Opportunities and barriers in diversified farming and the use of agroecological principles in the Global North

The experiences of Danish biodynamic farmers

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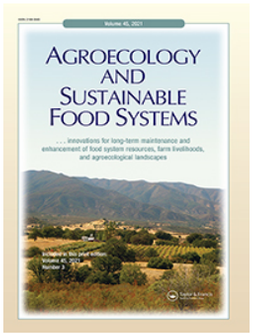
Published in:
Agroecology and Sustainable Food Systems

DOI:
10.1080/21683565.2020.1822980

Publication date:
2021

Document Version
Publisher's PDF, also known as Version of record

Citation for published version (APA):
Aare, A. K., Egmose, J., Lund, S., & Hauggaard-Nielsen, H. (2021). Opportunities and barriers in diversified farming and the use of agroecological principles in the Global North: The experiences of Danish biodynamic farmers. *Agroecology and Sustainable Food Systems*, *45*(3), 390-416. https://doi.org/10.1080/21683565.2020.1822980



Agroecology and Sustainable Food Systems

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/wjsa21

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To cite this article: Ane Kirstine Aare, Jonas Egmose, Søren Lund & Henrik Hauggaard-Nielsen (2021) Opportunities and barriers in diversified farming and the use of agroecological principles in the Global North – The experiences of Danish biodynamic farmers, Agroecology and Sustainable Food Systems, 45:3, 390-416, DOI: 10.1080/21683565.2020.1822980

To link to this article: https://doi.org/10.1080/21683565.2020.1822980

Published online: 27 Sep 2020.

AGROECOLOGY AND SUSTAINABLE FOOD SYSTEMS
2021, VOL. 45, NO. 3, 390–416
https://doi.org/10.1080/21683565.2020.1822980

Taylor & Francis
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Opportunities and barriers in diversified farming and the use of agroecological principles in the Global North – The experiences of Danish biodynamic farmers

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ABSTRACT

Diversification through agroecological principles may maintain and stabilize yields in an increasingly more unpredictable climate, including market price fluctuations, as well as preserve and enhance the threatened natural resource base and the environment. Based on a participatory interview process this article identifies the barriers encountered by a group of Danish biodynamic farmers striving for self-sufficient farm systems with no or very little dependency on imported materials by developing biologically, economically and socially diverse farms. Through an iterative interview process the study found that barriers outside farm management are hindering the transition toward diverse farming and that a further exploration of the need for and implications of food sovereignty in the Global North might generate the discussions needed to support implementation of more agroecological farming system practises.

KEYWORDS

Diversification; transitions; food sovereignty; resilience; farming systems; participatory research

Introduction

There is a growing need for alternatives to the industrial farming and food system that dominates the landscape of the Global North (Altieri et al. 2015; Frison 2016; Gliessman 2016). Industrialization of the agricultural sector has contributed to labor-efficient farming around the world that benefits from high-input production, monoculture, specialization and economies of scale. However, it has become clear that this development simultaneously contributes to the degradation of land, water and ecosystems, increased emissions of greenhouse gases, loss of biodiversity, as well as the economic and social stress experienced by farmers (Cristóvão, Koutsouris, and Kügler 2012; Díaz et al. 2019; Frison 2016). Meanwhile, the agricultural sector is subject to an increasing level of uncertainty due to climate change, degradation of soil and water quality, fluctuating market prices, shifting regulations and societal demands, all of which call for more resilient solutions (Duru et al. 2015; Folke 2006).

In 2016, the International Panel of Experts on Sustainable food systems (IPES) claimed that the current situation requires a move toward "diversified

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agroecological systems" that can "keep carbon in the ground, support biodiversity, rebuild soil fertility and sustain yields over time, providing a basis for secure farms" (Frison 2016). The need to increase the number of plant species at field level is recognized by the EU funding programme Horizon 2020, which supports a range of projects on crop diversity (https://www.cropdiversification.eu/).

Agroecology – as a research field, practice and movement – is proposed as a promising strategy toward the achievement of sustainable farming and food systems (El Bilali 2019; Wezel et al. 2009). It is inspired by traditional, small-scale farms around the world, where diversity is and always has been an important management tool that takes advantage of ecosystem functions and services (Altieri 2004). However, along with the chemical and technological advancement of the green revolution, new management tools have emerged, and the use and knowledge of diversity in farming has been in serious decline (Altieri 2004). Reintroducing greater diversity in crop species, genotypes and habitats in specialized and modern farming systems may facilitate nutrient conservation and retention in soil, suppression of pests and diseases, improvement of water quality and pollination, and buffering and mitigation of climate variabilities (Brooker et al. 2015; Lin 2011; Tomich et al. 2011). Increasing biological diversity, for example, through species mixtures, crop rotation, mixed crop-livestock systems or agroforestry, is therefore widely acknowledged as crucial in order to take advantage of ecosystem functions and services in the agricultural system while creating resilience and resource self-sufficiency (Hill and MacRae 1996; Wezel et al. 2014). The need for change toward more agroecological farming systems is acknowledged at international (FAO 2018), European (Wezel et al. 2018) and national levels (Gonzalez, Thomas, and Chang 2018).

Diversity in farming can be addressed at different scales including at field, farm or landscape level (Sirami et al. 2019), and apart from increased types of plants and animals the term can refer to a combination of several social or economic components (Kremen, Iles, and Bacon 2012). According to the IPES, "the economic situation of farmers in industrial farming systems, even highly subsidized ones, remains precarious" (Frison 2016). The current structures favoring the logic of industrialized farming hamper new development pathways for heavily indebted Danish farms (Larsen 2016). Diversification strategies can be used to create more economically sustainable and resilient farms (de Roest, Ferrari, and Knickel 2018; Knickel, Renting, and Ploeg 2004), help small-scale farmers survive in the current market through risk spreading and the inclusion of supplementary incomes such as agritourism (Renting et al. 2009), create jobs for marginalized or vulnerable groups, and serve educational purposes through community-supported agriculture among others (Cristóvão, Koutsouris, and Kügler 2012). Hence, diversity more

broadly becomes a key to avoid many biologically, economically and socially adverse effects of current dominant farming systems in the Global North.

Agroecological transition and food sovereignty

While acknowledging the social and ecological benefits of agroecological practices, it is relevant to ask how the shift can be made away from the current agricultural system toward more diversified and agroecological farming systems. This question prompts a conceptual model for understanding change and innovation. Transition theories are often used to analyze how and why technological innovations succeed in entering the current technological regime (Geels and Schot 2007). Concepts such as path dependency and lock-ins are relevant terms to account for the lack of progress toward an agroecological farming system (Elzen et al. 2017; Ollivier et al. 2018). Despite its relevance, socio-technical regime thinking in particular has been criticized for not paying attention to agency, thereby reducing the opportunities to identify power-related drivers with regard to the initiation or prevention of transitions (Smith, Stirling, and Berkhout 2005). In contrast, agroecological advocates have increasingly focused on power relations in the global food system and how these can prevent change. This suggests that the transitional path toward more sustainable food systems cannot be addressed at farm level alone, but must include changes in the wider food system(s). Gliessman, Friedmann, and Howard (2019) suggest that agroecological transitions of this kind consist of five levels. The first three levels are steps focused on changing farm management through: 1) efficient use of inputs, 2) substitution of chemical inputs with organic ones, and 3) the redesign of the system to function on the basis of a set of new ecological processes such as reintroducing diversity. The two remaining transitional levels are suggested to address elements outside farm management. These are: 4) to "(re)-establish a more direct connection between those who grow our food and those who consume it" and 5) on the foundations of level 1–4 to "build a new global food system based on equity, participation, democracy, and justice" (Gliessman, Friedmann, and Howard 2019). The fifth level not only requires adjustments in practices or the market, but calls for profound changes to be made to global structures of power and values. Gliessman, Friedmann, and Howard (2019) suggest that level five requires increased food sovereignty, defined at the Nyéléni summit in 2007 as "the right of peoples to healthy and culturally appropriate food produced through ecologically sound and sustainable methods and their right to define their own food and agriculture systems" (Gliessman, Friedmann, and Howard 2019).

The proposals for agroecological transitions and food sovereignty do not offer generic solutions. What is needed to increase food sovereignty depends on whether farmers are marginalized by the current global agricultural market

or trapped in non-agroecological practices due to debt and other path dependencies. In some places barriers are related to land tenure, in others to markets, regulation and subsidies, knowledge production and sharing or a lack of democratic influence (Frison 2016; Gliessman, Friedmann, and Howard 2019; Pimbert 2017a). Agroecology and food sovereignty are concepts that are used by activist movements in the Global South and have been incorporated into federal constitutions in several countries (Pimbert 2017b). Organizations in the Global North are also discussing food sovereignty, although it is still a new concept in this part of the world (Higgins 2015) where larger food chains take control of food systems including information and food culture thereby replacing traditional farming knowledge and making sustainable farming less profitable. Thus, consideration of what food sovereignty implies in a northern context questions the social and economic context in which farmers operate where traditional practices have been forgotten in agro-industrial practices. Hence, working with agroecology in the Global North not least calls for involving the farmers themselves in exploring these issues. This paper contributes to this discussion using exemplary participatory case studies of biodynamic farming in Denmark.

Biodynamic farming as an inspiration

Biodynamic farming can be perceived as a traditional farming system with similarities to organic farming. Today, organic farming is practised on close to 10% of Denmark's total agricultural area (The Danish Agricultural Agency 2019). The expansion of organic farming across Europe is being criticized for the trajectory toward conventionalization followed by demands for its original principles and values to be reintroduced (Brzezina et al. 2017). Biodynamic farmers are still a minority in Danish farming, with 43 Demeter-approved farmers registered by the Danish Biodynamic Association (http://www.biodynamisk.dk/sider/avlere.html). Rudolf Steiner formulated the principles of biodynamic farming at the start of the 20th century. Biodynamic farming differentiates from organic farming in that it adds a spiritual dimension to farming, and a perception of each farm as a self-contained organism. Apart from the standards in organic farming and focus on local production and distribution, biodynamic farmers comply with a separate certification, Demeter, which among other things requires the use of special preparations, usually consisting of fermented minerals, plants and/or animal manure extracts, for composts or direct soil amendments, and specifies how animals should be kept and handled (Demeter-International e.V 2018). Peer-reviewed research from controlled field experiments as well as case studies show the positive impact of biodynamic farming on cultural landscape designs, and the positive impacts biodynamic preparations have on yield, soil quality and biodiversity (Turinek *et al.*, 2009).

Biodynamic farms were chosen for this study due to the potential of their practices and systems to mitigate some of the detrimental effects of intensified agricultural systems (Reganold 1995) and harmonize the mutual interrelationships between plants, livestock, soil and humans. The limited role of biodynamic farming and its similarities with agroecological principles within the scientific literature were another reason for choosing biodynamic farmers as cases in this study.

An agroecological case study

In some literature agroecology is described as the use of the science of ecology to create more sustainable farming practices (Hazard et al. 2018). More activist advocates of agroecology criticize this approach, suggesting that science and society need to learn from farmers' knowledge and experience (Altieri 2004). This study was conducted with the intention of complying with the latter view.

The purpose of the study was twofold. First it aimed in an explorative manner to investigate the use of diversified farming among a group of biodynamic farmers in Denmark, including comparing it with the five levels of transition proposed by Gliessman, Friedmann, and Howard (2019), and second its objective was to discuss the change that is required to overcome the identified barriers and increase food sovereignty in a Global North setting.

Methodology

To understand opportunities and barriers for diversified farming agroecology (Gliessman, Friedmann, and Howard 2019) was used as an analytical framework for a participatory case study with Danish biodynamic farmers. The investigation was based on a participatory interview strategy where initial interviews were run, coded and analyzed producing a report of intermediate findings, which were then communicated back to interviewees initiating a second round of interviews prompting for further reflections on common findings. The participatory interview strategy was conducted to ensure farmers themselves to identify key issues, respond on theoretical analysis of these, and further qualify research results. Furthermore, the validation process potentially "strengthens the understanding of the situation and can possibly also enhance further action being taken" among both farmers and researchers (Nielsen and Lyhne 2016).

The interviews were conducted with seven Danish biodynamic farmers in February–March 2018 and May–August 2020. Contact was established through the Danish Biodynamic Association (Danish: *Foreningen for Biodynamisk Jordbrug*) and the farmers themselves volunteered to participate in the research. All participants signed a declaration of consent approved by the legal department of Roskilde University. Six of the first round of interviews

were conducted face-to-face on farms (Farmers 1–6) and one as a telephone interview (Farmer 7), and lasted between 1 and 2 hours, often either including or being followed by a walk around the farm. The interviews were carried out as requisite semi-structured interviews with the intention of allowing the farmers to express their reasoning, perceptions and knowledge based on their experience (Kvale and Brinkmann 2009). The farmers differed in several ways (see Table 1), allowing a range of diversification strategies to be explored. The farmers were interviewed to provide an insight into both the differences and similarities between this farming minority in Denmark. The very explorative way of conducting an interview is valuable for exploring problems faced through practical experience, producing heterogeneous empirical data that need to be analyzed iteratively in order to draw valuable conclusions. The interviews were fully transcribed, coded and analyzed in Nvivo (QSR International Pty Ltd. Version 12, 2018). The codes revealed common and divergent themes across the interviews, which were subsequently categorized into motivations, barriers and strategies for integrating diversity on the farm.

Gathering farmers for common discussion on the analysis was not possible with the available resources among farmers and researchers. Instead to ensure validity of the findings and to establish collective experiences and shared understandings among farmers and researchers all farmers received a short two-page summary of the analysis followed by a telephone interview where farmers and researchers discussed the findings from the first-round analysis. The summary contained different statements regarding barriers and possible solutions identified through researchers' analysis (see boxes in the *analysis*). The aim of presenting the outcome as statements was to make it easy for farmers to either recognize or disagree with the findings. As interviews capture momentary individual perspectives affected by current circumstances we included contributions from the second individual farmer interviews separately in the *analysis*. Furthermore, farmers' reflections on ways forward have been incorporated in the *discussion* section.

Most of the presented biodynamic farmers (Table 1) did not resemble the average Danish farmer as they are not full-time farmers and they cultivate a mix of horticulture, arable crops and animals. However, in order to investigate new agroecological farming systems, the group offers exemplary experience of diversified farming and of the changes required in the surrounding sector and society.

Analysis

Wezel et al. (2014) classify a range of agroecological practices in accordance with the level(s) of agroecological transition they support. In particular, to reach the third level (system redesign), they argue that diversity is crucial, including: i) crop choice and rotation, ii) intercropping and relay

Table 1. Farmers interviewed, including farm size, farm history, farmer, employees, sale channels and landscape in the year in which the first interview was conducted. Information from first individual farm interviews 2018.

Farmer ID	F1	F2	F3	F4	F5	F6	F7
Farm size	110 ha	11 ha	0,07 ha	10 ha 1500 m^2 greenhouse	33 ha	51 ha	250 ha
Farm history	Managed as biodynamic for 7–8 years. Current farmer is in the process of taking over from his parents	Managed as biodynamic for 28 years. Converted from conventional to biodynamic by current farmer	Managed as biodynamic by current farmer for 22 years	Managed as biodynamic by current farmer for 29 years	Managed by current farmer for 24 years, of which 12 years have been as a biodynamic farm	Managed as biodynamic for 32 years. Current farmer has worked on the farm for 13 years, and been its owner for 10 years	Managed by current farmer for 29 years who converted it to organic 28 years ago and biodynamic six years ago
Farmer	Him: Gardener and district manager in retail. Grew up on a biodynamic farm Her: Retailer. Did not grow up on a farm. Both: Full-time off-farm work	Agronomist, grew up on a farm. Part-time work on farm	Engineer, grew up on a farm. Now retired. No income from farming.	Farmer (biodynamic farming school in the Netherlands), grew up on a farm. Full-time job on the farm	Carpenter, engineer, grew up on a farm. Full-time job on the farm	Farmer (farming school + agro business and landscape management). Full-time job on the farm	Self-taught farmer, entrepreneur. Full-time off-farm job
Employees	None	Unpaid volunteers, trainees, seasonal workers	None	Unpaid volunteers, trainees	Socio-economic trainees, seasonal work/help from neighboring farmer	One employee, socio-economic workers, volunteers	One plant/production manager, socio-economic workers
Sale	*channels* Biodynamic mill, biodynamic or organic farmers	Own on-farm shop, selected retail stores in the capital	Restaurants and public kitchens, local retail store	Self-sufficiency, no sale	Local marketplace	Local restaurants, food boxes, public institutions	Food boxes
Landscape	70% of surrounding land is either forest reserve, summer cottage area, lake with a bird reserve or the sea	The farm was chosen by the current farmer for its diverse surrounding landscape	Situated in a diverse landscape with e.g. grass fields around	–[1]	-	4 ha of forest and the land is generally hilly, including streams, waterholes and meadow	-

intercropping, iii) agroforestry with timber, fruit or nut trees, and iv) integration and planting of (semi-natural) landscape elements at either field or landscape level (Wezel et al. 2014). In addition, it is argued that the integration of livestock in the farming system is a crucial way of increasing diversity, also often mentioned as a central strategy in agroecology (FAO 2018). Inspired by the classification of Wezel et al. (2014), the farmers' use of diverse farming practices at farm and field level are presented below.

Diverse farming practices as indicators of advancement in agroecological transition

All the farmers had a wide range of crops, including both horticultural crops, arable crops and trees (Table 2). Many of them used old varieties and breeds for preservation purposes (F6) to avoid unethical and "unnatural" exploitation of the production capacity of plants and animals (F1, F2) and because hybrids are unable to adapt to local conditions (F1). Species mixtures were used by farmers in both cash crops (F7), through undersowing or relay intercropping (F1, F4, F5, F6, F7), and mixed cover crops or grass mixtures (F1, F2, F4, F5, F6, F7). Many farmers also used complex crop rotations of approximately 5 years including horticultural crops, arable crops and animal grazing (F1, F4, F5, F6, F7).

Integration of livestock is an important part of the biodynamic system. F2 used pigs to prevent water voles coming into the orchard and F1 and F4 had tried to integrate pigs, hens and cows for tillage. However, for many farmers (F1, F4, F6) the supply of organic fertilizer was the main objective of keeping animals. F4 used the manure from different animals for different purposes as his experience indicated that each type of manure had different properties due to a complex combination of substances, minerals, decomposition processes, etc. He further explained that manure produced on the farm was adjusted to local conditions, thereby fulfilling the specific local requirements for plants and soil (F4). As for many biodynamic farmers, compost was mentioned as a central management technique by several of the farmers (F1, F4, F5). Due to the need for animals to produce manure (at farm or local level), it is argued that the use of organic fertilization can also be classified as a diversification practice.

Instead of using management to control pests and insects, most farmers stated that the stabilized ecosystem and healthy plants that they sought to generate reduced the prevalence and extent[2] of pests and diseases, as well as the requirements for nutrient supply (F1, F3, F4, F5, F6). F1 and F5 explained that they had experienced heavy attacks of slugs, aphids or specific weed varieties in the period of conversion to biodynamic farming, which they both found to be a symptom of an unbalanced ecosystem. F4 also stated that the diverse combination of crops on his fields hindered the spread of diseases.

Table 2. Activities and management of each case farm in the year in which the first interview was conducted[3]. These include diverse farming techniques in cultivation, produce, animals and other activities. Information from first individual farm interviews 2018.

Farmer ID	F1	F2	F3	F4	F5	F6	F7
Diverse farming techniques[4]	Feed mixtures of barley and pea, species mixtures in main crops, mixed cover crops (six species), undersowing in cereals, plant cover, 5-year rotation including grazing of animals	Cover crops between trees (flower mixture), 2–300 nesting boxes to attract birds, on-farm measures to attract insects	–[5]	Different varieties of vegetables, 5–6 year rotation including vegetables, cereal, legumes and grass, undersowing with clover grass, diverse clover-grass mixture (grasses, legumes, clovers etc.), living hedges, different varieties (e.g. 50 varieties of tomatoes)	Grass mixtures (grasses, clovers and herbs), undersowing in cereals with grass, approximately 5-year crop rotation including grazing of animals, 1 ha left untouched	Undersowing in cereals with clover grass (>15 species), crop rotation including vegetables, cereals, clover-grass mixture and holistic grassing	Species mixtures in main crops (on-farm-separation for sale for consumption), crop rotation of arable crops and clover grass, relay intercropping with mixed cover crops in all cereals and direct supplementary seeding just after harvest of main crop
Produce	**Vegetables**: Courgettes, potatoes, beetroots, Chioggia beets, leaks, cabbage, carrots, parsnips, parsley roots, dill, parsley, fennel, onions, butternut squash and lettuce **Arable crops**: Grass, cereals (consumption and feed)	**Trees**: 10–12,000 trees of 20 species including apples (50 varieties) pears, plums, damsons, sweet cherries, quince, hazelnuts, walnuts, sweet chestnuts, apricots, figs, Saskatoon berry, gooseberry, raspberry, pawpaw, silverberry, sea-buckthorn	**Trees**: Fruit, berries **Vegetables**: Carrots, parsley root, sun roots, onions, cabbage (several varieties)	**Vegetables**: Radish, spinach, spring onion, salad, carrots, onions, beetroots, garlic, celery, parsley, tomatoes, pepper, cucumber, aubergines, green beans, cabbage, leak, squash, parsnip, parsley root, sun roots **Arable crops**: Cereal, grass	**Vegetables**: Cabbage, leaks, root crops, potatoes **Arable crops**: Cereal, grass	**Vegetables**: 30 different species including carrots, potatoes, onions, cabbage, fennel, celeriac, beetroots, parsnip, parsley root, pumpkin etc.	**Arable crops**: Cereals (oat, wheat, rye, barley, spelt), linseed, oilseed rape, fava beans, peas, clover, grass-seeds
Animals	Cows, sheep and pigs	Bees	-	Cows, horses, goats and hens	Cows	Cows, hens	Cows
Other activities	On-farm shop	-	Teaches classes on biodynamic gardening, volunteer work in biodynamic association	Organizes open farm visits and visits for chefs, schools etc.	-	Kindergarten, home for disabled people	-

Another strategy articulated by F6 was to use varieties of vegetables with a high content of bitter substances in order to boost the crop's natural resistance.

F1, F3 and F6 mentioned the importance of varieties in the surrounding landscape for their farming system with regard to diversity in vegetation, topology, hydrology, etc. (Table 1), and F2 and F4 referred to the importance of living fences on their farm to sustain wildlife interactions. F5 had left one hectare untouched land in order to make room for other more undisturbed ecosystems to develop, emphasizing that this is proposed by the Demeter certification schemes.

Apart from the management practices of crop and livestock highlighted in Wezel et al. (2014), the biodynamic farmers also diversified through other livelihood strategies, such as off-farm jobs, on-farm shops, social inclusion etc. (Table 2)

Strategies for a greater connection between growers and consumers

The fourth step in the transition advocates that reestablishment of a direct connection between growers and consumers of food is needed for cultural, ethical and also economic reasons (Gliessman, Friedmann, and Howard 2019). All of the interviewed farmers traded some or all of their goods directly to consumers (on-farm shop, food boxes), restaurants, retailers or other farmers (Table 1). The link between growing and consuming was also facilitated by F3, who taught people about biodynamic gardening and was actively involved in increasing knowledge about and consumption of biodynamic products through the Biodynamic Association. F6 had people with disabilities working on the farm and a kindergarten on the property, increasing the understanding of farming among a broader group in society. F4 organized events with chefs, schools and the public to visit and learn about the farm, also creating opportunities for dialogue with end-users (Table 2).

Barriers to diversified farming

Despite the farmers complying with many of the ambitions for levels 1–4 (Gliessman, Friedmann, and Howard 2019), the interviews revealed that they also face challenges in several areas with regard to diversification practices. The following section presents the barriers encountered by the farmers when they implemented or wanted to enhance diversity on their farm, as well as the adjustments and/or additional reflections from farmers when confronted with the first-round analysis. In cases where the farmers used specific strategies to overcome a barrier, these are mentioned.

1. Diverse farming requires manifold knowledge and skills

Several farmers articulated the complexity involved in using several species, varieties, animals or activities on the farm because it means the farmer has

several jobs all at the same time. The farmer has to be specialist in every type of production (cereals, vegetables, livestock), pedagogy (working with the disabled), property ownership (finances) and technical skills (machine repair) etc. (F6). F6 found that every job description diluted the competences of each, creating a dilemma between diversification and specialization. Apart from the specific skills needed, understanding and implementing comprehensive and complex Danish and European policies is time-consuming including when receiving direct and greening payments from the European Common Agricultural Policy (F1). F1 thought that the comprehensive work involved in meeting Danish regulations on a diverse farm illustrated that the legislation is made for standardized productions (see barrier no. 3). The more activities on the farm, the more regulation the farmer needs to be aware of and follow. The need for manifold knowledge and skills and comprehensive insight into legislation puts biodynamic farmers at a disadvantage compared to less diverse farmers in the current farming system (see barrier no. 2 and 3).

Barrier 1 as presented to farmers

Diverse farming requires diverse knowledge and skills: Having to know something about both livestock, crops, pedagogy, sales, etc. is demanding and means that the individual farmer may have less specialised skills and knowledge about each of these. In addition, each farmer must know and comply with regulations for each of these activities. For that reason, the individual farmer may feel disadvantaged in relation to the more specialised farms.

Confronted by these results F4 and F7 expressed disagreement with the statement that the required knowledge and skills needed to manage a diverse farm was a barrier in their situations. F4 explained that during his time as a farmer he accumulated enough knowledge about what works in his local context. Such comments raise questions about whether diverse farming requires more knowledge and skills or just different kinds not currently taught or represented in the advisory service or educational system (see barrier no. 2).

In the second interview F2 shared his reflections triggered by the initial analysis. He thinks that farmers managing a diverse biodynamic farm often has an ethical perception on human-nature relations and food production. As technology and natural science do not hold such dimensions, farmers need to consider the ethical consequences of their management as well.

2. Farmers lack support due to limited research, education and advisory services on diverse farming

Farmers' experience was that agricultural advisors are specialists in specific strings of production, and therefore were less competent at advising farms with mixed production (F1, F6). As a result, the farmers said that they lacked advisory services that take into account the interplay, possibilities and restraints within a diverse farm. Another consequence of specialist advisory services was that farmers had higher costs from having a diverse range of

activities, which for some farmers resulted in a relatively limited use of advisory services compared to the amount of activities they have (F1, F4, F6).

F1 explained that students from farming schools were not allowed to do their training on his farm because the school required farms to be specialized (F1). Many of the interviewed farmers had not had a farming education, but some of them said that they experienced a lack of awareness of diverse farming and soil health in farming schools based on either their own or their trainees' experience (F1, F5, F6).

To overcome this gap in knowledge, several farmers sought knowledge from other sources (old books, (online) courses, Internet, networks etc.) (F1, F4, F5, F6). However, this was also time-consuming and presented a challenge for farmers with limited resources (F1). Less was said about the amount of knowledge-sharing between farmers, even when specifically asked about it. They would meet other biodynamic farmers when making preparations (F3, F4) and some participated in courses on regenerative farming (F5, F6). From the interviews, the farmers did not appear to have a strong platform for concrete knowledge-sharing, which may have been due to the fact that there are very few biodynamic farmers in Denmark and that they are scattered around the country. F5 said that he was not able to discuss anything with his neighbors because of their very divergent perceptions of farming. While some farmers expressed skepticism about scientific knowledge (F1, F3), they also referred to a lack of scientific experiments on good practices and the effects of diverse farms (e.g. on biodiversity, soil health, diseases and pests, etc.) (F1, F2, F6, F7).

Barrier 2 as presented to farmers

Lack of support due to limited research, education and advice in diverse agriculture: Advisors are specialised and therefore not trained in delivering advice for diverse farms. Farmer schools do not adequately teach diversity. Therefore, the individual farmer must search for knowledge online or from other farmers. The interviewed farmers are skeptical about agricultural research, but at the same time demanding more research on the effects of and interactions in diverse agriculture.

F4 told that he agreed in the analysis but that he did not feel the need for advice due to his accumulated local knowledge. However, he found it problematic that young farmers need to learn everything by themselves through trial and error (F4). Several of the farmers added to the findings that they believe that only one advisor in Denmark has the needed holistic understanding of farming systems (F1, F5, F7). F1 found this problematic as he observed that the supply of such holistic advisory service did not match the demand in the sector.

Some farmers called attention to the fact that since the first interview the Danish organic farming school changed practice by allowing internship at diverse farms. However, they found that managing a diverse farm was still not a part of the curriculum but needed to be learned at the farms (F1, F5).

Through the second interview farmers emphasized that the missing research and education about diverse farming is related to a clear lack of political interest in supporting diverse, biodynamic and small-scale farming through advisory, education and research (F1, F2, F3, F5, F7). As an example F1 shared their frustration about their lack of success in involving the municipality, ministry, funds or researchers in documenting the observed positive effects of a diverse farm on e.g. biodiversity.

3. Farmers' experience is that legislation is insufficient to meet their needs as diverse farms

Apart from the comprehensive governing control faced by farmers, several of the interviewed farmers also mentioned laws or regulations that are particularly challenging for diverse and multifunctional farms (F1, F2, F6). According to F1, there is no political strategy to support diverse farming and no continuity in regulations. This presented a challenge for farmers in their planning activities and their effort to adapt to regulations. F1 said that only specific breeds of hens were allowed if eggs are sold in supermarkets due to Danish (salmonella) legislation. They were obliged to buy hens through basic herds controlled by a very few breeders in Denmark, and were not allowed to breed themselves. According to F1, these specific breeds are not suitable for multifunctional purposes (see barrier 4). F2 had faced challenges with regulations concerning the integration of livestock on his plantation. He had previously used pigs, cows and goats to cultivate the soil and trim the living fences around his farm. However, due to legislation, he was unable to tether the animals but had to keep them behind double fences. This reduced the accessibility the farmer need to work on the plantation. For F1 it meant that they no longer had hens. F2 chose to not comply with the regulation, focusing instead on local markets that were not controlled by trade organizations.

Barrier 3 as presented to farmers

Legislation does not adequately meet the needs of diverse farms: There is no political strategy to support diversity in agriculture. On the contrary, regulations seem to limit the selection of, for example, varieties and livestock breeds.

Confronted with this F6 and F7 expressed that they experience legislation being strongly influenced by lobbyism, which challenge a minority like divers biodynamic farmers in having ones needs taken into account. Several farmers explicitly mention that they find it counterintuitive to be subjects to regulation implemented to prevent diseases, etc., which they perceive to be adverse effects of an industrialized farming system (F1, F2, F4, F6). As an example, F1 believe that regulation on e.g. mandatory medication of livestock prevents farmers in raising healthy and resistant animals. He therefore decided not to follow the requirements, which according to him has resulted in healthier animals.

However, F1 were convicted for offense, despite the fact that veterinarians expressed no concerns regarding animal welfare.

F7 also raised a critique of the Danish biodynamic certification system as Danish and international Demeter standards are not harmonized bringing disadvantages to Danish biodynamic farmers on the European market (F7).

4. The improvements in breeds and varieties are not developed for multifunctionality

Some of the farmers have experienced disadvantages with new breeds of livestock and crops (F1, F2, F6). For example, F1 found that new hen breeds do not go out on the plantation but stay close to the house eating fodder. F1's experience was that new breeds are made for a single purpose (for example, laying eggs or producing meat), which is inefficient on a farm using animals for multiple purposes (eggs, meat, tillage, grazing etc.). F6 also problematized the lack of bitter substances in new vegetable varieties. Several farmers mentioned that the nutritional value of their agricultural products was of great importance and they believed that very refined varieties lose the diversity of nutrition and quality (F1, F2, F6). An overall concern was that they want to mimic ecological systems or get as close to natural conditions as possible, and therefore find the very refined breeds and varieties "unnatural" (F1, F4, F5). According to F1 and F6, it is very hard to buy seeds that are not hybrids, which challenges the biodynamic requirements and the ambition of local adaption of the variety. F1 used old seeds found on the farm and his own seeds to ensure local adaptation of cereal and catch crop varieties. The offer and diversity of breeds and varieties did not satisfy farmers' needs with regard to the multifunctional use of animals and the ability to improve and diversify the genotype in relation to local conditions.

Barrier 4 as presented to farmers

Breeds and varieties are not developed for farms with multiple functions and diversity: Livestock breeds are bred exclusively for one function, namely high productivity and thus to a lesser extent suitable for performing other functions on the farm, such as nature management and tillage. Also crop varieties are exclusively bred for high yield at the expense of other traits such as nutritional value or resistance towards diseases. It is difficult to access seeds that are not hybrids, which is problematic when farmers want to use own seeds to achieve the best possible adaptation to local conditions over time.

Confronted with this F4 told that it is getting easier to encounter seeds or races suitable for diverse farming on the market. However, often seeds are only available through foreign seed distributors challenging the need for locally adapted seed varieties. Saving seeds and breeding animals yourself are therefore suggested as strategies that might allow farmers to partly overcome this barrier (F3, F4).

Confronted with the conclusions F6 shared his reflections on the need to include perennials in cropping systems to increase the delivery of ecosystem

services (e.g. carbon-storage) of diverse farming systems, challenging the current farming system even more.

5. Farmers struggle to make diverse farming economically sustainable in the current food system

Related to the first barrier, many of the farmers expressed difficulty in establishing a diverse and economically sound biodynamic farm (F1, F2, F3, F4, F6). In their experience, the use of several species, varieties and animals was more costly (in terms of time and money) than specialized production. This is due to the increased workload, equipment, capacity, advisory service, logistics, investment, administration, knowledge, etc. (F1, F2, F5, F6). Having different activities often meant smaller volumes, which made it harder to achieve a return on their investment (F5, F6). Furthermore, the sale channels often required large volumes. F4 explained that at least 100 cows were needed for collection from the milk tank. Retailers might also not be interested in buying mixed fractions, meaning that intercrops need to be used on the farm or sold directly to other farmers for fodder (F1).

Some of the extra costs in diverse and biodynamic farming are compensated for through increased prices for end-users of certified products. However, F2's experience was that too high a percentage of the margin was kept as a profit for retailers. With regard to compliance with regulations, one control for every type of production is required, increasing the costs on diverse farms (F1). F1 added that these costs mainly influenced the overall gross budget for small farmers, whereas larger companies were obviously less affected by such mandatory payments.

Several farmers mentioned their financial situation as a main factor for not having a more diverse farm (F1, F5, F6). According to F4, one of the reasons for his financial difficulties was his debt. F1 had a pragmatic approach to the amount of diversity possible on their farm, while F2 found that compromising with the amount of diversity is problematic because he thought this would leave biodynamic farming in the same trajectory of conventionalization as organic farmers. F3 was critical toward the financial future for biodynamic farmers in Denmark, leaving these practices for idealists with off-farm jobs. F5 recognized that it is costly to be pioneers. According to F1, there has been very little experience of how to construct an economically sustainable biodynamic farm due to the limited number of full-time biodynamic farmers in Denmark.

Some of the farmers had off-farm jobs to supplement their farm income. In the case of F1, this was because the farm was not yet profitable on its own. F7 had a full-time off-farm job but was able to hire a full-time manager. This was also the largest farm, which might benefit from economies of scale. F4, F5 and F6 lived off their farms even though most of them found it a challenge to make a profit from farming.

Barrier 5 as presented to farmers

It is difficult to run economically sustainable diverse farms in the current farming and food system: It requires more resources to have different livestock and crops due to the increased need for labor, equipment, advice, logistics, etc. Smaller volumes are harder to sell on the current market. Although biodynamic products are more expensive in stores, the real additional price for farmers are marginal due to the high share of the retail sector. Inspection costs are higher for small diverse farms than for large farms. The tight economy means that the majority of the interviewed farmers have other sources of income than farming.

Several of the farmers had comments and new experiences related to the economic challenges. F6 sold his farm due to economic difficulties, he explained that he could not make a viable business after 12 years due to fluctuating land prices and low demand for his products in the local area. F1 closed the on-farm shop and gave up the idea of making a living from farming. F7 was also challenged economically, which made him focus on high-value products and change sale channels to direct sale to end-users through online platform and export 80% of his produce to Germany and France due to a 20% higher price on biodynamic products compared to organic. F5 expanded his production area with a greenhouse made possible by savings from previous off-farm income. F2, F3 and F4 only experienced smaller changes in their circumstances and/or farming strategies. F4 believed that he is only able to manage economically because of loyal local customers.

All farmers articulated that prices on food in Denmark is too low (F1, F2, F3, F4, F5, F6, F7), some suggesting that the "real" price might be 10 times the current price level (F1). The extra cost related to having a diverse biodynamic farm compared to industrialized organic production results in a deficit because of equal prices on organic and biodynamic products (F1, F2, F5, F6, F7). Some found that lack of public education about the quality and benefits of products and management as one of the reasons (F1, F6). Finally, profiting from the benefits of diverse farming takes many years, making it even more challenging for farmers to enter a transition toward diverse farming systems (F6)

Discussion

In contrast to most modern conventional farmers (Brooker et al. 2015), the farmers interviewed strive for a high level of diversity as a fundamental part of their management practices (Table 2). We argue that these farmers complied with many of the characteristics of the first four levels of the agroecological transition proposed by Gliessman, Friedmann, and Howard (2019), but struggled to achieve the fifth level of transition since it requires drastic changes within the global food system. The analysis also validated

the notion that all levels of transition are interdependent (e.g. level 5), making it misleading to perceive it as a stepwise guide. Instead, change need to happen at all levels simultaneously (Gliessman, Friedmann, and Howard 2019). Based on the knowledge derived from the interviews, suggestions for change are discussed below that could increase the opportunities for diversified farming using agroecological principles in the Global North.

Training of advisors and farmers to increase multifunctionality and diversity

As agroecology advocates the use of a broader range of knowledge, especially local and informal knowledge, it is relevant to discuss the role of advisory services in an agroecological paradigm. The study indicates that new types of knowledge is needed (barrier no. 1) and that advisors need to be listening to local experiences considering the uniqueness and complexity of every farm (barrier no. 2). Research shows that advisors can play an important part with regard to the uptake of new innovations and change among farmers (Labarthe et al. 2018). In Denmark there is a strong farm advisory service tradition with an integrated and very important knowledge transfer role (Pedersen 2014). Within the agroecological literature and movement, a lot of agricultural science is accused of reproducing a reductionist paradigm that does not favor a transition to agroecology (Blann and Light 2017). Likewise, the close link between science and advisory services might foster dependency on seeds, chemicals, loans and advice, rather than increase food sovereignty. Several studies have also found that both the competencies of the advisors, the organizational structures and even a lack of incentive to move away from being an expert are some of the reasons why advisors are not assisting with learning processes toward more sustainable farming practices (Klerkx and Jansen 2010; Magrini et al. 2016). The creation of arenas for knowledge sharing among practitioners is suggested as an appropriate alternative or supplement (Šūmane et al. 2016), thereby also reducing the need for costly knowledge input (barrier no. 1 and 5).

There is also a strong tradition in Denmark of farmers' groups, with regular meetings with an advisor discussing and observing in the local farmers' fields for knowledge exchange and learning. Often these groups focus on specific technical issues or are very dominated by the advisor's knowledge rather than a systemic farm perspective (Vaarst et al. 2007). Training might be needed for both farmers and advisors (barrier no. 2) to change their traditional roles dominated by a specialization paradigm (Klerkx and Jansen 2010). Farmer Field Schools are an example of how this tradition can be modified and possibly used to foster even more peer-to-peer learning, including holistic perspectives on farm management (Vaarst et al. 2007). Facilitating and gaining

knowledge to run a farmers group is however time consuming for farmers with a busy work-life (barrier no. 5).

Knowledge about multifunctionality and the use of diversity in farming systems can also be addressed in farmers' education (barrier no. 2). Education has been shown to have a very crucial impact on farmers' practices and strategies (Fielke and Bardsley 2014; Niewolny and Lillard 2010). Integrating a greater focus on farming *systems* discussing sustainability, agroecology and diverse farming in both farming education and higher education in agriculture could be a way to create the awareness and skills farmers, advisors and scientists need to initiate experiments and develop agroecological practices and knowledge (Eksvärd et al. 2014; Frison 2016).

Adjustment of legislation and support to promote agroecological practices

In order to be able to innovate, conduct experiments and adjust the farming system to local conditions, simpler and more flexible legislation, with attention on structural conditions favoring diversified farming, would be desirable from the perspective of the interviewed farmers (barrier no. 3). Performing a holistic farm analysis rather than individual control and regulation for each activity on the farm could ease the heavy administrative burden (barrier no. 1). A greater degree of decentralization for improved action planning and implementation is needed, while at the same time ensuring that regulations still work in accordance with their intention. For example, allowing more breeds for professional hen keeping has to be weighed against the risk of spreading salmonella etc. Allowing and even encouraging the use of a greater diversity of breeds and varieties (barrier no. 3 and 4) would create more resilient farming systems (Lin 2011). As this study was being carried out, these concerns were partially being recognized because the Danish parliament agreed to initiate a new simplified and flexible control system, particularly for small-scale farmers, operating from 2019 to 2022 (Ministry of Environment and Food of Denmark 2018 (in Danish)). However, in the second interview several farmers mention that despite appreciation of the acknowledgment they do not find the actual regulatory adjustments ambitious enough to challenge the existing farming system as required at the fifth level of agroecological transition (Gliessman, Friedmann, and Howard 2019).

Farmers in the present study registered several benefits of their diverse farming system practices, even though these were not generally paying off financially in the current food market systems. The biodynamic farmers provide ecosystem functions and services such as biodiversity, living soils, nutrient cycling etc., but market prices do not reflect such public goods (Frison 2016). The study also shows that several farmers are willing to challenge the system by e.g. not complying with regulation in order to ensure what they perceive as optimal management practices (barrier no. 3). A more prominent

role for farmers could open up more integrated solutions by linking society's goals with the management already practised by farmers supporting these goals (Vanclay 2004). At the same time this integration can help other farmers learn, for example, by also developing peer-to-peer incubator settings for farmers who do not have the resources or skills to take their business in this direction (Meynard et al. 2013).

The study found that the interviewed farmers would be willing and able to provide even more diverse farms if the regulation and market acknowledged the associated quality and benefits (barrier no. 3 and 5). In accordance with recommendations by IPES, inclusion of new sustainable indicators and thereby change of the current subsidies for farmers is proposed by the interviewed farmers as a way to value the public benefits of diversified farming (Frison 2016). The launched concept of eco-schemes in the new CAP reform (Commision 2018) could be one way to recognize the benefits of agroecological practices and diverse farming. However, along with such initiatives, a much broader change to economic incentives is needed in order to ease the transition toward agroecology. Despite the opportunity of creating actual change in the broader food system, such an approach might also be a way for the European Union to "reclaim public policy for the public good" (IPES-Food 2019).

That said, Gonzalez, Thomas, and Chang (2018) argue that the translation of agroecology into institutions might lead to hybridization, resulting in agroecology being reduced to technical solutions and practices rather than challenging the socio-political system as experienced by the Danish farmers with the new simplified and flexible control system. In agreement with farmers the authors state that this is due to the influence of the dominant actors in the current regime creating a path dependency and diminishing the radicalism in the original agroecological approach (Gonzalez, Thomas, and Chang 2018). However, it could be argued that the institutionalization of agroecology provides a window of opportunity and resources to develop science, regulations, advisory services etc., thus stimulating discussion and raising awareness (Bellon and Ollivier 2018), which, according to farmers, is a vital part of gaining public recognition.

In EU's *farm-to-fork*-strategy several of the barriers identified in the present study are recognized by e.g. suggesting increased seed security and diversity, specific economical recognition of small-scale farmers, strengthening of farmers' position in the sector and reduction of the length of value chains (European Commission 2020). However, it is less clear how these are related to more fundamental changes within the food and farming system questioning the potential of the strategy to support a fifth level of agroecological transition.

Support for agroecological science

The biodynamic farmers in Denmark requested more research on practices and complexity achieved in diverse farming systems, including breeding, which favor the characteristics of multiple purposes and synergies (barrier no. 2 and 4).

Participatory plant breeding research programmes have been used to breed varieties suitable for local contexts and farmers' needs (Dawson et al. 2011). Typically, together with scientists, farmers are offered the opportunity to choose and develop, in their own environment, the varieties that best suit their needs and conditions, overcoming the limitations of conventional breeding (Ceccarelli and Grando 2007; Dawson, Murphy, and Jones 2008). Originally, the farming sector was driven more by public research and the farmers' own ingenuity (Clancy and Moschini 2017). Dawson, Murphy, and Jones (2008) assume that "while these methods do not compromise scientific integrity, it will take a shift in priorities and perspectives at many institutions." (Dawson, Murphy, and Jones 2008).

Participatory research in general is especially important when challenging the reductionist paradigm in order to know what advantages are recognizable and valuable for farmers and what barriers are encountered when trying to integrate diversity in farming systems (Wezel et al. 2014). Participatory research does not require farmers to lead the researchers, but it establishes farmers' needs, experiences and success criteria as guiding principles for the research.

Food sovereignty in the Global North

In the light of a transition toward agroecology, this study found that the knowledge, market, science, legislation and resources on which the interviewed farmers are either dependent or to which they are subjected emphasize the relevance of discussing food sovereignty in the Global North. As diverse farming has been marginalized, biodynamic farmers become representatives of the Global South in the Global North. Food sovereignty asserts a need for communities to engage in trade on their own terms rather than being subjected to speculation by international commodity markets (Desmarais and Wittman 2014; IPES-Food 2019). Food sovereignty is a strong movement receiving federal attention in the Global South, in contrast to the Global North where it is not yet applied in governance structures (Roman-Alcalá 2015). Despite conditions probably being better for Danish farmers than for farmers in the Global South, with regard to land tenure and access to water and seeds for example, we argue that the challenges of overcoming the barriers encountered might be extensive in a different way. Loss of knowledge and comprehensive debt and path dependencies derived

from rapid development in the industrialized agricultural sector are a difficult starting point for agroecological farming in Denmark. While diversification in farming practices might be possible within the current regime, with the risk of co-optation and its consequences however, this might not lead to increased food sovereignty. In that sense, food sovereignty is a strategic goal in a situation where the industrialized sector constitutes the hegemonic, conventional socio-technical regime. In a Danish context, food sovereignty might require farmers to no longer depend on the players defining the current agricultural regime and in the long term the establishment of a food system regime that is not optimized for one-size-fits-all, but rather that allows multiple ways of farming (El Bilali 2019). Allowing for manifold farming practices and strategies in the new global food system is crucial if food sovereignty is to be created – a "democratization of food systems, policy, practice, knowledge and the rights and autonomy of food producers (Levkoe, Brem-Wilson, and Anderson 2019).

Despite the theoretical potential of creating more economically resilient farming systems through diversification strategies (de Roest, Ferrari, and Knickel 2018) the interviewed farmers struggle economically *because* of their diverse farming systems (barriers no. 5). Especially through the second interview farmers expressed that they do not feel able to overcome the identified barriers at a farm level nor that they have an influence on a farming system strongly dominated by other players. Instead farmers suggest radical changes in the farming and food system (level 5) through e.g. increasing the demand through public procurement, state-regulated commodity prices, economical advantages depending on management strategies (exemption on VAT, taxations etc.), as well as new forms of ownership and organization of farmers.

The Danish interest group for small-scale farmers and member of the international peasant movement, La Via Campesina, recently published a report on food sovereignty in Denmark that indicated an urgent need for radical change:

> *"Even in a wealthy country, three conditions must be met if it is to consider itself food sovereign. First, the physical basis for food production must be intact. Second, the physical basis must be either a commons or properly owned. And third, policies for food production must derive from democratic process. Denmark falls short on all three counts."* (La Via Campesina Denmark 2017)

Offering an additional perspective on transition within the food system, we find food sovereignty to be a useful parameter for addressing the deep roots of the lock-in of industrialized agriculture today, as suggested in the above quotation. The concept calls for profound change and also forces us to ask: "What implications does an engagement with food sovereignty carry for academic researchers and academically-situated processes of knowledge

production?"(Levkoe, Brem-Wilson, and Anderson 2019). Food sovereignty as a goal is in radical opposition to the global food system of today, with many questions to be answered by the second generation of food sovereignty and the agroecological movement (Edelman et al. 2014).

Conclusions

This study investigated diverse agroecological farming practices as important elements for transitions toward more sustainable and resilient farming. Identifying the barriers faced by biodynamic farmers in Denmark, the study provided exemplary insight on farm-specific and structural challenges for these practices within broader landscapes of industrial farming systems. Biodynamic farmers are a minority group in Danish agriculture who work with diversity as the foundation of their management practices. These practices show how it is possible to create more integrated and diverse systems that harmonize the mutual inter-relationships between plants, livestock, soil and humans, and mitigate some of the detrimental effects of intensified agricultural systems. However, the farmers highlighted a number of key barriers that are a challenge for the paradigm shift required to allow for such systems. Diverse farming requires manifold knowledge and skills; farmers need support due to an absence of research, education and advisor knowledge on diverse farming; legislation does not favor diversity and multifunctionality; the improvement of breeds means varieties are not made for diversity and multifunctionality; and diverse farming is barely economically sustainable within the current Danish food system. While some of these challenges are linked to internal farm management, transformations in external structures, including legislation, market, infrastructure and knowledge, are paramount in order to enable diversified farming to be practised. To understand these barriers, we argue that the structural barriers outside farm management in particular can be perceived as a lack of food sovereignty. This suggests that enabling diversified farming implies addressing essential questions on food sovereignty, including the physical basis for food production, land ownership and policies for food production, related to broader redefinitions of food and farming systems.

Notes

1. No specific information about the landscape was giving in the interviews with F4, F5 and F7
2. F5 and F4 emphasized that they still had attacks of pest and diseases, but as they never spread very far, any harm is limited.

3. Several farmers said that they had more animals or crops before or were planning to have greater diversity in future. This is omitted from the table to demonstrate the situation on the farm at the time at which the interview was conducted.
4. Refers to techniques articulated by farmers to increase diversity at field or farm level (e.g. species mixtures, mixed crop-livestock farming, crop rotation etc.)
5. No information provided in the interviews about the given category in the empty areas of the table.

Acknowledgments

We thank the interviewed farmers and the Biodynamic Association Denmark for taking their time to participate in this study.

This work was supported by the European Union's Horizon 2020 Research and Innovation Programme under Grant No. 727217-funding the project "Redesigning European cropping systems based on species mixtures"(ReMIX) with the aim to "exploit the benefits of species mixtures to design more diversified and resilient agroecological arable cropping systems" (remix-intercrops.eu) with a specific focus on implementation and farmer involvement due to the Horizon 2020 requirements for a multi-actor-approach (EIP-Agri 2017). The opinions expressed in this paper are not necessarily those of the EU.

Funding

This research has been funded by the European Union's Horizon 2020 Research and Innovation Programme under Grant No. [727217].

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