Cultural lock-in and mitigating greenhouse gas emissions: the case of dairy/beef farmers in Norway

Abstract

Meeting targets for reducing greenhouse gas emissions from agriculture will require the implementation of effective mitigation measures. The Intergovernmental Panel on Climate Change (IPCC) has recently recognised that to succeed we need to understand more about the conditions within which mitigation measures are applied, and for this, they note, we need insights from social science disciplines including sociology. We addressed this knowledge gap by using the concept of path-dependency and lock-in to explore barriers to change in dairy/beef systems in Norway. A qualitative survey of 29 farms found that changing parenting, recreational and spousal role expectations are driving farmers towards intensification (and thus higher emissions) in order to purchase milking robots, which, in turn, provide increased time for the expected role changes. Structural change is thus predominantly directed towards farm continuity which is making it increasingly difficult to meet mitigation targets in the future. The study illustrates how mitigation measures might be made more effective by understanding and addressing the broader cultural/structural environment within which farmers and their families operate.

Introduction

Climate change is a societal problem that needs to be addressed by all sectors of society. Although concern remains predominantly focused on the use of fossil fuels, the continuing increase in greenhouse gas (GhG) release from the farming sector has led calls to reduce emissions from agriculture – and particularly livestock farming – to become increasingly urgent (Richards et al., 2018). However, government led agricultural mitigation measures have so far proved ineffective – with Grosjean et al. (2018) going so far as to suggest that within Europe the potential for agriculture to contribute to emissions reduction is both unexploited and dormant. Whether it is "dormant" or not is debateable, but mitigation measures certainly do not appear to be well organised. Howlett (2014) contends that what we have witnessed from governments so far (in agriculture and other sectors) has been a pattern of largely symbolic activities based on small scale projects and experiments, but all within an overall framework of limited procedural response. Little has been done to scale up experiments, and little has been done to coordinate policies.

One of the problems with mitigation according to the IPCC's Fifth Assessment Report Working Group III is that there is still no consensus on which measures are most effective in "real world" contexts (Victor et al., 2014, p. 114). The report identifies this as a "knowledge gap", observing that mitigation analysts have just begun examining how mitigation costs and feasibility might be compatible with the practical realities on farms and in wider society, and that, addressing these issues will require the "integration of insights from a wide array of social science disciplines".

We contend that one of the key issues for mitigation is that the “real world” context within which mitigation measures are applied is currently a difficult one for farmers as they struggle with survival in an industry that, for many, is only marginally profitable (European Commission, 2010). However, critically, this is not the only issue. In addition, farmers are facing the challenge posed by the changing social and cultural expectations of wider non-agricultural society that are, inevitably, pulling agricultural communities to adapt to those changes.

A good example of this is changing gender roles as male farmers are increasingly expected to participate in caring for children rather than focusing purely on agricultural work (Brandth and Overrein, 2013; Brandth, 2019). At the same time, both farmers and their spouses have different lifestyle goals, with expectations of, for example, more leisure time (holidays from the farm), better quality housing, and more independence from the previous generation than has been the case in the past (e.g. Thwaites et al., 2008; Burton, 2018). Adding further pressure are broader changes in social structures and institutions. In particular, it has become increasingly common in the case of divorce for property to be divided evenly between husband and wife, meaning marriage breakups have become a threat to the survival of the farm (Haugen et al., 2015). That farmers across Europe are dealing with similar issues can be seen in the fact that farmers in many countries are struggling to find successors to take over the farm – raising questions for the continuity of agriculture in some regions (Burton and Fischer, 2015).

Although these social and cultural changes may be seen as isolated from climate mitigation measures, in this paper we argue that this is not the case – but rather they represent a neglected sociological “real world” context within which mitigation approaches must be applied. This paper, which explores this issue, is structured as follows. First, we present a brief outline of the concept of path dependency and “lock-in” in agriculture – particularly focusing on the issue of why it may be a useful concept in sociology when addressing questions of climate change. Next, we outline the methodology behind a qualitative study of 29 dairy/beef farms in two regions of Norway. The results are then analysed, focusing on an exploration of how changing lifestyle expectations are locking dairy/beef farmers into productivist approaches to agriculture that, in turn, affect their ability to mitigate climate change. Finally we discuss the implications of our findings and particular the need for understanding the broader social and cultural context within which mitigative measures are implemented.

Lock-in in agricultural systems

This paper emerged as part of a larger interdisciplinary project, where the objective was to explore local path dependencies within the dairy/beef system (as a basis for an agent-based modelling exercise). As such, our study was carried out within the frames of interdisciplinary theory on sustainability transitions, based on the idea and concept of pathways (development trajectories) (Rosenbloom, 2017). The theoretical pathways/ transition approach yet has to fully embrace social practice and lifestyle considerations, in favour of more rational-economic understandings of human behaviour (Rosenbloom, 2017). However, our explorative study of path dependencies and lock-in[1], based on data collected at the farm level, led to certain findings that encouraged this paper to combine transition concepts and various sociological lifestyle-related literature. Throughout the paper we will demonstrate how this brings valuable insights to the research field on low-carbon transitions within agriculture.

Our particular focus was on the concept of lock-in. While “lock-in” has not been widely applied within general sociological studies as a conceptual framework, it has been used extensively by historical sociologists (Mahoney, 2000) and is frequently used to examine the relationship between society and structural (particularly technological) change. For example, Feyereisen et al. (2017, p. 312), writing in this journal, use transition theory to observe how existing power structures within the dairy system in Belgium lock it in to a productivist approach and, in doing so, limit the agency of actors to establish an alternative. The authors note that

> The identification of lock-ins within transition studies is a key point for understanding what prevents the transition of a system, and how it could be possible to unlock the possibility of such a transition.

The use of lock-in has also been strongly advocated with respect to understanding the social causes of climate change. In particular, sociologist John Urry (2010, 1) observes,

> in order to overcome the problems of this high carbon world it is necessary to bring about a wholesale shift to an interlocking set of low carbon systems – this involves establishing and examining the sociological characteristics of such a low carbon “economy-and-society”.

Thus, Urry suggests that understanding the role of sociological factors in interlocked high carbon systems is an essential step to engendering a societal shift towards low carbon systems.

A common perspective in the study of climate change is that human behaviour is part of a well-developed system formed by an alignment of technologies, regulations, institutions, and cultural discourses that link them together (Geels, 2004; Unruh, 2000). Geels (2004) termed these systems “socio-technical regimes” and contended that they create deep-structural rules that guide actors’ perceptions and actions – social and cultural lock-ins. Once established, these systems can be exceptionally difficult to change as barriers to cultural change are common, subtle and powerful (Allenby, 2012; Geels, 2004). For example, Allenby (2012, p. 2) observes that integrated technical, social, cultural, institutional and psychological systems “reinforce cultural patterns and activities that may be easily seen as suboptimal but are highly resistant to change, even when most participants recognize such a need”.

Many studies of lock-in focus on structural and institutional factors, however, culture can play an equally important role. A well studied non-agricultural example in the literature is the lock-in of car use by factors such as urban sprawl, favourable policies, investment and the lax regulation of development which make removing the car from society exceptionally difficult (O’Mahony et al., 2013). However, with over a century of car use a “car culture” has also emerged. Use of the car for social purposes such as leisure activities, work, and attending social gatherings, has led to the car becoming tied to “patterns of kinship, sociability, habitation and work” and deeply involved in “affective and embodied relations between people, machines and spaces of mobility and dwelling” (Sheller, 2004, p. 222). Consequently, the cultural importance of the car is now such that access to a private vehicle is seen by some as an inalienable human right (Urry, 2004).

Research into farmers' climate change mitigation is beginning to investigate system lock-in. For example, Mylan et al. (2015, p. 27) observe that attempts to develop an innovation system for nitrogen efficient wheat varieties are made difficult by a lack of demand from farmers who face "institutional lock-in to the 'recommended list' of seed varieties". Similarly, Stuart and colleagues (Stuart, 2018; Stuart et al, 2014; Stuart and Schewe, 2016) contend that farmers in the US are institutionally "locked-in" to productivism through corporate control of the agri-food system. In their case, farmers were willing to undertake measures to mitigate climate change, but only so far as they did not contradict the (institutionally led) productivist ideology – leading the authors to conclude that structural lock-ins play a significant role in limiting the mitigation of climate change. Beudou et al. (2017) examined how cultural services locked farmers into particular livestock systems in France. Cultural factors such as festival events that were centred around the livestock, the symbolic value of the breeds, the cultural landscapes associated with the breeds, and local products of cultural heritage importance locked farmers into the system and prevented agro-ecological transition.

Our investigation explored, among other aspects of lock-in, whether social and cultural changes such as those raised in the work by Brandth (2019) and Haugen et al. (2015) were limiting the adoption of mitigation technologies in the beef/dairy sector. It is important to note that the path dependencies in this case are not caused by the stability of the socio-technological system itself, but by a lock-in to social goals of ensuring farm family continuity – long a key objective of farming families (e.g. Flemsæter and Setten 2009; Fischer and Burton, 2014; Glover, 2014). This lock-in, we argue in the paper, pushes farmers down an intensification (productivist) pathway that leads to investment in the development of farming systems that can be unfavourable to the introduction of climate mitigation practices. "Lock-in" in this sense does not mean that structural aspects of the system are unchanging – in fact, as we argue considerable changes are underway – but that these changes are intended to maintain system stability (the stability of the farm family and production) rather than to challenge it (as is the case in other studies of agricultural lock-ins, as witnessed by Feyereisen et al., (2017)).

Methodology

We examine this issue through an empirical exploration of Norwegian dairy/beef[2] farming. The dairy/beef sector was chosen for a number of reasons, namely: the sector is currently under pressure to cut its emissions (Ministry of Agriculture and Food, 2008-2009; Ministry of Climate and Environment, 2011-2012), dairy/beef farmers are being encouraged to increase domestic production (Ministry of Agriculture and Food, 2011-2012), and the importance of dairy/beef production for many Norwegian rural communities (Almås, 2004). Norway is an interesting case. The discovery of oil in the 1960s enabled the government to provide substantial subsidies to maintain small agricultural producers (Olsson et al., 2011) while, on the other hand, creating a generation of farmers with many more career choices than was historically the case (Brandth and Overrein, 2013). Consequently, it is difficult to attract farmers to enter or remain in agriculture in Norway, as is evident from over 24,000 active holdings becoming non-active between 1999 and 2010 (Forbord et al., 2014).

Twenty-nine semi-structured interviews (both with individual farmers and farm couples) were conducted with dairy/beef farmers in two regions of Norway: 17 in Namdalen in Central Norway and 12 in Jæren in Southern Norway. As important dairy/beef production regions with active farming communities, mitigation in these two regions could contribute significantly to reducing emissions in the future. For logistical reasons, the sampling framework for the survey was drawn from two geographically separate municipalities from within each region. Lists of dairy/beef farmers were provided by municipal agricultural offices. These lists included information about farmer's gender, the number of milking cows, and whether the farmer was farming jointly with another farmer (a relatively common practice for dairy farmers in Norway) or not – enabling us to ensure that farmers in variety of different social and economic situations were contacted.

Fifty farmers from each municipality were sent a letter providing a summary of the project and requesting an interview – as well as a short questionnaire asking for more detailed information on the farm to enable us to (a) further define the farmers selected for the sampling frame, and (b) ensure that we obtained basic structural data for each farm. This recorded gender, age, marital status, allodial status (yes/no), crop land area, furthest distance to crop land, distance to nearest town, number of milking cows, milking robot status (yes/no), and the probability the farm will still be in dairy production in 10 years' time. From this process we were able to arrange 23 interviews. To obtain the remainder of the sample we used a snowballing or "chain referral" (Salganik and Heckathorn, 2004) approach to recruit interviewees for a second round, asking first round interviewees if they knew of potential survey participants that met the required criteria. This resulted in a final sample of 37 farmers from 29 farms (including eight couples), where the farms were staffed by the household members in different ways, as shown in table 1. The age of the farmers ranged between 30 and 64.

Table 1 to be placed about here

An interview guide was constructed with the primary objective of identifying potential social and structural lock-ins into their current mode of production. To achieve this, the interviewer focused not only on the farmer's management strategy, but also on why they were following that particular course of action and what considerations facilitated or restricted choice. This was because of the importance of focussing on actors and choices in matters of lock-in, since to understand lock-in requires developing an understanding of the situations within which actors frame their options and make their decisions (Popp and Wilson, 2007). Interviews were recorded and transcribed verbatim, before being analysed using NVivo employing a 'cross-sectional code and retrieve' approach, where a common system of conceptual and analytical categories is applied across the data set to enable the search and retrieval of labelled data (Spencer et al., 2003).

While farmers were aware the study was on mitigation response to climate change, the issue of climate change was not the focus of the questionnaire. Our primary objective was to understand how the farming system functioned in order to identify lock-in because, as many of the management responses to mitigate GHG levels are also good practice in agriculture (e.g. Moran et al., 2011), we wished to avoid enhancing the opportunity for climate change to be promoted as a rationale behind decision-making over business decisions. In addition, an earlier representative survey indicated that only 2% of Norwegian farmers had taken mitigative measures against climate change and only 15% believed Norway's agricultural GHG emissions were too high (Brobakk, 2018)[3], which suggested that specific questions on climate change mitigation would be unrewarding. Instead, farmers were provided the opportunity to state climate change mitigation as a rationale behind decision-making but were neither encouraged to nor discouraged from doing so. Towards the end of the survey we asked how potential national, already publicly debated, regulations for a more climate-beneficial agriculture would affect their farm, to further reveal their thoughts around the issue of climate mitigation.

Analysis of Norwegian dairy/beef farming systems

Productivist strategies and a lack of tradition

Farmers in our survey predominantly maintained a production-oriented perspective on agriculture (also found by Brobakk, 2018), with a focus on achieving productivity and economic goals rather than farming for traditional reasons[4]. Norway does have tradition-oriented dairy farmers. Norbye (2018), for example, observes that dairy farmers in her study (in Hemsedal) viewed traditionality as an important factor in being seen as a “real farmer”, i.e. the following of old customs of summer grazing was seen as positive despite it being time consuming and economically unrewarding. However, both our study areas had active farming communities with a relatively strong commercial focus and fell outside traditional summer farm regions. In our study areas, farming has increasingly found itself positioned within a social and economic milieu based on quite different employment/lifestyle expectations, and where continuation of long-held practices are decreasingly valued.

For most farmers in the survey the strategy for maintaining profitability was focused on building existing production. There were two reasons for this. First, all interviewees had taken over or bought farms with established infrastructure for dairy/beef production, which made boosting dairy/beef production an easy strategy for increasing profitability. Second, some of the farms were only suited to grass production, and were hence compelled to follow a dairy/beef production strategy (with sheep being less remunerative). Choices of herd management approach were also structurally constrained.

In particular, the size and qualities of the cowshed and availability of arable land determined the extent of dairy production and the degree to which farmers were able to raise bull calves to maturity for meat. In this way, the key driver of the farm development pathway was a combination of the desire of farmers to enhance profitability and the material resources available on the farm – which together acted to lock farmers into a dairy/beef development strategy.

While most farmers wanted to develop their farms further, certain conditions made expansion or modernisation difficult. In particular, the lack of accessible land at a manageable distance for expansion limited the size of dairy/beef production, as land area available determines both milk quota size and the number of milking cows. These in turn affect farmers' ability to finance potential cowshed improvements. Many of the interviewees reported difficulties gaining access to additional land a manageable distance from the farm and were not willing to drive long distances as the travel costs and time considerations made profitability marginal (see Forbord et al., 2014, for a discussion on land fragmentation in Norway). Overall, many structural conditions affect the opportunities available for further farm development, but, in general, farmers managed their farms in a manner that tried to first optimise the use of existing resources.

The role of tradition and social norms in determining the trajectory of farm development was limited but not entirely absent. In particular, farmers' strategies were often driven by a desire for the farm to be passed on to the next generation. For example, a male farmer from Jæren noted:

> I think that previous farm managers also had to make a living from this farm based on its land. However, I don't feel what they did is something that constrains me to a significant degree. I believe anyone who has been a farmer thinks it is nice that there is someone who carries on the business. (male farmer, Jæren)

The lack of emphasis on tradition meant farmers within our study did not feel a significant peer pressure from within the farming community. Consequently, we concluded that norms within the local work environments, farming traditions, cultural resistance to change, or emotional attachment to farming in general did not constitute a significant lock-in to farmers' decisions concerning activities on and the development of the farm.

The arrival of the milking robots

Production intensification was achieved mainly through the installation of a milking robot (or automated milking system – AMS). The arrival in Norway of milking robot technologies in 2000 (Ministry of Agriculture and Food, 2016-2017) facilitated radical change in Norway's dairy/beef farms, but in a way that built on existing production-based development trajectories. In part, the success was fortuitous. Most milking robots are designed for a capacity of around 60 cows – a size that fits particularly well with the relatively small herds common in Norway (Hansen and Jervell, 2015). Norway now has the highest share of dairy farms with AMS in the world, and within few years it is anticipated that half of all milking cows in the country will be milked by robots (Ministry of Agriculture and Food, 2016-2017). Estimates of the efficacy of AMS suggest a labour saving of between 18% and 38% and an increase in milk production of between 2% and 20% over conventional milking systems but, because of the higher fixed costs of AMS, profit margins are almost identical (Bijl et al., 2007).

The majority of farmers in our survey (the exceptions being those with very few cows) had already invested or wanted to invest in AMS technology. Purchasing an AMS system in Norway costs more than $US 150 000 (Almås, 2018), but many farmers also need to rebuild or remodel their cowsheds to be able to install and utilise the system. To raise the necessary capital farmers had to enhance the profitability of their farms which, given the constrained land availability, existing infrastructure and limited production options, was generally achieved by increasing productivity rather than changing the farming system. One of the male farmers from Jæren, who recently had invested in a cowshed with an AMS, described the strict requirements for increased profitability following from such an investment:

> It is quite constraining, because it is a high debt. So now I have to obtain good results and pay off on the debt. So that is what is at stake, to get the debt under control.

Several interviewees reported that it is easy for farmers to get a loan from the bank in Norway nowadays, as long as they can demonstrate that they are able to increase their income by a suitable degree. What stands out as very clear, is that the AMS investment is not a strategy to increase profit, but rather increased production and profitability are a necessary condition to enable these technological investments to be made.

Intensifying production for a better work-life balance?

The critical question here, is why take on the additional work involved in intensification to be able to invest in an AMS if there is no financial advantage to doing so? Previous studies have suggested that productivism in contemporary agriculture has been driven either by the pursuit of profit (e.g. Walford, 2003) or the desire to generate culturally valuable symbols of "good farming" (e.g. Burton, 2004). However, in our study the motivation for increasing productivity was neither monetary gain nor to demonstrate "good farming", but for the purpose of pursuing lifestyle goals. For example, one farmer currently intensifying production on the farm observed:

> Now we are much more flexible in the cowshed. You don't have to be there at 6 o'clock in the morning, nor at 4 o'clock in the afternoon. You can be there around 2 o'clock and 7 o'clock instead, it is not important anymore. […] The cows fix it themselves. I haven't regretted this for one single day. Before the robot I could never join the children's activities. It was always in conflict with my time in the cowshed. Today, I have these opportunities. (male farmer, Namdalen)

Another farmer with an AMS commented likewise:

> What I really appreciate now is that the afternoons, around four-five o'clock, have become valuable hours to us. When the children come home for dinner nowadays, we don't have to walk out to the cowshed before half past five, while previously we had to be there at four o'clock. So this is so much better, because everyone comes home for dinner once a week. (female farmer, Jæren)

AMS thus allow for a more normal family life, where the farmer is not stuck in the cowshed at specific times of the day that coincide with important family times. This is driven in part by cultural change. Brandth and Overrein (2013) observe a difference in parenting between older generations and the current generation in Norway, with the younger farmers practicing childcare within the cultural norm of “intensive parenting”, i.e. unlike previous generations, young farmers wished to spend time with their children. In our study, cowshed work was clearly interfering with this activity.

Farmers without families also focused on the lifestyle advantages of AMS, in particular the opportunities for more flexible weekdays, such as this farmer, who was in the process of constructing a new cowshed with AMS

> I was thinking, either I have to end this project, or I have to develop the farm. It wouldn’t have worked 10 …15 … 20 years more in the way it is here now. It’s just personal, I cannot stand the thought of continuing working this much for the next 10 years. […] I have other values in life than just work. I need time to do other things than just milking. (male farmer, Jæren)

This quote illustrates how important it has become for farmers to achieve lifestyle goals other than those based around the farm (unlike older generations of Norwegian farmers – Brandth and Overrein, 2013). The milking robot represents a solution to farmers’ efforts to find a better work-life balance, i.e. providing both quality of working life and private life (Guest, 2002). In some cases a better work-life balance was also perceived to contribute to the physical health of the farmer. Two farmers without a milking robot reported poor health as a result of the physical strain caused by conventional milking machines. Another farmer who had health issues prior to installation noted that the AMS had saved his shoulders from the constant pain caused by conventional milking (also see Stræte et al., 2017).

The benefits of AMS for family life, lifestyle, and health noted in this study are not restricted to the Norwegian case. Even in the early years of implementation, Mathijs (2004) observed that 67% of European farmers surveyed gave the same social reasons as we outline here as the most important reasons for adopting AMS. In Norway, research has repeatedly shown that farmers value the technology predominantly because it offers greater time flexibility that can then be used in their social and family lives (Hansen, 2015; Hansen and Jervell, 2015; Jacobs and Siegford, 2012; Norbye, 2018; Stræte et al., 2017). Thus, as we contend above, AMS is not a technology implemented as part of a strategy for productivity/profitability gain, but one that predominantly serves to bring dairy farming more in line with the lifestyle expectations of today's generation of farmers and non-farmers.

Farmers also recognised the installation of AMS as a measure necessary to attract the next generation of farmers onto the farm. Placing it in the context of Fischer and Burton's (2014) endogenous succession cycles, the investment in AMS appears to play an important role in the co-construction of a succeedable family farm and a related successor identity. For example, a male farmer from the Namdalen region observes:

> It would be great if the next generation wants to continue. That is one of the reasons why I have made this [AMS] investment (…). They must see that there is development going on here, all the time, so that they know the work is becoming easier and easier, and so they see that, "now, we are farming in a very modern way". And they can see that, "today, we will go to the cowshed at 2 o'clock since there is a party at 5 o'clock – that's no problem". (male farmer, Namdalen)

Another farmer, who was in possession of too little arable land to develop the farm and therefore wanted to go into joint farming with the neighbour in order to modernise the cowshed, likewise shared his concern for poor succession prospects if he failed to modernise his operation with an AMS:

> The way I see it, if I continue farming the same way as now, just maintaining it as it is, then I don't think the children will be interested in taking over. But if we go into joint farming with the neighbour it will suddenly be more interesting, because then they will see that the farming is more modern, but also easier, because you actually will get some leisure time. (male farmer, Namdalen)

This generational shift in Norwegian farmers' lifestyle expectations has been observed in earlier literature. Villa (1999) suggests the change occurred at turn of the 21st century, with farmers' children no longer willing to live a life constrained by economies and social expectations while, at the same time, women marrying into farming were unwilling to accept the traditional roles and gendered opportunities agriculture had previously provided (Brandth, 2002). Failure of a husband to spend time with the wife and family or a lack of leisure time could be grounds for divorce (Haugen and Brandth, 2017) – something that, while in the past unthinkable, has become increasingly common across Europe (e.g. Haugen et al., 2015 – Norway; Shortall, 2017 – Ireland). Maintaining farm transfer has thus become a matter not just of making the farm profitable but of providing an acceptable "modern" lifestyle and, for dairy/beef farmers in Norway, this means purchasing an AMS.

Not having a robot has become problematic. Some of the farmers in the survey were unable to purchase an AMS as a result of having too much debt to borrow the additional capital required to invest in enhancing production (i.e. purchasing the cows, land, quota *and* a new cowshed/robot) or being constrained by factors such as uncertainty of succession or risk aversion. With the expected "role" and lifestyle of a dairy/beef farmer changing, failing to keep up with the trend creates a feeling of relative deprivation (Runciman, 1966). As a female farmer from Jæren observed:

> I would like to have a robot. Then we would have been more flexible. Maybe some more spare time, and easier to get a relief worker in the future. Maybe somewhat more attractive. (…) Most of them we know, they've got a robot, and that bothers us a bit.

In summary, this section illustrates how redefining the roles of dairy/beef farmers around the AMS technology is creating a situation whereby failing to install an AMS system makes it problematic to continue dairy/beef farming. The opportunities to meet contemporary lifestyle and gender role expectations both provides for the continuation of the farm and, in cases where installing an AMS is not possible, places increasing pressure on the remaining farmers to do likewise. Changes to wider cultural expectations can thus have implications for climate change mitigation as the following section outlines.

The implications of farm structural change for GHG mitigation

The radical restructuring of the dairy/beef sector currently around the AMS technology is likely to have major implications for Norway's ability to reduce sectorial emissions. While improved productivity via improved efficiency can reduce GHG emissions there are three issues associated with the restructuring of the sector to meet lifestyle goals that could lead to higher emissions becoming locked in to future dairy/beef production in Norway.

First, to finance a robot, farmers generally need access to additional land for fodder production. This is problematic for a number of reasons including complex land purchasing mechanisms in Norway and an unwillingness to sell farmland (Forbord et al., 2014), strong competition for land from neighbouring farmers (Stokka et al., 2018), and even competition from non-agricultural land uses (e.g. Vinge, 2018). As a result of the difficulties of purchasing land, the most common means of increasing farm size is to rent (Forbord et al., 2014; Stokka et al., 2018). However, nearby rental land is often unavailable and fails to offer the same level of financial security for farmers. Thus, despite the difficulties involved, many farmers have resorted to developing unused peatland on their farms – an action that leads to the increased emission of GHGs (Oleszczuk et al., 2008; Regina et al., 2016)[5]. A preventative ban on the conversion of peat land was then under consideration by the Norwegian government (Ministry of Agriculture and Food, 2017) and created considerable concern for dairy farmers[6]. Those who were about to implement an AMS system were extremely negative towards any ban on peatland cultivation. The female farmer of a farm couple in Namdalen who wanted to invest in AMS, was afraid of such a ban:

> Then there would be no hope anymore, then there would be nothing here. Because we have nothing but peatland left to cultivate. We have nothing else to use.

The male farmer further explained how they were dependent on having the opportunity to cultivate their peatland gradually, because they had neither the time nor resources to cultivate all the land needed at once. Although peatland soil is recognised as being more difficult to cultivate than other soils and farmers were aware of the environmental implications, many saw this as their only means of developing the farm.

A second consequence of the land shortage was that farmers who had both grass and cereal production stopped cereal production in order to produce more coarse fodder in the necessary volumes to supply the more intensive dairy production. This frequent development can be illustrated by the following quote from a male farmer from Namdalen, who was about to invest in AMS:

> I have had grain production in addition to the cows. However, there will be less grain now, when we are going to extend the cowshed [i.e., the dairy production].

Conversion of arable land to fodder production has implications for GHG emissions. As a global average, the production of 100g of protein from a dairy/beef herd leads to the release of 17kg CO2e while, in comparison, 100g protein from grain/cereal production averages out at 2.7 kg CO2e (Poore and Nemecek, 2018). At the same time, higher grain production in Norway reduces the need for imports, consequently reducing the transport related emissions that accompany it. Norway has a very limited area of land environmentally suited to grain production (Ministry of Agriculture and Food, 2016-2017) and, in order to maintain production, the Norwegian government provides cereals with a subsidy advantage. Our data suggests, however, that the need to meet lifestyle goals more than compensates for the higher subsidies offered for grain – and despite there being no financial advantage to installing milking robots.

A third issue relates to the location of available land for expansion and the increasing distances farmers need to travel. The additional fuel needed to move machinery across greater distances is one reason why this is likely to increase GHG emissions, but not the only reason. The amount of time spent travelling also affects the amount of time farmers have to apply climate mitigation soil management techniques.

Spreading manure along the ground in strips (band spreading) or injecting it into the soil (slot injection) is recognised as more beneficial to climate than using a manure spreader (broadcast spreading) (Stoate et al., 2009). Consequently, Norwegian regional governments are encouraging the use of an *umbilical system* for manure application. In this system a transport hose is used to feed liquid manure from the manure store to a self-propelled in-field applicator with trailing hoses[7] (Sørensen, 2003) set up behind a smaller tractor. Trailing hoses allow band spreading, and the umbilical system allows the manure to be conveyed directly to the field, eliminating the need for heavy transport with tankers that can lead to soil compaction (Sørensen, 2003) – another cause of enhanced GHG emissions (Monteny et al., 2006). However, several farmers pointed out that process is difficult if the land is not on or adjacent to the main farm. When asked how he would be affected if the umbilical system were made compulsory on dairy farms one farmer with a 6 km drive to the most distant crop field, replied:

> That is very difficult when it comes to rented land distant to the farm. You first have to drive with a truck to get the manure to the land, and then use the band

> spreader from there. To spread with a regular manure wagon would be most efficient. If you have to transport the manure with a truck, that will be expensive, and then you end up not giving a damn and putting on fertiliser instead. (male farmer, Namdalen)

Another farmer, with a 4km distant crop field, responded likewise:

> I have considered buying one, but haven't done it yet. I only have a regular broadcast manure spreader. That is what I chose, since I also have about 10 hectares located some distance away from the farm, and there the use of umbilical spreading is impossible. (female farmer, Namdalen)

Additional costs, difficult logistics and increased working hours – where farmers are actively attempting to reduce working hours – thus conspire against the use of the climate friendly umbilical system where the cropland does not adjoin the farm, a finding validated by the national agricultural advisory service (Norsk landbruksrådgivning, undated).

Where farmers were taking actions that may mitigate climate change, these appeared to be inadvertent and associated with efficiency gains in agriculture rather than specifically addressing climate change. For example, several farmers mentioned that they wanted to optimise the use of manure and fertiliser – not because of the consequences for increased emissions – but because overuse of fertiliser is an inefficient use of farm resources. The main reason for not ploughing peatland, as noted above, was because it is labour and time intensive, while cultivating land closer to the farm was preferred because it limited the time and resources necessary for management – not for any reason of mitigating GHG emissions. Even the umbilical manure system promoted for its use in mitigating climate change was employed principally for the purpose of enhancing yields via more efficient manure distribution. The same desire for efficiency (noted in the introduction as one way of addressing GHG emission) will doubtlessly also be applied to the systems restructured around the AMS, however, if the system itself inherently produces higher levels of GHG emissions a focus on the structure of the faming system itself is also necessary.

Discussion and conclusion

Norwegian dairy/beef farmers are currently restructuring in a manner that is unlikely to promote mitigation of climate change. A superficial analysis might suggest they are doing this in order to generate additional income, but our analysis of the wider farm system illustrates how the underlying driver is changing lifestyle expectations. Intensification is simply a means of purchasing an AMS, and an AMS is a means of creating a farm that supports the expectations of the current generation of Norwegians, in particular, freeing up time for the family at critical times of the day and providing for more leisure time. We contend that this interaction between the social/cultural needs of the farm family and the structural formation of the farm has an influence on GHG emissions by encouraging farmers to plough up peatland, produce a higher proportion of animal protein, and/or rent land at a distance from the main farm – thus making it difficult to install low GHG emission manure spreading technologies.

It is important to acknowledge that our study did not measure emissions from the dairy/beef system, but was rather focused on the question of cultural/structural lock-ins and inference on emissions was drawn from this. A full analysis would need to look across a wider variety of system changes – for example, the effect of any change of diet on emissions from enteric fermentation (e.g. Jayasundara et al., 2016) or the means by which manure is stored prior to spreading (e.g. Aguirre-Villegas and Larson, 2017). Here we have picked out some of the more obvious areas where AMS will enhance the emission levels of dairy/beef farms. We leave a more comprehensive analysis of the overall GHG output and final judgement to researchers with a different set of skills. However, the point we wish to establish is that climate change must be addressed not only by improving the efficiency of technologies, educating framers, or introducing market mechanisms, but by addressing the broader social (non-economic, non-technological) drivers of change in the agricultural sector.

The implications of this study extend beyond Norway. The global market for milking robots is expected to grow at a combined annual growth rate (CAGR) of 11.8% between 2014 and 2025 (Million Insights, 2018) and, if the switch to milking robots has similar effects outside Norway, this issue should be a major focus for climate change mitigation studies. However, it attracts almost no attention. The use of academic search engine "hits" provides a means of assessing the extent to which an issue is receiving attention in the scientific literature (e.g. Bezlepkina et al., 2011). A search of one of the main academic search engines SCOPUS using separately the terms "milking robot", "robotic milking system", or "automated milking system" combined with "climate change" or "greenhouse gas" returned only two hits – neither of which related to the impact of the rapid increase in milking robots on the ability of the industry or government to control GHG emissions. In light of the findings presented here, this could be a major omission. Why are we not seeking to understand the climate change impact of transitions such as these and, importantly for mitigation, addressing the question of whether there is some alternative means of assisting farmers to meet their lifestyle goals and thus prevent such system changes?

Ours is not the first study to suggest the need for understanding structural influences on intensive farming systems in order to mitigate climate change. In particular, Stuart et al (2014), Stuart and Schewe (2016) and Stuart (2018) observe that farmers in the US were “locked in” to productivism through the control of the agri-food system. In their case, farmers were willing to undertake measures to mitigate climate change, but only so far as they did not contradict the productivist ideology – leading the authors to conclude that structural barriers play a significant role in limiting the mitigation of climate change.

We add to this understanding of structural lock-ins by observing how it is not just power structures within the agricultural sector that influence production-oriented behaviours, but also the social structures outside of the agricultural sector, as well as material structures. The question is, what can be done to resolve these cultural/structural lock-ins? Stuart and Schewe (2016) suggest either companies could encourage farmer participation in mitigation measures, or governments us anti-trust measures to break down the concentrated power held within the agri-food sector. This would enable, they contend, farmers to form contracts with companies that did not discourage the adoption of environmental practices. Norwegian studies have also suggested solutions to enhancing GHG mitigation in agriculture. Both Flemsæter et al.’s (2017) and Brobakk’s (2018) studies of farmers’ response to climate mitigation measures suggest that the solution lies in public sector support – in Brobakk’s case through economic support or higher prices for food, while Flemsæter and colleagues suggest policy-based initiatives should “look beyond the traditional toolbox of regulatory and economic policy instruments” (p.14) to turn farmers into "climate citizens". In both cases the solution is one or a mix of regulation, economic incentives and/or attitudinal change.

However, this would not work in the case of dairy/beef farmers. Market mechanisms would be unlikely to solve the issue directly because the main lifestyle concern of farmers was not for their income level, but the time-consuming nature of conventional milking and the way this conflicted with their expected roles as fathers and husbands. Making farmers pay for carbon emissions would simply make the change more difficult, while any measure regulating or paying farmers not to plough up peatland (e.g. the Voluntary Carbon Farming Initiative in Australia) would need to first resolve the problem of land availability. Likewise, educating farmers on climate change mitigation is unlikely to have changed many farmers' decisions as they are faced with a stark choice of adopting an AMS system or ultimately exiting agriculture. Improvements to technology also may not enhance mitigation. While regional authorities are encouraging the use of an umbilical system for the application of manure, if farms are restructuring in a manner that makes these technologies unsuitable, it is unlikely they will be efficacious.

Neither can the problem be addressed by cultural change. Besides decision-maker's reluctance to engage with measures that foster lifestyle change (Axon et al., 2018) it is neither feasible nor desirable to lower lifestyle expectations or change the social/family roles simply to meet climate goals. The question for policy-makers therefore, is how can we help farmers to meet lifestyle goals in a manner that supports the application of the improved mitigation approaches? One possible approach is to first address the difficulties of land transfer – which both formed the key motivation for acts of intensification (ploughing of peat land) and, via the effect on land fragmentation, promoted the failure to install "climate friendly" manure application systems. Therefore, the first step in promoting mitigation measures in Norway may be to facilitate the consolidation of farm land into single units. Some measures could be relatively easily implemented – for example, providing assistance to help buyers and sellers of land communicate and plan ahead for land consolidation rather than transferring the land on the basis of family connections as is often the case (Forbord et al., 2014). Perhaps more effectively, removing legal and regulatory obstacles to land transfer lies entirely within the capability of the government and could have a significant impact on farm structure. In order to apply seemingly unrelated measures such as these we believe we need to know more about cultural/structural lock-ins within farming systems. Consequently, we re-emphasise the IPCC's observation that more work is required on understanding how mitigation actions work in the "real world" and their call for "insights from a wide array of social science disciplines" (Victor et al., 2014, 114).

Notes

1. The concept of "lock in" is widely used in studies of socio-technological and other complex social-structural systems to describe a range of forces that hold the system together such as economies of scale, sunk investment, shared beliefs and discourses, power relations, and consumer lifestyles and preferences that have become adjusted to the system. Together these create path dependencies that make it difficult for change to take place (Geels, 2011).
2. The term dairy/beef is used because the most popular cattle breed in Norway, the Norwegian Red, is used for both milk and meat production.
3. Note that while this post-dates our survey, this paper is an English reprint of an earlier paper published in Norwegian based on a survey conducted in 2011.

4. The concept of traditional reasons is here pointing to a focus on maintaining and running the farm the same way it was handed over from the former generation.
5. Carbon loss from cultivated peatlands is a significant source of GHG emissions in Norway (Grønlund et al., 2008).
6. This measure was implemented as of April 2019, with opportunities to apply for exemption.
7. A similar, umbilical system also exists, where the manure applicator has its mobile/drag hose connected to in-field hydrants instead of to the manure store directly.

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References

Aguirre-Villegas, H.A. and R.A. Larson (2017) Evaluating greenhouse gas emissions from dairy manure management practices using survey data and lifecycle tools. *Journal of Cleaner Production* 143 pp. 169-179

Allenby, B.R. (2012) Geoengineering as a response to cultural lock-in. Symposium on Sustainable Systems and Technology (ISSST), 2012 IEEE International. 16-18 May 2012, Boston

Almås, R. (2004) *Norwegian agricultural history*. (Trondheim: Tapir Academic Publishers)

Almås, R. (2018) *Klimasmart landbruk. Korleis kan norsk landbruk bidra til det grøne skiftet?* [Climate-smart agriculture. How can Norwegian agriculture contribute to the green shift?] (Melhus: Snøfugl Forlag)

Axon, S., J. Morrissey, R. Aiesha, J. Hillman,, A. Revez *et al.* (2018) The human factor: Classification of European community-based behaviour change initiatives. *Journal of Cleaner Production* 182 pp. 567-586

Beudou, J., G. Martin and J. Ryschawy (2017) Cultural and territorial vitality services play a key role in livestock agroecological transition in France. *Agronomy for Sustainable Development* 37 (4) article no. 36

Bezlepkina, I., P. Reidsma, S. Sieber and K. Helming (2011) Integrated assessment of sustainability of agricultural systems and land use: Methods, tools and applications. *Agricultural Systems* 104 pp. 105–109

Bijl, R., S.R. Kooistra and H. Hogeveen (2007) The profitability of automatic milking on Dutch dairy farms. *Journal of Dairy Science* 90 pp. 239–248

Brandt, U.S. (2013) The implication of extreme events on policy responses. *Journal of Risk Research* 17 (2) pp. 221-240

Brandth, B. (2002) Gender identity in European family farming: A literature review. *Sociologia Ruralis* 42 (3) pp. 181-200

Brandth, B. (2019) Farmers framing fatherhood: Everyday life and rural change. *Agriculture and Human Values* 36 (1) pp. 49–59

Brandth, B. and G. Overrein (2013) Resourcing children in a changing rural context: Fathering and farm succession in two generations of farmers. *Sociologia Ruralis* 53 (1) pp. 95–111

Brobakk, J. (2018) A climate for change? Norwegian farmers' attitudes to climate change and climate policy. *World Political Science* 14 (1) pp. 55-79

Bullock, D. (2012) Emissions trading in New Zealand: Development, challenges and design. *Environmental Politics* 21 (4) pp. 657-675

Burbi, S., R.N. Baines and J.S. Conway (2016) Achieving successful farmer engagement on greenhouse gas emission mitigation. *International Journal of Agricultural Sustainability* 14 (4) pp. 466-483

Burton, R.J.F. (2004) Seeing through the 'good farmer's' eyes: towards developing an understanding of the social symbolic value of 'productivist' behaviour. *Sociologia Ruralis* 44 (2) pp. 195-216

Burton, R.J.F. (2018) Preserving Cultural Landscapes: A Cultural Sustainability Perspective. In I. Birkeland, R.J.F. Burton, C. Para and K. Siivonen eds., *Cultural* *sustainability and the nature-culture interface: Livelihoods, policies, and methodologies* (London: Taylor & Francis)

Burton, R.J.F. and H. Fischer (2015) The succession crisis in European agriculture. *Sociologia Ruralis* 55 (2) pp. 155–166

Burton, R.J.F. and S. Peoples (2014) Market liberalisation and drought in New Zealand: A case of 'double exposure' for dryland sheep farmers? *Journal of Rural Studies* 33 pp. 82-94

Cameron, K.C., H.J. Di and J.L. Moir (2014) Dicyandiamide (DCD) effect on nitrous oxide emissions, nitrate leaching and pasture yield in Canterbury, New Zealand. New Zealand Journal of Agricultural Research 57 (4) pp. 251-270

Eckard, R.J., C. Grainger and C.A.M. de Klein (2013) Options for the abatement of methane and nitrous oxide from ruminant production: A review. *Livestock Science* 130 pp. 47–56

European Commission (2010) Developments in the income situation of the EU agricultural sector. DG for Agriculture and Rural Development. Available online at https://ec.europa.eu/agriculture/rica/pdf/hc0301_income.pdf. Accessed November 2019

Feyereisen, M., P.M. Stassart and F. Mélard (2017) Fair trade milk initiative in Belgium: Bricolage as an empowering strategy for change. *Sociologia Ruralis* 57 (3) pp. 297-315

Fischer, H. and R.J.F. Burton (2014) Understanding farm succession as a socially constructed endogenous cycle. *Sociologia Ruralis* 54 (4) pp. 417–438

Flemsæter, F. and G. Setten (2009) Holding property in trust: Kinship, law and property enactment on Norwegian smallholdings. *Environment and Planning A* 41 (9) pp. 2267–2284

Flemsæter, F., H. Bjørkhaug and J. Brobakk (2017) Farmers as climate citizens. *Journal of Environmental Planning and Management* 61 (12) pp. 2050-2066

Forbord, M., H. Bjorkhaug and R.J.F. Burton (2014) Drivers of change in Norwegian agricultural land control and the emergence of rental farming. *Journal of Rural Studies* 33 pp. 9-19

Franks, J.R. and B. Hadingham (2012) Reducing greenhouse gas emissions from agriculture: Avoiding trivial solutions to a global problem. *Land Use Policy* 29 (4) pp. 727– 736

Geels, F.W. (2004) From sectoral systems of innovation to socio-technical systems. Insights about dynamics and change from sociology and institutional theory. *Research Policy* 33 (6-7) pp. 897–920

Geels, F. (2011) The multi-level perspective on sustainability transitions: Responses to seven criticisms. *Environmental Innovation and Societal Transitions* 1 pp. 24–40

Glenk, K., V. Eory, S. Colombo and A. Barnes (2014) Adoption of greenhouse gas mitigation in agriculture: An analysis of dairy farmers' perceptions and adoption behaviour. *Ecological Economics* 108 pp. 49–58

Glover, J.L. (2014) Gender, power and succession in family farm business. *International Journal of Gender and Entrepreneurship* 6 (3) pp. 276 - 295

Grosjean, G., S. Fuss, N. Koch, B.L. Bodirsky, S. De Cara *et al.* (2018) Options to overcome the barriers to pricing European agricultural emissions. *Climate Policy* 18 (2) pp. 151-169

Grønlund, A., A. Hauge, A. Hovde and D.P. Rasse (2008) Carbon loss estimates from cultivated peat soils in Norway: a comparison of three methods. *Nutrient Cycling in Agroecosystems* 81 pp. 157–167

Guest, D.E. (2002) Perspectives on the study of work-life balance. *Social Science Information* 41 (2) pp. 255-279

Hansen, B.G. (2015) Robotic milking-farmer experiences and adoption rate in Jæren, Norway. *Journal of Rural Studies* 41 pp. 109-117

Hansen, B.G. and A.M. Jervell (2015) Change management in dairy farming. *International Journal of Sociology of Agriculture and Food* 22 pp. 23-40

Haugen, M.S., B. Brandth and G. Follo (2015) Farm, family, and myself: Farm women dealing with family break-up. *Gender, Place & Culture* 22 (1) pp. 37-49

Haugen, M.S. and B. Brandth (2017) Gender identities and divorce among farmers in Norway. Pp. 185-197 in S. Shortall and B. Bock eds., *Gender and rural globalisation: International perspectives on gender and rural development* (Oxford: CAB International)

Howlett, M. (2014) Why are policy innovations rare and so often negative? Blame avoidance and problem denial in climate change policy-making. *Global Environmental Change* 29 pp. 395-403

Jacobs, J.A. and J.M. Siegford (2012) Invited review: the impact of automatic milking systems on dairy cow management, behavior, health and welfare. *Journal of Dairy Science* 95 pp. 2227-2247

Jayasundara, S., J.A.D.R.N. Appuhamy, E. Kebreab and C. Wagner-Riddle (2016) Methane and nitrous oxide emissions from Canadian dairy farms and mitigation options: An updated review. *Canadian Journal of Animal Science* 96 pp. 306–331

Mahoney, J. (2000) Path dependence in historical sociology. *Theory and Society* 29 pp. 507-548

Mathijs, E. (2004) Socio-economic aspects of automatic milking. Pp. 46-55 in A. Maijering, H. Hogeveen and C.J.A.M. de Koning eds., *Automatic milking - a better understanding* (Wageningen: Wageningen Academic Publishers)

Million Insights (2018) Milking robots market size & Forecast Report, 2014 – 2025. Available online at https://www.millioninsights.com/industry-reports/milking-robots-market?utm_source=referral&utm_medium=paid&utm_campaign=prn_june27_milking robotics_rd1. Accessed November 2018

Minstry of Agriculture and Food (2008-2009) Klimautfordringene – Landbruket en del av løsningen. Meld. St. 39, 2008-2009 (Oslo: Ministry of Agriculture and Food)

Ministry of Agriculture and Food (2011-2012) Landbruks- og matpolitikken – Velkommen til bords. Meld. St. 9, 2011-2012 (Oslo: Ministry of Agriculture and Food)

Ministry of Agriculture and Food (2016-2017) Endring og utvikling. En fremtidsrettet jordbruksproduksjon. Meld. St. 11, 2016-2017 (Oslo: Ministry of Agriculture and Food)

Ministry of Agriculture and Food (2017) 1. Forslag til lov om endring av lov om jord. 2. Forslag til endring av forskrift om nydyrking. Høringsnotat [Consultation paper]. Available online at: https://www.regjeringen.no/contentassets/799c5d26365d477098e2a245023efba9/horingsnotat-nydyrking-juli-17.pdf. Accessed September 2018

Ministry of Climate and Environment (2011-2012) Norsk klimapolitikk. Meld. St. 21, 2011-2012 (Oslo: Ministry of Climate and Environment)

Monteny, G-J., A. Bannink and D. Chadwick (2006) Greenhouse gas abatement strategies for animal husbandry. *Agriculture, Ecosystems and Environment* 112 pp. 163–170

Moran, D., M. Macleod, E. Wall, V. Eory, A. McVittie *et al.* (2011) Marginal abatement cost curves for UK agricultural greenhouse gas emissions. *Journal of Agricultural Economics* 62 (1) pp. 93–118

Mylan, J., F.W. Geels, S. Gee, A. McMeekin and C. Foster (2015) Eco-innovation and retailers in milk, beef and bread chains: Enriching environmental supply chain management with insights from innovation studies. *Journal of Cleaner Production* 107 pp. 20-30

Norbye, A-K.B. (2018) Ambivalence and contradictions: A case from mountain agricultural landscape conservation. *Ethnos* 83 pp. 440-454

Norsk landbruksrådgivning (undated) Jord som voksemedium. Available online at: https://www.fylkesmannen.no/globalassets/fm-hedmark/dokument-fmhe/06-landbruk-og-mat/jordbruk/fjellandbruk/plansjer-27.01.2016/husdyrgjodsel-slangespr.-nlr.pdf. Accessed June 2018

Oleszczuk, R., K. Regina, L. Szajdak, H. Höper and V. Maryganova (2008) Impacts of agricultural utilization of peat soils on the greenhouse gas balance. Pp. 70-97 in M. Strack ed., *Peatlands and climate change* (Jyväskylä: International Peat Society)

Olsson, E.G.A., K. Rønningen, S.K. Hanssen and S. when (2011) The interrelationship of biodiversity and rural viability: Sustainability assessment, land use scenarios and Norwegian mountains in a European context. *Journal of Environmental Assessment and Policy Management* 13 pp. 251–284

O'Mahoney, T., P. Zhou and J. Sweeney (2013) Integrated scenarios of energy-related CO_2 emissions in Ireland: A multi-sectoral analysis to 2020. *Ecological Economics* 93 pp. 385–397

Poore, J. and T. Nemecek (2018) Reducing food's environmental impacts through producers and consumers. *Science* 360 (6392) pp. 987-992

Popp, A. and J. Wilson (2007) Life cycles, contingency, and agency: Growth, development, and change in English industrial districts and clusters. *Environment and Planning A* 39 pp. 2975-2992

Regina, K., A. Budiman, M.H. Greve, A. Grønlund, Å. Kasimir *et al.* (2016) GHG mitigation of agricultural peatlands requires coherent policies. *Climate Policy* 16 pp. 522-541

Richards, M.B., E. Wollenberg and D. van Vuuren (2018) National contributions to climate change mitigation from agriculture: Allocating a global target. *Climate Policy* 18 (10) pp. 1271-1285

Rosenbloom, D. (2017) Pathways: An emerging concept for the theory and governance of low-carbon transitions. *Global Environmental Change* 43 pp. 37-50

Runciman, W.G. (1966) *Relative deprivation and social justice: a study of attitudes to social inequality in twentieth-century England* (London: Routledge & Keagan Paul)

Salganik, M.J. and D.D. Heckathorn (2004) Sampling and estimation in hidden populations using respondent-driven sampling. *Sociological Methodology* 34 pp. 193–239

Sheller, M. (2004) Automotive emotions: Feeling the car. *Theory, Culture & Society* 21 (4/5) pp. 221–242

Shortall, S. (2017) Changing gender roles in Irish farm households: Continuity and change. *Irish Geography* 50 (2) pp. 175–191

Spencer, L., J. Ritchie and W. O'Conner (2003) Analysis: Practices, principles and processes. Pp. 199-218 in J. Ritchie and J. Lewis eds., *Qualitative research practice: A guide for social science students and researchers* (London: SAGE)

Stoate, C., A. Baldi, P. Beja, N.D. Boatman, I. Herzon *et al.* (2009) Ecological impacts of early 21st century agricultural change in Europe – A review. *Journal of Environmental Management* 91 pp. 22–46

Stokka, T., W.E. Dramstad and K. Potthoff (2018) The use of rented farmland in an area of intensive agricultural production in Norway. *International Journal of Agricultural Sustainability* 16 (3) pp. 243-254

Stræte, E.P., J. Vik and B.G. Hansen (2017) The social robot: A study of the social and political aspects of automatic milking systems. Proceedings in system dynamics and innovation in food networks 2017. *International Journal of Food System Dynamics*, DOI: http://dx.doi.org/10.18461/pfsd.2017.1722

Stuart, D. (2018) Climate change and ideological transformation in United States agriculture. *Sociologia Ruralis* 58 (1) pp. 63-82

Stuart, D. and R.L. Schewe (2016) Constrained choice and climate change mitigation in US agriculture: Structural barriers to a climate change ethic. *Journal of Agricultural and Environmental Ethics* 29 pp. 369–385

Stuart, D., R.L. Schewe and M. McDermott (2012) Responding to climate change: Barriers to reflexive modernization in U.S. agriculture. *Organization & Environment* 25 (3) pp. 308–327

Stuart, D., R.L. Schewe and M. McDermott (2014) Reducing nitrogen fertilizer application as a climate change mitigation strategy: Understanding farmer decision-making and potential barriers to change in the US. *Land Use Policy* 36 pp. 210– 218

Sørensen, C.G. (2003) A model of field machinery capability and logistics: The case of manure application. *Agricultural Engineering International: The CIGR Journal of Scientific Research and Development* 5 pp. 1-20

Thwaites, R., A. Curtis, N. Mazur and D. Race (2008) Understanding rural landholder responses to climate change. Report No. 48. Institute for Land, Water and Society, Charles Sturt University

Unruh, G.C. (2000) Understanding carbon lock-in. *Energy Policy* 28 pp. 817-830

Urry, J. (2004) The ‘system’ of automobility. Theory, Culture & Society 21 (4/5) pp. 25–39

Urry, J. (2010) Sociology facing climate change. *Sociological Research Online* 15 (3) 1

Victor D.G., D. Zhou, E.H.M. Ahmed, P.K. Dadhich, J.G.J. Olivier *et al.* (2014) Introductory chapter. In O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner *et al.* eds., *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge: Cambridge University Press)

Villa., M. (1999) Born to be farmers? Changing expectations in Norwegian farmers’ life courses. *Sociologia Ruralis* 39 (3) pp. 328-342

Vinge, H. (2018) Farmland conversion to fight climate change? Resource hierarchies, discursive power and ulterior motives in land use politics. *Journal of Rural Studies* 64 pp. 20-27

Walford, N. (2003) Productivism is allegedly dead, long live productivism. Evidence of continued productivist attitudes and decision-making in South-East England. *Journal of Rural Studies* 19 pp. 491–502