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RESILIENT FOOD PRODUCTION – RESILIENT LANDSCAPES

The role of heterogeneity and scale

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Norwegian agricultural history in a nutshell

Climate restricts yields and types of crops that can be grown in Norway due to its northern location (OECD, 2021). Only 3.5% of Norway is fully cultivated land, and arable land is a scarce resource (Statistics Norway, 2021a). To compensate for the lack of arable land and to tackle variations in, for example, climate, farms relied on a very diverse resource use, different productions and sources of income. Outfield areas such as mountains were used for grazing and hay production, branches and leaves as winter fodder and seaweed as fertilizer (Acksel et al., 2019; Lunden, 2004; Olsson, Austrheim & Grenne, 2000). Each farm typically produced grain, meat, and milk as basic products (Almås, 2004). Growing of potatoes did not become common until the early 19th century, and fruit and vegetable production has also been rather limited (Almås, 2004). In general, productions focused on farm self-sufficiency. Farming was commonly combined with other types of activities. Combinations differed among regions, however, to a large extent dependent on available resources and geographical location. In coastal regions, for example, fishery added to farm resources, in forest regions, forestry played the same role (Almås, 2004). Resource use was on the scale of the single farm and each farm had access to a proportion of different local resources.

As in other European countries, specialization and rationalization are ongoing trends within Norwegian farming since about the Second World War (Almås, 2004). Artificial fertilizer, commonly in use by the end of the Second World War (Gjerdåker, 2004), reduced the dependency on outfield resources by increasing infield yields. The rising production in infield areas made outfield resources increasingly marginal. At the same time, agricultural production followed an ideal of efficiency, i.e., increased output per invested unit of time, along the lines of the ideals of industrialization, as also described so well by Smiley (1997). To

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become more efficient, production has been specialized, in general leading to a smaller number of productions, including crops grown, per farm. Specialization has been combined with the ideal of large units to benefit from the 'economies of scale'. In the landscape, these developments are visible in terms of larger individual fields and increased average field size (Potthoff, 2020; Stokstad & Krøgli, 2012). Similar to the development in many other countries (Eurostat, 2021), number of active farmers has been in decline since the Second World War in Norway, however. While Norway had 213,441 active farms (with more than 0.5 ha of land) in 1949, the number of active farms declined to 38,633 in 2020 (Norges Offisielle Statistikk, 1950; Statistics Norway, 2021b). The amount of farmland has changed to a lesser degree, though, due to an increase in land renting (Stokka, Dramstad & Potthoff, 2018). However, there is a limit to how large a farm can become, before farm size and land located at a distance will have an effect on productions. Farmers have a restricted amount of time and a restricted number of days with weather good enough for harvesting (Vik & Flø, 2017). During this time, farmers can manage a certain amount of farmland while the remaining farmland is dealt with during less optimal weather conditions. Carrying out farmland operations during non-optimal conditions means reduced productivity. While climate change may result in increased temperatures, an extended growing season and a larger time window for farm operations, other changes, such as occurrences of new weeds or diseases and cold hardening of plants challenged by increased autumn temperatures may negatively impact productions (Neset, Wiréhn, Klein & Käyhkö, 2019; Uleberg, Hanssen-Bauer, van Oort & Dalmannsdottir, 2014; Wiréhn, 2018).

'Economies of scale' have been accompanied and driven by a comprehensive technological development within the agricultural sector (Almås, 2004). Many labour-intensive agricultural practices have been almost entirely abandoned, such as haymaking and pollarding. To make hay, the grass was manually cut with a scythe and dried on wire systems mounted in the fields – called *hesjer* in Norwegian, a work typically involving the entire family, including children and elderly family members, during a couple of long working days when the weather and season was right (Almås, 2004). This practice changed as machine harvesting and storing grass as silage took over. Similar paths of development can be seen in a number of farming operations, e.g., feeding and milking. Automated milking systems, common since the year 2000, being one example of a more recent technological development (Rønningen, Fugestad & Burton, 2021). While technological development was a key driver for more efficiency in farming, it also provided opportunities for farmers to have 'normal' working hours and holidays. A case study from Southern and Central Norway even showed that intensifying production and investment in automated milking systems was driven by a desire for a better work-life balance (Burton & Farstad, 2020). Technological development can move productions towards reduced flexibility as the introduction of automated milking systems shows; it ties the livestock to the area close to the stable (Rønningen et al., 2021).

Since the Second World War, Norwegian agriculture has been linked to a selection of explicitly articulated aims, such as to upkeep settlement and employment in rural areas and to increase food production (Bjørkhaug & Rønningen, 2014). To ensure the best use of the scarce farmland and thereby maximize food production, what has been described as a canalization policy was introduced in the 1950s. The policy encouraged grain growing in areas most suitable for this kind of production (i.e., southern and eastern Norway) whereby livestock husbandry was concentrated in those areas less suitable for grain production (i.e., western and northern Norway) resulting in a strong regional differentiation of agricultural production (Almås, 2002; Jones & Rønningen, 2007).

Norway's current degree of self-sufficiency is 36% (data from 2018 and 2019), fish and imported concentrated feedstuffs excluded (Rustad, 2020). To sustain and preferably increase self-sufficiency – also taking into consideration expected population growth – the Norwegian government aims at increasing food production by 20% from 2011 to 2030 (Meld. St. 9 (2011–2012)). In 2016, the government confirmed the aim of increased production although no specific percentage was given (Forbord & Vik, 2017).

Agricultural production is carried out within a comprehensive legislative and regulatory framework and cost efficiency in productions has been encouraged by adjusting subsidies to benefit larger farms (Bjørkhaug & Rønningen, 2014; Forbord & Vik, 2017). At present, agricultural production is but one small element in a larger food system, a network of processes on national and global scales (Bjartnes, 2018; Nyström et al., 2019). In 2020, Norway imported c. 39% (784,350 t) of the raw material to be used for concentrated feed production (Landbruksdirektoratet, 2022). Although roughage is used in livestock productions, pig and poultry productions rely entirely on concentrated feed (Nysted, Uldal & Vakse, 2020). In addition to input transported to Norway from abroad, dependency on long-distance transport has increased also inside Norway to process and distribute products. The number of slaughterhouses is reduced, from 65 in 1996 to 39 in 2005, the number of mills accepting grain for further treatment has declined from 139 in 1998 to 70 in 2017, and at present only 11 locations accept animal wool and skins (Animalia, 2020; Hillestad & Bunger, 2019; Svin, 2018). The declining number of locations processing products result in comprehensive transport costs. Nortura drives ca. 17 million km to transport living animals to the slaughterhouse and eggs for packaging, while the main milk processing company in Norway (TINE) drives 55.5 million km to distribute its products (Hillestad, 2014). The coverage of other farm related services such as repair of machinery may also become patchier with a declining number of farms, further increasing the need for transport.

To analyse and discuss resilience in food production and landscapes, we selected three municipalities in different parts of Norway (Figure 3.1). The municipality of Rakkestad is located in Eastern Norway in an area with good conditions for grain production (Figure 3.2). Animal husbandry as well as vegetables are important productions in Time municipality, located in Western Norway (Figure 3.3).

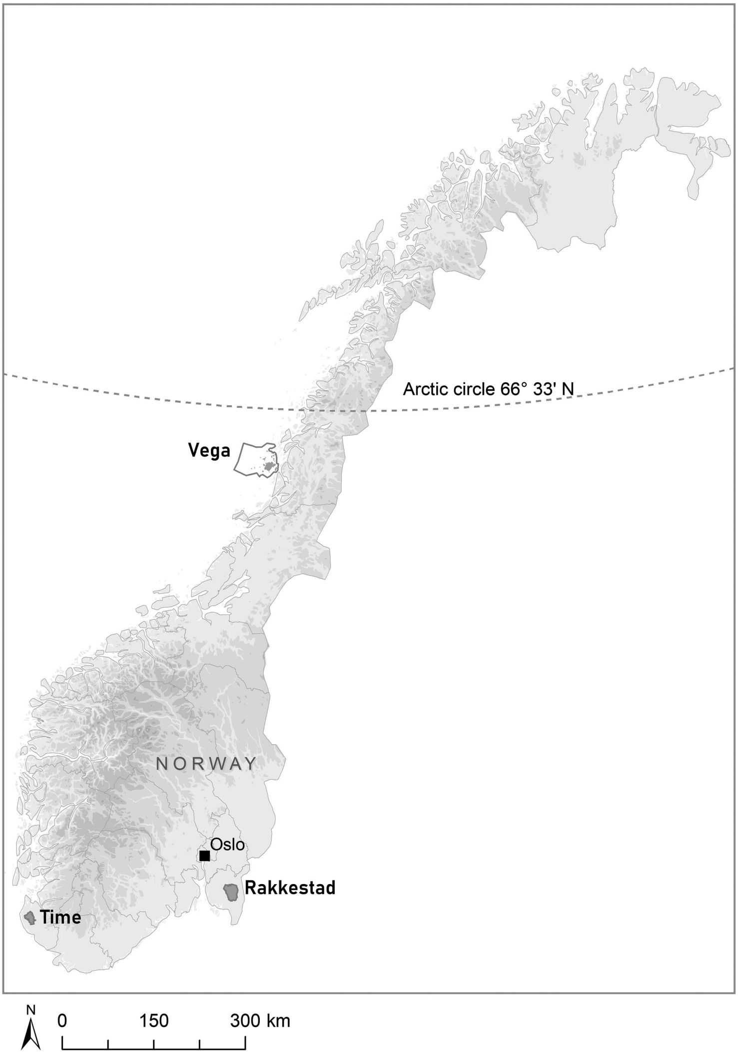

FIGURE 3.1 The municipalities of Rakkestad, Time and Vega, marked in grey. The grey line in Vega illustrates that the sea makes up a large part of the municipality (© NIBIO).

Due to its northern location, farming is constricted by climate in the municipality of Vega. Most important productions are animal husbandry.

Despite differences in the importance of productions and amount of agricultural land, agriculture production in all municipalities reflects the changes common for the whole country presented above. Productions have gone through an up-scaling with fewer farms managing an increasing amount of

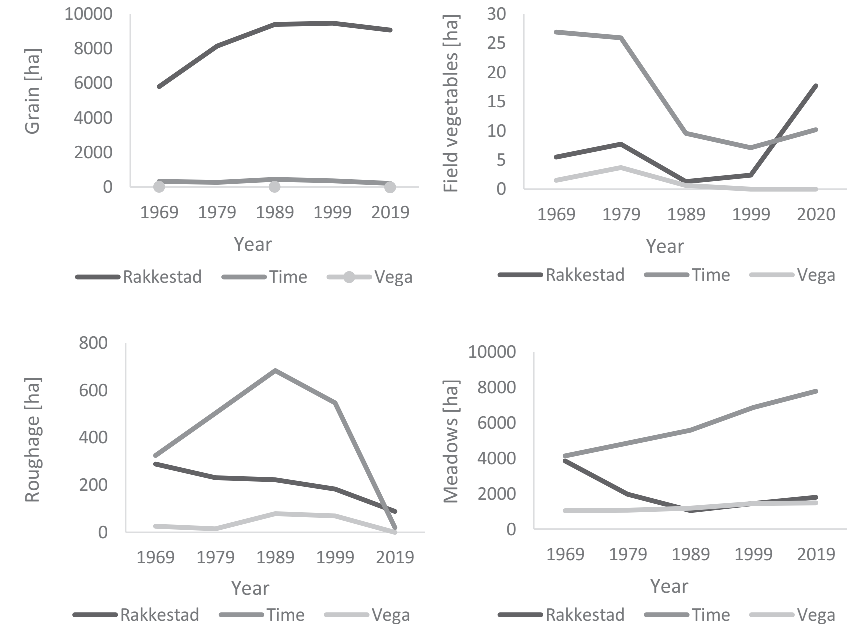

FIGURE 3.2 Changes in production of grain, roughage, field vegetables and meadow area from 1969 to 2019. Data for vegetables are lacking for 2019, data for 2020 have been used instead; data for grain production in Vega are 22 ha (1969), 26 ha (1989) and 0 ha (2019) (Statistics Norway, 2021d). (Note difference in scale on vertical axis).

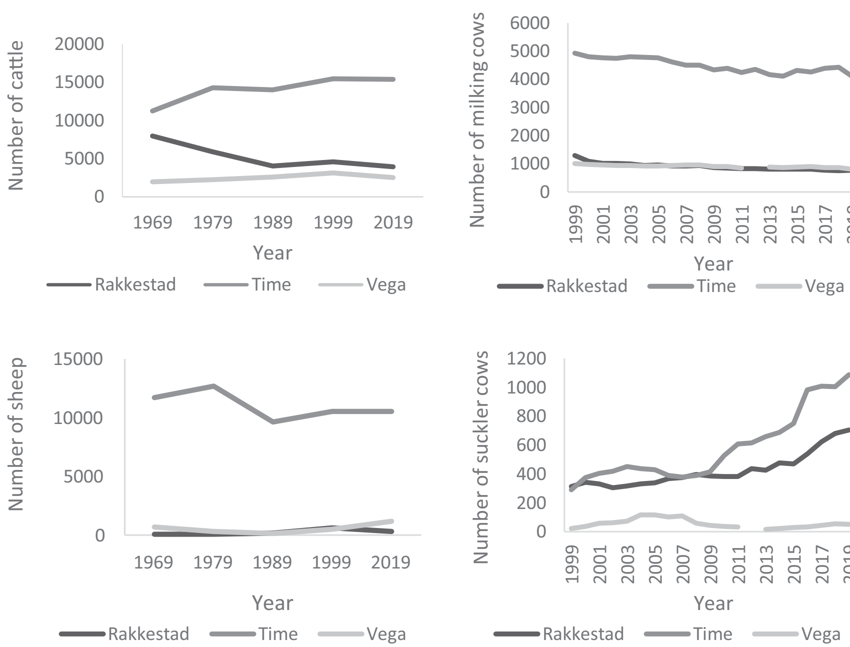

FIGURE 3.3 Changes in livestock productions from 1969 to 2019. Data separating milking and suckler cows is only available since 1999, thus annual data since 1999 have been used (Statistics Norway, 2021c). (Note difference in scale on vertical axis).

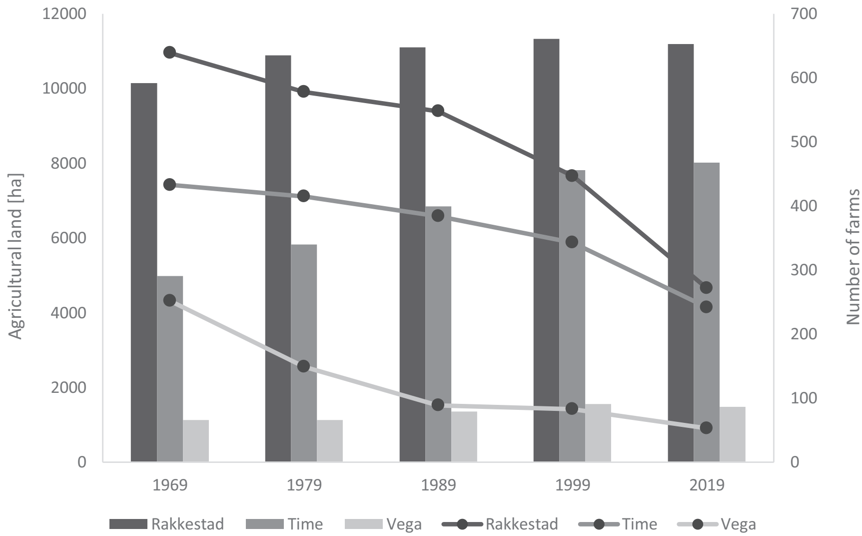

FIGURE 3.4 Change in agricultural land (columns) and number of farms (lines) from 1969 to 2019 (Statistics Norway, 2021e).

land per farm (Figure 3.4). Pig and poultry productions – relying entirely on concentrated feed (Nysted et al., 2020) – occur in all municipalities with Time having the largest number of animals (Statistics Norway, 2021c). The consequences of the canalization policy are visible in the strong importance of grain production in Rakkestad while the decline in milking cows reflects a specialization in production.

Declining diversity and heterogeneity – declining landscape resilience

The brief overview about Norway's agricultural history indicates that technological development and socio-economic and political frameworks are important drivers for how agricultural landscapes have developed and are currently managed. Selman (2012) highlights a number of similarities between cultural landscapes, in our case agricultural landscapes, and social-ecological systems. For instance, both 'are a combination of social (governmental, economic, human, built) and ecological (biotic, physical) subsystems' (Selman, 2012, 42). Agriculture is one example of a key relationship that links social and ecological subsystems into social-ecological systems (Cumming, 2011). Considering landscapes as social-ecological systems, landscape resilience can, in line with Folke et al. (2010), be defined as the ability of a landscape to adapt to continuously ongoing change and to tackle disruptions while at the same time retaining its essential function. From an anthropocentric point of view, a landscape's essential function can be defined as the provision of ecosystem services, such as food production. In the same way, as ecological resilience is improved by greater biodiversity and social resilience by diversification of livelihoods, an agriculture based on a diverse resource use enhances, according to our understanding, landscape resilience (Cumming, 2011). Thus, we argue that farmland management and the manner in which food is produced in agricultural landscapes influence landscape resilience.

Diverse resource use in agricultural productions is one strategy to tackle shocks (Ashkenazy et al., 2018; International Fund for Agricultural Development, 2021), shocks that in the past could be generated by e.g. crop failure due to pests or adverse weather conditions during the growing season. Being prepared to deal with shocks was an important prerequisite to survive as farmers, most likely not only in Norway but in any farming society. However, Norway's northern location made the ability to tackle shocks especially important due to potentially unstable growing conditions during summer and certain crops being grown on the northern boundary of their potential range.

Thus, within Norwegian agricultural history, access to a variety of resources contributed to a high degree of resilience within the farming system. This resilience was mainly on farm scale and enabled an individual farm or a local farming community to absorb disruptions and shocks. If one resource failed, other resources could be used more intensively. An unintended outcome of this approach was a highly diverse landscape, where a multitude of different types of land could be harvested when needed. This diverse land-use and resource exploration produced very spatially heterogeneous landscapes, again mainly on farm scale. Thus, diversity and heterogeneity seem to be key concepts that can be used to further analyse landscape resilience since they reflect the extent to which agricultural production is based on a diverse resource use.

Heterogeneity and diversity are commonly used in ecology and landscape ecology (Collinge, 2009). When applying these concepts on land and landscape assessment, diversity is used to describe the number of different land cover / land-use types present, and if required also their relative coverage. Heterogeneity adds valuable information about landscape structure (Fjellstad, Dramstad, Strand & Fry, 2001), as the spatial distribution of the differing land cover / land-use types is captured. For both measures, several quantitative indices have been developed based on a desire to enable comparison of landscapes over time (for examples see Andreasen, O'Neill, Noss & Slosser, 2001; Magurran, 2003; McGarigal & Marks, 1995). We will not calculate quantitative indices, however, but intend to discuss the application of the measures from a more theoretical perspective founded in our knowledge about the historical and current state in our three case areas. In the following, we highlight important landscape changes in the case areas and discuss afterwards some consequences of changes in landscape heterogeneity and diversity for the provision of ecosystems services.

FIGURE 3.5 Farming landscape in Rakkestad in 1953 and 1992. White arrows: examples of grasslands that have disappeared in 1992, black arrows: examples of narrow grassy banks that have disappeared in 1992 (Old aerial photo © FotoNor, newer aerial photo © kilden.nibio.no).

The landscape changes in our case studies reflect the three main pathways common for agricultural landscapes throughout the whole of Europe: intensification and upscaling, extensification and land abandonment, and urban and industrial sprawl (Bieling, Plieninger & Trommler, 2011). Intensification and upscaling are clearly visible in Rakkestad (Figure 3.5) and Time (Figure 3.6). Although agricultural production and land use in Rakkestad were already rather specialized in 1953, the changes until 1992 reflect a further upscaling of productions. Fields are merged into larger units, making the majority of the narrow grassy banks disappear by 1992. These narrow grassy banks often separated fields used for different crops, as farming was based on a traditional system of crop rotation. Another important change is diminishing grasslands. While the 1953 aerial photo shows several grasslands, in 1992, their number is strongly reduced.

In Time, similar to Rakkestad, a patchwork of small fields was merged into larger units. The aerial photo from 1953 visualizes a range of different crops and productions, as can be seen from the different shades of grey. This heterogeneity is much reduced in 2019. Fences or stones removed from the fields and located at the edge of the fields were typical field diversions. Some of these narrow diversions are more visible in 2019 than in 1953, as can be seen from the rows of bushes or small trees marking property borders. We assume that bushes and trees have been able to grow since the use of larger machinery does

FIGURE 3.6 Aerial photos of the same agricultural landscape in Time municipality, in 1953 and 2019, respectively (Old aerial photo © FotoNor, newer aerial photo © kilden.nibio.no).

not allow to cut grass close to property borders. Moreover, farmers would try to avoid carrying out any farm operation that could damage elements constituting property borders since 'challenging' the borders would not be considered good conduct. In the 1940s and 1950s when more time was invested in managing the land than in the 2010s, and when how crops developed was more important than at present, trees and bushes would probably have been removed by hand to prevent them from shading the crop and using nutrients from the field.

While merging of smaller fields occurred in Vega as well, Vega is probably the example among our cases where extensification and abandonment of former agricultural land is most common (Figure 3.7). The aerial photos show a number of clearly designated crop fields in 1953 that are hardly visible in 2009. Such a landscape change results in reduced heterogeneity and diversity, as more and more land turns into shrubland. While there could have been a variety of crops and crop varieties grown in 1953, what remains is fields with more or less similar successional stages and very little variation. Finally, the aerial photographs of Time show urban sprawl – the development of housing accompanied by a new road – on what used to be agricultural land.

FIGURE 3.7 Aerial photos showing a landscape from Vega municipality in 1965 and the same landscape in 2009 (Old aerial photo © FotoNor, newer aerial photo © kilden.nibio.no).

Merging of fields and increased average field size as a consequence of small fields being abandoned allow for the use of big machinery and speeding up farm operations (i.e., upscaling of production). However, large fields and an accompanying use of a small selection of crops, and abandonment of marginal land may weaken a farm's availability of resources in times of crises. The dry summer of 2018 with high temperatures and little precipitation during a period of almost five months, resulting in forest fires and impacting agricultural production in the whole of Europe, showed that access to a diversity of resources including mountain resources were important for Norwegian farmers to tackle the climatic shock (Beitnes, Kopainsky & Potthoff, 2022; Skaland et al., 2019). Moreover, on farm scale, the production of a variety of crops made it possible to use grasslands for natural flood control. Grasslands were particularly important in depressions affected by flooding and along the river. When a river raised above its normal level, e.g., during snowmelt, grasslands could function almost like detention ponds. The water would cause limited erosion and little other damage. When a farm only produces grain crops, the adaptation of maintaining grasslands is no longer feasible. In former grasslands – now turned into fields for annual crops – flooding causes severe erosion problems and potentially also crop damage.

The removal of small landscape elements such as grassy banks is not clearly visible in land-use/land cover statistics, since they do not constitute a large proportion of the total in terms of area (Fjellstad & Dramstad, 1999); however, their disappearance may have important effects on a landscape's ability to provide food, as well as the visual appreciation of the landscape by the general public (Stokstad, Krøgli & Dramstad, 2020). Narrow strips across fields are also well documented to be important for biological pest control, e.g., by providing habitat for carabid beetles, key predators of aphids (Altieri, Nicholls & Fritz, 2005;

Dennis, Fry & Andersen, 2000). Further, the use of bigger machinery, necessary to make operations and transport more efficient, is not feasible on small fields. When farm operations were done manually, like haymaking, small fields were no hindrance.

While merging fields and removal of landscape elements may impact on the way food is produced, production is bound to be reduced when the area used for farming is declining as in the example of Vega. What would be needed in terms of investments to bring these areas back into agricultural use again, for example, in times of crises, depends on how far the natural succession has come. An important prerequisite to make use of such areas is the availability of knowledge of and technology for, how to use, for example, marginal resources. Erosion of knowledge may be a bigger challenge than of soil. Housing development in Time is an example of a land-use change that most likely will terminate any possibility to use the land for future agricultural production.

So far, we have argued that a diverse resource use, visible in a high landscape diversity, may enhance resilience. However, the housing development in Time shows that not any kind of increased resource use diversity may result in enhanced resilience, at least not when food production is the goal. The change from farming to housing is a reminder that trade-offs will always occur. Time is located in an economically fast-developing region in which the demand for new housing areas competes with the use of land for agricultural production (Stokka et al., 2018). On the one hand, availability of housing is important for the economic development of the region, on the other hand, we can argue that – taking the small amount of arable land in Norway into consideration – Norway has no agricultural land to lose. This example illustrates that a landscape can never provide all its essential functions within one piece of land, and the provision of one service may exclude the availability of another.

Until now, our discussion of potential consequences of decreasing diversity and heterogeneity for a landscape's ability to produce food has focussed on the farm scale. However, heterogeneity, diversity and related issues of resilience cannot be properly addressed without considering other scales. When policy affects the geographical distribution of different productions on regional scale – as in our case, moving from local to regional scale will increase diversity, since a greater range of productions will be considered. At the national scale, an even larger selection of productions will be included. Thus, at the national scale, the diversity of landscapes and their different productions may in sum still provide a range of products broad enough to ensure a certain degree of resilience. However, considering the national scale only may give an illusion of being resilient, an illusion dependent on many prerequisites. In a country such as Norway, reaching from 58 to 71°N, transport distances are extensive and – as pointed out in the previous section – transport costs are high. Productions taking place in northern Norway cannot contribute to food security in southern Norway without, for example, an efficient transport system. Such a transport system is dependent on a functioning infrastructure, a distribution system, fuel, and durability of products.

Further, farming in Norway is dependent on multiple external input factors, such as import of raw material for concentrated feed production (see previous section). Such a resilience can be called coerced since the maintenance of production levels is dependent on anthropogenic input that in our case even comes from outside the country (Rist et al., 2014). Dependence on external input factors will increase with loss of farmland to other types of land uses and as a result of farmland abandonment.

Reconnection to landscapes' production potentials

In our perspective, the previous sections have highlighted that the current framework in which the agricultural sector operates puts the resilience of local landscapes under pressure. This pressure on resilience is a consequence of reduced opportunities for diverse and flexible use of local resources, visible in a declining heterogeneity and diversity. Climate change may further challenge landscape resilience as the dry summer of 2018 revealed (Beitnes et al., 2022) (see the previous section for more details). Prospects of climate change in all our case municipalities include a probable increase of rain occurring at higher frequency and with greater intensity and – as a consequence – problems with surface water and increased flood events (Hisdal, Vikhamar-Schuler, Førland & Nilsen, 2021). Higher temperatures during summer may result in droughts due to increased evaporation (Hisdal et al., 2021). These changes may all challenge agricultural production, but exactly which production that will suffer the most from any particular event may differ. As long as shocks of any type can be buffered by getting access to resources from other parts of Norway or other parts of the globe; the agricultural sector may continue along the current trajectory for production system development, with its focus on increased efficiency and little attention to the production potential of local landscapes.

However, at the same time as access to resources globally may support a country's resilience, it may make food production dependent on external inputs more vulnerable. Within global interconnected food systems any small-scale event may impact productions at great distances (Nyström et al., 2019). Also food systems in the resource-strong Nordic region can potentially be threatened by the collapse of long supply changes (Nordic Council of Ministers, 2020). The disconnection of where food is produced and where it is consumed increases vulnerability to infrastructure disruptions (Nyström et al., 2019), and disruptions at specific points – 'chokepoints' – such as the Suez Canal may get disproportionally large-scale consequences for food security (Wellesley, Preston, Lehne & Bailey, 2017). In addition, transport contributes to the emission of CO_2, and thus, climate change, which again may have negative impacts on food security. Not at least, relying on external resources can lead to land grabbing; and while providing potential economic opportunities for rural populations, it may also challenge the livelihoods of local people (Santurnino, Hall, Scoones, White & Wolford, 2011).

Thus, a different kind of agriculture would be needed to strengthen landscape resilience. What could such an agriculture be like? We definitely do not mean to romanticize past agriculture with its hardships for farming communities and its restricted choice of products in terms of, for example, vegetables. However, we would argue that we need an agriculture that builds to a larger extent on a production base available in the local landscape. Our concern is that the pendulum now has moved too far towards efficiency, as used in other industries and typically linked to the idea of 'economy of scales', as also discussed by Smiley (1997). In this context, also the land sharing versus land sparing debate is relevant, but as outlined by Grass, Batáry and Tscharntke (2021), multifunctional landscapes should preferably include elements from both approaches.

Key points of our vision for more resilient food productions and thereby resilient landscapes are:

1 A farm size scaled to allow carrying out at least most farm operations during optimal weather conditions. This would contribute to increased production, reducing the existent yield gap, thus decreasing dependence on resources from other places.
2 Field sizes that increase landscape diversity and heterogeneity and give room for 'non-productive' landscape elements such as grassy banks between fields. Accepting and adapting productions also on smaller fields would open up for a greater selection of products on farm scale, while a diversity of different landscape element would help support natural pest control or attenuate the impacts of extreme weather events.
3 Marginal resources that are kept in a productive state. The assessment of the value of resources should consider in which way their use can help reducing need for transport and dependency on global resources, and if their value may increase in times of crisis. However, considerations must be done on a longer timescale, and not be based solely on the situation 'here and now'.
4 A technological development that addresses the needs of a more small-scaled farming. The experiments of a Norwegian agriculture school to sow grass using a drone, or the agriculture robot designed at the Norwegian University of Life Sciences are examples of technological development that according to our understanding would allow the use of smaller fields in an efficient way (Flatås & Alisubh, 2021; Robotikkgruppen, 2021). Such a development may contribute to counteracting the drivers founded in the desire of continuously increased efficiency (i.e., output per unit).

Path to the future – the responsibility of a multiplicity of stakeholders

A large number of stakeholders in addition to farmers and landowners impact directly or indirectly on how food is produced in agricultural landscapes (Meuwissen et al., 2019). This multiplicity of stakeholders implies that the responsibility for remaining or becoming resilient should not rest only on the farmers but be shared among stakeholders (Darnhofer, 2014; Darnhofer, Lamine, Strauss & Navarrete, 2016). As presented in the section 'Norwegian agricultural history in a nutshell', policy makers are key stakeholders of the agricultural sector. The fact that farmers have expressed greater worries about politically induced structural changes than about climate change underlines how strongly policy impacts the Norwegian agricultural sector (Beitnes et al., 2022). In line with the Common Agricultural Policy (CAP) of the EU, the Norwegian subsidy system includes payments to encourage sustainable land use such as area and cultural landscape payments (Bjørkhaug & Rønningen, 2014; Daugstad, Rønningen & Skar, 2006). However, increased efficiency and production are still important policy goals and are encouraged by the subsidy system (Forbord & Vik, 2017). Also, Schiere, Darnhofer and Duru (2012) point out that efficiency and stability –stimulated by European policy – may mean less flexibility and resilience.

Agricultural policy, globally, in an EU and Norwegian context, seems to encourage farming systems to strengthen their robustness (FAO, 2021; Manevska-Tasevska et al., 2021; Meuwissen et al., 2020; Nicholas-Davies, Fowler & Midmore, 2020; Potthoff & Kopainsky, in preparation; Paas et al., 2021; Reidsma et al., 2020). However, robustness, a farming system's ability to tackle stress and shocks (i.e., to persist), is only one resilience capacity (Meuwissen et al., 2019) and buffering shocks by resources external to a local landscape may not be resilient in the long run. Other resilience capacities – adaptability (ability to make changes without changing the structure of the farming system) and transformability (ability to make significant changes) (Meuwissen et al., 2019) – may become more important in the future taking into consideration future challenges for agricultural production, such as climate change.

What kind of agricultural policy could stimulate farming systems to increase their resilience? Basically, such a policy and its related subsidy system would need to give more room for a flexible and diverse resource use. More flexibility could, for example, encourage farmers to keep marginal areas in use that can become important in times of crisis and to sustain a broader selection of productions. Moreover, 'hidden' costs such as transport costs should be considered carefully when evaluating cost efficiency within productions. Not at least, trade-offs between increasing resilience through, for example, diversification and efficiency would have to be addressed (FAO, 2021). Encouraging technological development and innovation could reduce the costs of declining efficiency by making the management of small fields less time consuming and by identifying values and usages of seemingly valueless or marginal resources. Examples of the latter are projects about using 'worthless' sheep wool as fertilizer (McKinnon, 2021) and identifying values of outfield resources (Strand et al., 2021).

Among the multiplicity of stakeholders impacting on food production we would like – besides the role of policy makers – to stress the importance of consumers. Through our choices as consumers of food, we have an impact also on the agricultural landscape and its resilience. Buying locally and regionally produced and processed food can support farmers in offering a larger diversity of products and in taking into use a broader selection of their farm resources. Consumer choices and the willingness to pay a higher price for food have thereby also an important impact on the degree to which knowledge to harvest local resources is preserved and farmers can benefit from natural pest control. The possibility to make informed choices depends, of course, on whether information is available to us. In this context, media and the processing industry can play a role as stakeholders. Media can ensure, through informing the public and policymakers, that local food production and product diversity is on the agenda. The processing industry can make sure that information about origin of products is easily available. Increased interest in locally produced food bought in shops and directly from the producer during the COVID-19 pandemic in Norway (September 2020 to August 2021) indicate a trend of a higher consumer awareness for whatever reason (Johnsen, 2021).

We believe that through our vision for agriculture – keeping land in production, adapting production to the landscape, and lessening the drivers for increased efficiency – we can increase agricultural resilience. This vision, we would argue, should be a key to future agricultural development, in Norway as in other countries, even though the way forward may be different in different parts of the world and different production and policy systems.

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References

Acksel, A., Giani, L., Stasch, C., Kühn, P., Eiter, S., Potthoff, K., Regier, T., & Leinweber, P. (2019). Humus-rich topsoils in SW Norway – Molecular and isotopic signatures of soil organic matter as indicators for anthropo-pedogenesis. *Catena, 172*, 831–845.

Almås, R. (2002). *Norges Landbrukshistorie 1920–2000. Frå bondesamfunn til bioindustri* (Vol. IV). Oslo: Det Norske Samlaget.
Almås, R. (Ed.) (2004). *Norwegian Agricultural History*. Trondheim: Tapir Akademisk Forlag.
Altieri, M. A., Nicholls, C. I., & Fritz, M. A. (2005). *Manage Insects on Your Farm. A Guide to Ecological Strategies*. College Park: Sustainabile Agricultural Research and Education.
Andreasen, J. K., O'Neill, R. V., Noss, R., & Slosser, N. C. (2001). Considerations for the development of a terrestrial index of ecological integrity. *Ecological Indicators, 1*(1), 21–35.
Animalia. (2020). Ullstasjoner i Norge. Retrieved from https://www.animalia.no/no/Dyr/ull-og-ullklassifisering/ullstasjoner-i-norge/
Ashkenazy, A., Chebach, T. C., Knickel, K., Peter, S., Horowitz, B., & Offenbach, R. (2018). Operationalising resilience in farms and rural regions – Findings from fourteen case studies. *Journal of Rural Studies, 59*, 211–221.
Beitnes, S. S., Kopainsky, B., & Potthoff, K. (2022). Climate change adaptation processes seen through a resilience lens: Norwegian farmers' handling of the dry summer of 2018. *Environmental Science & Policy, 133*, 146–154.
Bieling, C., Plieninger, T., & Trommler, K. (2011). Cross the border – Close the gap: Resilience-based analysis of landscape change (Editorial). *European Countryside, 2*, 83–92.
Bjartnes, A. (2018). Utslipp fra jord til bord. In A. Bjartnes (Ed.), *Matsystemet under Press* (Vol. Rapport nr. 02/2018, pp. 6–7). Bergen: Norwegian Climate Foundation.
Bjørkhaug, H., & Rønningen, K. (2014). Crisis? What crisis? Marginal farming, rural communities and climate robustness: The case of Northern Norway. *International Journal of Sociology of Agriculture and Food, 21*(1), 51–69.
Burton, R. J. F., & Farstad, M. (2020). Cultural lock-in and mitigating greenhouse gas emissions: The case of dairy/beef farmers in Norway. *Sociologia Ruralis, 60*(1), 20–39.
Collinge, S. K. (2009). *Ecology of Fragmented Landscapes*. Baltimore: John Hopkins University Press.
Cumming, G. S. (2011). Spatial resilience: Integrating landscape ecology, resilience and sustainability. *Landscape Ecology, 28*, 899–909. doi:10.1007/s10980-011-9623-1
Darnhofer, I. (2014). Resilience and why it matters for farm management. *European Review of Agricultural Economics, 41*(3), 461–484.
Darnhofer, I., Lamine, C., Strauss, A., & Navarrete, M. (2016). The resilience of family farms: Towards a relational approach. *Journal of Rural Studies, 44*, 111–122.
Daugstad, K., Rønningen, K., & Skar, B. (2006). Agriculture as an upholder of cultural heritage? Conceptualizations and value judgements—A Norwegian perspective in international context. *Journal of Rural Studies, 22*, 67–81.
Dennis, P., Fry, G. L. A., & Andersen, A. (2000). The impact of field boundary habitats on the diversity and abundance of natural enemies in cereals. In B. Ekborn, M. E. Irwin & Y. Robert (Eds.), *Interchanges of Insects between Agricultural and Surrounding Landscapes* (pp. 195–214). Dordrecht: Springer.
Eurostat. (2021). Farms and farmland in the European Union - statistics. Evolution of farms and farmland from 2005 to 2016. Retrieved from https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Farms_and_farmland_in_the_European_Union_-_statistics#Farms_in_2016
FAO. (2021). *In Brief. The State of Food and Agriculture 2021. Making Agrifood Systems more Resilient to Shocks and Stresses*. Rome: FAO.

Fjellstad, W., Dramstad, W. E., Strand, G.-H., & Fry, G. L. A. (2001). Heterogeneity as a measure of spatial pattern for monitoring agricultural landscapes. *Norsk Geografisk Tidsskrift – Norwegain Journal of Geography, 55*(2), 71–76. doi:10.1080/00291950119811

Fjellstad, W. J., & Dramstad, W. E. (1999). Patterns of change in two contrasting Norwegian agricultural landscapes. *Landscape and Urban Planning, 45*(4), 177–191.

Flatås, S., & Alisubh, T. (2021). I denne åkeren er gresset sådd med drone – kaller prøveprosjektet en suksess. Retrieved from https://www.nrk.no/trondelag/naspirer-gressfroene-i-norges-forste-dronesadde-aker-1.15523604

Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T., & Rockström, J. (2010). Resilience thinking: Integrating reslilience, adaptability and transformability. *Ecology and Society, 15*(4), 1–9.

Forbord, M., & Vik, J. (2017). Food, farmers and the future: Investigating prospects of increased food production withing a national context. *Land Use Policy, 67*, 546–557.

Gjerdåker, B. (2004). Continuity and modernity 1815–1920. In R. Almås (Ed.), *Norwegian Agricultural History* (pp. 235–293). Trondheim: Tapir Academic Press.

Grass, I., Batáry, P., & Tscharntke, T. (2021). Combining land-sparing and land-sharing in European landscapes. *Advances in Ecological Research, 64*, 251–303. doi:10.1016/bs.aecr.2020.09.002

Hillestad, M. E. (2014). *Transport i landbruket. Fylkesveier som like viktige stamveier* (Vol. 2). Oslo: AGRI Analyse.

Hillestad, M. E., & Bunger, A. (2019). *Kornhøsting i våtere klima*. Oslo: AgriAnalyse.

Hisdal, H., Vikhamar-Schuler, D., Førland, E. J., & Nilsen, I. B. (Eds.). (2021). *Klimaprofiler for fylker. Et kunnskapsgrunnlag for klimatilpasning*: Norsk klimaservicesenter.

International Fund for Agricultural Development. (2021). *Transforming food systems for rural prosperity*. Rome: International fund for Agricultural Development.

Johnsen, A. M. (2021). Eventyrlig vekst i salget av lokalmat i butikk, nedgang i storhusholdning. Retrieved from https://stiftelsennorskmat.no/no/aktuelt/salgstall-lokalmat-2020-2021

Jones, M., & Rønningen, K. (2007). Jordskifte og kulturlandskap. In Ø. Ravna (Ed.), *Areal og eiendomsrett* (pp. 371–390). Oslo: Universitetsforlaget.

Landbruksdirektoratet. (2022). Kraftfôrstatistikk. Retrieved from https://www.landbruksdirektoratet.no/nb/statistikk-og-utviklingstrekk/utvikling-i-jordbruket/kraftforstatistikk

Lunden, K. (2004). Recession and new Expansion 1350–1814. In R. Almås (Ed.), *Norwegian Agricultural History* (pp. 144–158). Trondheim: Tapir Akademisk Forlag.

Magurran, A. E. (2003). *Measuring Biological Diversity*. Oxford: John Wiley & Sons.

Manevska-Tasevska, G., Petitt, A., Larsson, S., Bimbilovski, I., Meuwissen, M. P. M., Feindt, P. H., & Urquhart, J. (2021). Adaptive governance and resilience capacity of farms: The fit between farmers' decisions and agricultural policies. *Frontiers in Environmental Science, 9*, 1–13. doi:10.3389/fenvs.2021.668836

McGarigal, K., & Marks, B. (1995). *FRAGSTATS: Spatial pattern analysis program for quantifying landscape structure* (Vol. 351). Portland: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

McKinnon, K. (2021). Lavverdiull til planteproduksjon – utprøving av ullpellets som gjødsel. Retrieved from https://www.norsok.no/prosjekter/2021/lavverdiull-til-planteproduksjon-utproving-av-ullpellets-som-gjodsel

Meld. St. 9 (2011–2012). *Landbruks- og matpolitikken. Velkommen til bords*. Oslo: Landbruks- og matdepartementet.

Meuwissen, M. P. M., Feindt, P. H., Midmore, P., Wauters, E., Finger, R., Appel, F., Spiegel, A., Mathijs, E., Termeer, K. J. A. M., Balmann, A., de Mey, Y., & Reidsma, P. (2020). The struggle of farming systems in Europe: Looking for explanations throught the lens of resilience. *EuroChoices, 19*(2), 4–11. doi:10.1111/1746-692X.12278

Meuwissen, M. P. M., Feindt, P. H., Spiegel, A., Termeer, C. J. A. M., Mathijs, E., de Mey, Y., Finger, R., Balmann, A., Wauters, E., Urquhart, J., Vigani, M., Zawalińska, K., Herrera, H., Nicholas-Davies, P., Hansson, H., Paas, W., Slijper, T., Coopmans, I., Vroege, W., Ciechomska, A., Accatino, F., Kopainsky, B., Poortvliet, P. M., Candel, J. J. L., Maye, D., Severini, S., Senni, S., Soriano, B., Lagerkvist, C.-J., Peneva, M., Gavrilescu, C., & Reidsma, P. (2019). A framework to assess the resilience of farming systems. *Agricultural Systems, 176*, 1–10.

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

Nicholas-Davies, P., Fowler, S., & Midmore, P. (2020). Telling stories – farmers offer new insights into farming reslience. *EuroChoices, 19*(2), 12–17. doi:10.1111/1746-692X.12279

Nordic Council of Ministers. (2020). *What Can the COVID-19 Pandemic Teach Us about Resilient Nordic Food Systems?* Copenhagen: Nordic Council of Ministers.

Norges Offisielle Statistikk. (1950). *Jordbrukstellingen i Norge 20. juni 1949. Første Hefte. Areal, Husdyrholdet M.V. Herrredvise oppgaver.* Oslo: Statistisk sentralbyrå.

Nysted, T. E., Uldal, S. H., & Vakse, I. (2020). Hva spiser norske husdyr – egentlig. In A.-K. Kjos, O. Nafstad, H. Odden, T. A. Ruud, T. Saltnes & M. Ytterdahl (Eds.), *Kjøttets tilstand 2020. Status i norsk kjøtt- og eggproduksjon* (pp. 6–11). Oslo: ANIMALIA.

Nyström, M., Jouffray, J. B., Norström, A. V., Crona, B., Jørgensen, P. S., Carpenter, S. R., Bodin, Ö., Galaz, V., & Folke, C. (2019). Anatomy and resilience of the global production system. *Nature, 575*(5), 98–108.

OECD. (2021). Policies for the future of farming and food in Norway. Retrieved from https://www.oecd-ilibrary.org/sites/177645e6-en/index.html?itemId=/content/component/177645e6-en

Olsson, E. G. A., Austrheim, G., & Grenne, S. N. (2000). Landscape change patterns in mountains, land use and environmental diversity, Mid-Norway 1960–1993. *Landscape Ecology, 15*, 155–170.

Potthoff, K. (2020). Endringer i norske jordbrukslandskap. In J. Aasetre & J. Cruickshank (Eds.), *Innføring i miljø- og ressursgeografi* (pp. 199–223). Bergen: Fagbokforlaget.

Potthoff, K., & Kopainsky, B. (in preparation). Norwegian low-intensity ovine and bovine farming systems – a reslience perspective.

Paas, W., Coopmans, I., Severini, S., van Ittersum, M. K., Meuwissen, M. P. M., & Reidsma, P. (2021). Participatory assessment if sustainability and resilience of three specialized farming systems. *Ecology and Society, 26*(2). doi:10.5751/ES-12200–260202

Reidsma, P., Meuwissen, M., Accatino, F., Appel, F., Bardaji, I., Coopmans, I., Gavrilescu, C., Heinrich, F., Krupin, V., Manevska-Tasevska, G., Peneva, M., Rommel, J., Severini, S., Soriano, B., Urquhart, J., Zawalińska, K., & Paas, W. (2020). How do stakeholders perceive the sustainability and resilience of EU farming systems? *EuroChoices, 19*(2), 18–27.

Rist, L., Felton, A., Nyström, M., Troell, M., Sponseller, R. A., Bengtsson, J., Österblom, H., Lindborg, R., Tidåker, P., Angeler, D. G., Milestad, R., & Moen, J. (2014). Applying resilience thinking to production ecosystems. *Ecosphere, 5*(6), 1–11.

Robotikkgruppen. (2021). Landbruksroboten Thorvald. Retrieved from https://www.nmbu.no/fakultet/realtek/forskning/forskergrupper/robotikk/prosjekter/thorvald

Rustad, L. J. (2020). Ferske tal om norsk sjølvforsyning. Retrieved from https://www.nibio.no/nyheter/ferske-tal-om-norsk-sjolvforsyning

Rønningen, K., Fugestad, E. M., & Burton, R. (2021). Path dependencies in Norwegian dairy and beef farming communities: Implications for climate mitigation. *Norsk Geografisk Tidsskrift – Norwegain Journal of Geography, 75*(2), 65–78.

Santurnino, M. B. J., Hall, R., Scoones, I., White, B., & Wolford, W. (2011). Towards a better understanding of global land grabbing: An editorial introduction. *The Journal of Peasant Studies, 38*(2), 209–216.

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

Selman, P. (2012). Landscapes as integrating frameworks for human, environmental and policy processes. In T. Plieninger & C. Bieling (Eds.), *Resilience and the Cultural Landscape. Understanding and Managing Change in Human-Shaped Environments* (pp. 27–48). Cambridge: Cambridge University Press.

Skaland, R. G., Colleuille, H., Andersen, A. S. H., Mamen, J., Grinde, L., Tajet, H. T. T., Lundstad, E., Sidselrud, L. F., Tunheim, K., Hanssen-Bauer, I., Benestad, R., Heiberg, H., & Hygen, H. O. (2019). *METinfo. Tørkesommeren 2018* (Vol. 14/2019). Olso: Meteorologisk institutt.

Smiley, J. (1997). Farming and the landscape. In J. I. Nassauer (Ed.), *Placing Nature: Culture and Landscape Ecology* (pp. 33–44). Washington, DC: Island Press.

Statistics Norway. (2021a). Arealbruk og Arealressurser. Tabell 09594: Arealbruk og arealressurser, etter arealklasser (km^2) (B) 2011–2021. Retrieved from https://www.ssb.no/statbank/table/09594

Statistics Norway. (2021b). Gardsbruk, jordbruksareal og husdyr. Tabell 03312: Jorbruksbedrifter (F) 1969–2020. Retrieved from https://www.ssb.no/statbank/table/03312

Statistics Norway. (2021c). Gardsbruk, jordbruksareal og husdyr. Tabell 06447: Husdyr, etter husdyrslag (K) 1969–2020. Retrieved from https://www.ssb.no/statbank/table/06447/

Statistics Norway. (2021d). Gardsbruk, jordbruksareal og husdyr. Tabell 06462: Jordbruksareal, etter bruken (dekar) (K) 1969–2020. Retrieved from https://www.ssb.no/statbank/table/06462/

Statistics Norway. (2021e). Gardsbruk, jordbruksareal og husdyr. Tabell 12658: Jordleie (K) 1969–2019. Retrieved from https://www.ssb.no/statbank/table/12658/

Stokka, T., Dramstad, W. E., & Potthoff, K. (2018). The use of rented farmland in an area of intensive agricultural production in Norway. *International Journal of Agricultural Sustainability, 16*(3), 243–254. doi:10.1080/14735903.2018.1471262

Stokstad, G., & Krøgli, S. O. (2012). *Størrelsen på jordstykker.* Ås: Skog og landskap.

Stokstad, G., Krøgli, S. O., & Dramstad, W. (2020). The look of agricultural landscapes – How do non-crop landscape elements contribute to visual preferences in a large-scale agricultural landscape? *Norsk Geografisk Tidsskrift–Norwegian Journal of Geography, 74*, 111–122.

Strand, G.-H., Svensson, A., Rekdal, Y., Stokstad, G., Mathiesen, H., & Bryn, A. (2021). *Verdiskaping i utmark. Status og muligheter* (Vol. Vol. 7, Nr. 175). Ås: NIBIO.

Svin. (2018). Her er Norges 23 griseslakterierer. Retrieved from https://svineportalen.no/her-er-norges-23-griseslakterier/

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

Vik, J., & Flø, B. E. (2017). *Scenarioer for norsk landbruksproduksjon. En snål rapport, et tverrfaglig eksperiment, og et diskusjonsgrunnlag* (Vol. 3). Ås: NIBIO.

Wellesley, L., Preston, F., Lehne, J., & Bailey, R. (2017). Chokepoints in global food trade: Assessing the risk. *Research in Transport Business & Management, 25*, 15–28.

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