traditions. Other research has also shown that local food value chains have a positive impact on some aspects of sustainability – for example, added value at the local level (Brunori et al. 2016). In the project, a Life Cycle Assessment was performed at the Icelandic model farm Thorvaldseyri. This included looking at environmental impacts and energy-use on the farm. The results can be used to demonstrate how environmental impacts and use of resources can be minimised to improve sustainability and reduce footprint (Smárason 2016).

5.2 Local malting of barley from the Northern Periphery region

Recognising that the production of good quality local malt is dependent on growers producing grain of an appropriate quality, the project identified grain quality criteria normally required for malting barley and then developed region-specific growing guidelines to help farmers obtain grain of this quality. However, research trials associated with the project in Northern Norway demonstrated the difficulties in achieving this in more challenging parts of the region. Thus, 2015 was a good growing season with a timely harvest, and the grain had a reasonable moisture content and all seven varieties tested showed good germination and malted successfully (Thomsen 2016). In contrast, 2016 and 2017 were much less favourable for growing, resulting in later harvests, higher grain moisture content at harvest and grain with a very low germination percentage (66% and 30% from the 2016 and 2017 crops, respectively), even 7 months after harvest (Halland 2018). Low germination, as a result of seed dormancy, also challenged malt production in Iceland (Sveinsson et al. 2016). In contrast, in Orkney where growing conditions were more favourable, it was possible in all growing seasons from 2015 to 2017 to produce good-quality barley for malting which had lost seed dormancy by about 4 months from harvest, giving around 98% germination.

As most of the breweries involved in the project were unfamiliar with details of the malting process, a high priority was given to knowledge exchange activities related to malting. This included carrying out small-scale malting within the partner regions and making the results available through reports or case studies as well as through presentations. In parts of the region, traditional floor malting of barley is still carried out and it was recognised that this is a low-cost, easily transferable method of malting which might be appropriate for some commercial partners. The floor malting process is also ideal for demonstrating the steps involved in malting. One of the Orkney associate partners in the project was a distillery with floor malting facilities and the company agreed to malt a test batch of 7.5 t of Orkney-grown Golden Promise barley for use by an Orkney brewery and to allow the process to be documented as a case study (Martin et al. 2016b). Laboratory analysis of the malt showed that it was of good quality, although it had a lower extract than would have been obtained from modern malting varieties. In Norway, seven varieties grown in Tromsø were test malted at the Agricultural University of Norway (Thomsen 2016). Malting qualities were found to vary between varieties, but the conclusion was that "we have however, so far no reason to believe that it is not possible to grow malting barley in Northern Norway." In Iceland, test malting trials discovered large variation in germination, but were able to malt successfully around 200 kg of Iskria for further processing (Sveinsson et al. 2016; Sigurðsson 2018). The variation in initial grain quality is a challenge for local malting in the Northern Periphery region. To achieve good malt, it is necessary to adjust the malting process according to the initial quality. For instance, it is especially important to ensure even-sized kernels and a more even germination by screening the grain. Thomsen et al. (2018) addressed this in a test malting of four different barley varieties from four different regions with varying initial quality and using three different malting processes. The conclusion from their work was that the malting method chosen has a strong influence on malting quality and extract yield.

The lack of small-scale equipment for malting in the region is a constraint, but the project suggested some key recommendations for inexpensive floor malting (Martin et al. 2016b). These included steeping vessels that can be easily filled and emptied, a sufficiently large floor area for the scale of malting being carried out, machinery for turning the malt and clearing the floor, drying facilities that allow for temperature regulations, bagging equipment for storing the malt, as well as milling equipment. To assist further with knowledge exchange about malting, a distillery still doing floor malting in Orkney agreed to provide placements for partners from other regions to learn the technique, and eight individuals from SMEs in Iceland, the Faroes and Northern Norway took up placements. Since then, some of these have implemented their own floor malting operations.

5.3 Market potential for local malt and beer

Although it has been difficult in most of the regions, within the life of the project, to develop beers made from locally grown barley, there have been some notable successes. In Northern Norway, three breweries produced beers using local barley and one of these included a traditionally made smoky malt from a farm in Stjørdal, near Trondheim. In Orkney, Bere was used by a local brewery for producing two new beers. The same brewery also used locally grown and malted Golden Promise to produce a new beer, but preferred to use Bere, in spite of

its lower malt extract, because of its effect on beer flavour, its long association with the islands, and its unique marketing story.

The potential for higher value food and drink products from locally grown barley in the Northern Periphery region results from a global trend of increased consumer interest in both high provenance and local food and drink products (Martin et al. 2016a). In part, this is a reaction to the anonymity and complexity of today's global supply chains. The main reason then for increased local malt production is "based on a wish for local malt, greater self-sufficiency, shorter supply-chains and last but not least the special qualities obtained in these areas" (Thomsen et al. 2018).

In the Northern Periphery region, there has been an increase in the number of local food producers and microbreweries, as well as an increased focus on local food experiences in tourism. Recent data from Norway show that sales of local food increased three times as fast as the total food sales in grocery stores (Nielsen Scan Track 2016). There has also been a huge growth in tourism in the Northern Periphery region and tourists are increasingly asking for local food and drink as part of their experience (Turistundersøkelsen 2016).

In the Northern Periphery region, there has been a significant increase in the craft beer industry over the last 10 years. The craft beer revolution started in the United States in the early 1980s, but did not fully reach the Northern Periphery region until about 2010. However, in the last 5 years there has been a large increase in the number of microbreweries. In 2017, in Norway 4% of the total volume of beer sold came from microbreweries, and the Brewery and Beverage Association in Norway estimates that the market for beer from microbreweries can reach 8–10% of national sales before 2020.

In addition to using malt in beer, there was considerable interest among project associate partners in all regions in using local barley for whisky production. This reflects strong global demand for high provenance whiskies, which can be seen from the growth of premium products such as Scottish single malt whisky (Scotch Whisky Association 2018). It also stems from an expansion in microdistilleries in parallel to that of microbreweries.

6 Discussion

The project utilised various methods to tackle the different challenges (Figure 1) along the value chain from barley to beer. The review of outcomes shows that much new knowledge was gained, and development has been achieved. For each step of the value chain, Table 3 summarises the work undertaken, the results obtained and the partners and stakeholders which were involved.

It is clear from Table 3 that the main focus in the Northern Cereals project was on the upstream parts of the value chain, growing and malting barley. However, the knowledge generated and work done on the farming part of the value chain were also used when working on the value chain from barley to food products, which was also an important part of the project. There were three main reasons for the emphasis on the upstream value chain. First, growing high-quality barley in the Northern Periphery region, especially for malting, is generally in its infancy and needs to be increased for providing sufficient raw material for making local beer. Second, apart from in Orkney, local malting was almost non-existent in the region, and new knowledge needs to be generated to obtain malt for brewing. Third, none of the R&D partners had an academic background in marketing or economics. In spite of this, the project was able to deliver upstream outcomes based on the combination of the background of the researchers and the expertise of the brewery stakeholders. Most researchers came from applied research institutes with good brewing industry links and a knowledge of the practical challenges faced by the industry in all parts of the value chain. Within the region, many microbreweries have been operating for several years, and these have good knowledge and practical experience of brewing, product development and marketing. Researchers were therefore able to rely on the expertise of the microbreweries themselves for achieving outcomes in the brewing and marketing part of the value chain.

The role of microbreweries in delivering upstream project outcomes was very much a reflection of the project's transdisciplinary approach. According to Tress et al. (2005), such an approach combines researchers from different academic disciplines as well as stakeholders, and all should work together towards a common goal where theory and knowledge are integrated. In the Northern Cereals project, the objectives sought were mainly tangible, concrete outcomes, in addition to practical knowledge building. Integration of different academic theories was, therefore, to a large degree, not needed to allow the various disciplines "to talk together" and solve common tasks. Stakeholder involvement, mainly farmers, extension workers and microbreweries, was crucial to the success of the project and imperative to achieving concrete results such as new barley production, improved drying, malting and new beer products. Although the value chain perspective of the project might have benefitted from

Table 3: Summary of methods utilised, outcomes and actors involved along the barley to beer value chain in the project Northern Cereals

Value chain segments	Farming	Malting	Brewing	Marketing
Methods	Test production Quality testing Various guidelines for growing, potential land use, sustainability and grain drying and storage Knowledge exchange	Test malting Quality testing Malting guidelines Knowledge exchange Malting placements	Test brewing Knowledge exchange	Product development Review of market situation
Outcomes	Climatic factors in all areas specified for cereal production Arable land cross the regions quantified Old varieties tested and seed multiplied in OR, FO and NO Testing of modern Icelandic varieties in all countries Quality testing of grain in NO, OR and IS Demonstration plots in OR, FO and NO Farmer handbook for growing barley in all languages Knowledge exchange, local and transnational, all regions. Farm visits in OR and IS	Test malting in OR, IS and NO Quality testing of malt in OR and NO Malting process experiments in NO with varieties from NO, IS and OR Malting guidelines in English and Norwegian Knowledge exchange in all regions Malting placements in OR for eight companies from IS, FO and NO	Test brewing of locally grown barley by microbreweries in OR, IS and NO Company visits in all regions Knowledge exchange from company to company, all regions	Product development by microbreweries in IS, OR and NO Review of market potential, all partners
Partners and stakeholders involved	R&D partners Farmers (microbreweries)	R&D partners Microbreweries External R&D specialists	R&D partners Microbreweries	Microbreweries R&D partners

FO = Faroes Islands, IS = Iceland, NO = Norway, OR = Orkney, R&D = research and development.

research partners from marketing and innovation disciplines, the shortages of grain and malt would still have been the limitation in complete value chain development. It is recommended, however, that such expertise should be included in a follow-up project to realise the full potential of local beer products.

Transnational cooperation was at the core of the Northern Cereals project. The project acknowledged that the regions (and research partners) had different strengths and challenges in the value chain, and because of this each partner concentrated on the aspects that were considered the most important locally. Table 3 shows that partners from all regions participated in many of the outcomes, and there was no outcome where only a single partner/region was involved. This shows that transnational cooperation was truly an integral part of this project.

Producing the many outcomes shown in Table 3 does not occur by transnational cooperation in itself. A good plan, appropriate expertise and careful follow-up during the project period are essential for such cooperation resulting in concrete outcomes. In addition, success depends on the nature and quality of the cooperation (Colomb 2007), and where there are historical or other pre-existing links between the partners in the project, transnational cooperation can be very important (Dühr and Nadin 2007). Partners in The Northern Cereals project came from an area where cultural–historical roots go back more than 1,000 years, and still today there are many similarities in cultural expression, food, language, social interaction, etc. In addition, the climate and environment are similar enough for the knowledge to be transferable, but sufficiently different for interesting comparisons to be made. We found that the similarities among the many partners and stakeholders strengthened the cooperation, for example, by making the many study trips and company visits of immediate relevance. One of the benefits of transnational cooperation according to Ray (2001) is "to reach critical mass". The Northern Periphery Area is sparsely populated, and the geographical distances are long so that transnational cooperation can help overcome the shortage of critical mass for development and knowledge building. Another advantage is that it can be easier to share company knowledge with the companies in other regions and countries that are not direct competitors in the market.

7 Conclusion

We found that transnational cooperation proved to be very beneficial for achieving the aims of the Northern Cereals project and for maximising the impact of a small pool of cereal R&D expertise spread across a large geographic region. To tackle the complexity of the challenges, a transdisciplinary approach was taken and a wide variety of practical and theoretical studies were undertaken utilising the specialist knowledge from many disciplines. The inclusion of many SMEs and other stakeholders ensured that the research was focused on overcoming the various challenges in the value chain, and made, we believe, the outcomes of the Northern Cereals project of major practical relevance to the involved parties. Although stakeholder involvement was probably the project's main strength, the lack of academic knowledge on marketing and innovation may have been a shortcoming.

A particularly useful outcome of the Northern Cereals project has been the identification of constraints on the development of the barley to beer value chain, and addressing these should be the priority of future R&D work. Foremost among these is the development of locally adapted varieties of barley which are suitable for malting. This requires a long-term commitment to a regional plant breeding programme in which the development of malting types would be part of a wider programme of developing barley for a range of purposes. The Agricultural University of Iceland's current programme is an excellent starting point for this, but it could be made even more effective by increasing collaboration with researchers and breeders in other northern countries/regions and by testing materials across the region. Another very specialised area requiring attention is the need for small-scale malting equipment, grain drying equipment and development of appropriate methods for malting barley produced in the region. Such facilities would be particularly valuable in the most remote areas (Iceland, Northern Norway and the Faroes). Although the project did not investigate in detail economic and policy issues, it is recognised that these also have a strong influence on barley production. For example, it is known that the lack of cereal production in Northern Norway is partly due to political reasons accompanied by lower subsidies for such production in this region (Bunger and Tufte 2016). Other important areas are product development issues related to using local barley for beer and the need for marketing and economic support to obtain maximum benefit from its high provenance. All of the above future R&D activities would benefit from a transnational and transdisciplinary approach. Although much work remains to further increase cereal production and the use of local grain in the Northern Periphery region, we

believe that this project has laid a good foundation for further progress.

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