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Danish agriculture - sustainable management of the commons

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Abstract
Denmark is an agricultural country with 62 pct. of the area owned by farmers with legal private property rights. Efficiency in both productivity and strong cooperation throughout the product chain has enabled this position. However, this development has given rise to negative impact on common resources such as decreasing water quality, reduced soil fertility and loss of biodiversity challenging public expectations. Through three different approaches for involving farmers practicing Conservation Agriculture the possibilities for common understanding, knowledge conduction and production as well as facilitation of transition towards sustainable agricultural practices are investigated. The paper suggests increased involvement of actors in order to create democratic and sustainable agricultural management while questioning optimal methods for common solutions for increasing public goods.

Keywords: Sustainable agriculture, Commons, Transition, Conservation Agriculture, Intercropping, Co-design, Future Workshop, Actor-Network Theory, Socio-technical analysis

1. Introduction

1.1 Land-use and food production

In 1968 Garret Hardin introduced the concept “tragedy of the commons” to explain the overexploitation of common resources (Hardin, 1968). Despite private ownership, land-use including agricultural production is still today a battlefield for management of the commons.

Since the beginning of the Industrial Revolution agriculture has contributed with 214 ± 67 petagrams of carbon (Pg C) to the atmosphere from land-use change compared to the estimated almost equivalent 270 ± 30 Pg of C from fossil fuel combustion (Zomer *et al.*, 2017). Today the food production is bigger than ever but still around 815 million people suffer from hunger while 1.9 billion is diagnosed with overweight and obesity (IAASTD, 2009). Future generation’s ability to survive in a world with increasing challenges caused by climate change depend on coming global food production, distribution and diet. Agriculture and food is by far the world’s largest business and therefore closely linked to sustainable development. However, many agricultural strategies currently face major environmental challenges generally connected to fertilizer and pesticide use, soil erosion, soil pollution and widespread loss of biodiversity. Public attitudes towards current practices is also challenging the European Common Agricultural Policy (CAP) with new directions pointing towards subsidies to further increase public goods deliverables like climate change and energy related issues, water management, environmentally friendly farming (e.g. organic farming), Less Favoured Areas including Environmentally Sensitive Areas, etc. (EU, 2017).

The Danish agriculture and food industries are world leading in contributing to the increased global food demand, including increasing market demand for animal products. Efficiency in both productivity and strong cooperation throughout the product chain has enabled this position. Denmark is one of the world's most intensively farmed countries (Folke *et al.*, 2002) covering up to 67 pct. of the total area, leaving 16 pct. for forest and heathlands, 7 pct. for environmental sensitive areas and about 10 pct. for the total built-up area (StatBank Denmark). Danish farmers are producing an amount of food sufficient to supply 15 million people every year - three times the Danish population (Danish Agriculture and Food Council, 2015). However, this development has given rise to negative impact on common resources (Frison, 2016). The Danish agricultural sector faces challenges with e.g. land-based nitrogen loading to Danish surface waters (Kronvang *et al.*, 2008), climate change with agriculture accounting for about 17 pct. of the total national GHG emissions (Nielsen *et al.*, 2013), loss of biodiversity including important pollinators (Cairns *et al.*, 2017) and a decrease in the total soil carbon storage due to intensive cultivation involving drainage and ploughing practices (Adhikari *et al.*, 2014).

The negative impacts of the agricultural production has given rise to increasing public awareness and opinions about the agricultural practices of today, which challenge the development of the sector. Some concerns are manifested through regulations like EU environmental policies on resource efficiency, sustainable use of natural resources, protection of biodiversity and habitats and provision of ecosystem services, and others expressed through increased demand for organic food products (Prost *et al.*, 2017). Nevertheless, the percentage of money spend on food in Denmark has been strongly decreasing the last 40 years and today less than 15 pct. on average of a Danish budget is spend on food products, beverages and tobacco (DST, 2017). At the same time the amount of people who feel concerned about farming activities and their consequences is increasing, while the number of citizens with a link to agriculture has diminished (Meynard, Dedieu and Bos, 2012). Danish agriculture is increasingly challenged to keep-up its global position while satisfying policy requirements for delivering public goods and satisfying more value-based consumer needs whilst maintaining healthy and productive agroecosystems (Tilman *et al.*, 2002). Furthermore, the distribution of wealth gains attributable to the agricultural production is to an increasing degree claimed by input suppliers through protection of formal intellectual property rights. Quite an illogicality for a sector once largely influenced by public research and the farmers' own ingenuity (Clancy and Moschini, 2017).

There is no doubt that mechanisms of global market have put the modern farmers under considerable pressure – economically as well as socially (Elzen *et al.*, 2012). Pressures like global market price settings require cost-effective intensification to gain profits challenging the ability to introduce new management practices leading to more sustainable farming (Morgan and Murdoch, 2000). The agricultural sector is a very innovative sector, which has undergone radical changes during the last century. Nevertheless, strong traditions, cultures and norms are embedded in the profession challenging potential transitions to new agricultural practices. Many farmers inherit the agricultural land and practice through generations and the profession has a great influence on their private lives. Consequently, agricultural production involves many emotions for both farmers and consumers leading to an often intense public debate about the development of the agricultural sector.

The Danish agriculture is strongly represented in the political landscape through organisations such as the Danish Agriculture and Food Council. Today the Danish Agriculture and Food Council represents the whole food cluster including 30,000 farmers and 300 companies varying in size from small to global operating all across the value chain (Danish Agriculture and Food Council, 2018). The development towards an organisation representing the whole food cluster has brought farmers to raise questions whether the size and structure of the Danish Agriculture and Food Council allows the organisation to continuously represent the interests of farmers, which further questions whether farmers' knowledge and opinions are represented in the dialog of sustainable transition of the Danish agricultural sector.

1.2 Facilitation of transition

Due to their complex nature wicked problems such as those related to the transition towards a more sustainable agricultural system must be addressed in dissimilar ways and from different perspectives (Darnhofer, Gibbon and Dedieu, 2012; Ashwood *et al.*, 2014). Confrontation with and integration of a multiple perspectives, insights, experiences and ideas is needed. Not at least involving farmers and other practitioners in both knowledge production and sharing as well as innovation and implementation of more sustainable agricultural systems is required (Duru *et al.*, 2015; Prost *et al.*, 2017). By integrating different forms of knowledge of academic as well as non-academic actors being implicit, explicit, experiential, informal or formal it is possible to obtain knowledge that is both scientifically credible and socially valuable supporting a more democratic and sustainable management of the common land.

To overcome obstacles for a future sustainable agricultural production EU requires researchers participating in the Horizon2020 program to work according to the multi actor approach (MAA) by integrating a broad range of actors including firms, users, policy makers, scientists, and other relevant actors in the research process. The aim of the MAA is to ensure valuable perspectives, knowledge, experiences and ideas essential for handling complex problems while ensuring implementation and communication along the process (EIP-Agri, 2017).

It is assumed by the authors of this article that common goals and understanding regarding the future Danish agricultural practices are needed and has to be developed by challenging perceptions, routines, rules and regulations, and the social and economic context in which farmers operate. Successful transitions require local negotiations by relevant actors to be effective. Consequently, more inclusive research-for-transition approaches are tested taking actor-driven objectives as a starting point.

1.3 Agroecology, ancient knowledge and Conservation Agriculture

One of the approaches to combat future challenges with e.g. transition through more resilient farming systems is to revitalize new or maybe forgotten knowledge around agroecology and ecosystem functions and services (Olsson and Folke, 2001; Altieri *et al.*, 2015).
Farmer knowledge has originally been linked to specific conditions in local communities and inherited through generations (Altieri, 2004; Prost *et al.*, 2017). This "intimate knowledge of their land holdings, its fertility, composition and so on" have been uniquely developed for the specific local conditions and attuned to the "rhythms of nature"(Morgan and Murdoch, 2000).

The growth of agricultural science especially tied to the development of inputs entailed the removal of knowledge production from farms to laboratories creating a vertical organization and generation of standardised generic knowledge (Fonte, 2008; Šūmane *et al.*, 2016). Generic knowledge for heterogeneous farms were to some extent made possible due to the new post war regime that aimed at controlling production through eg. the use of synthetic inputs (Šūmane *et al.*, 2016; Prost *et al.*, 2017). As the negative effects of modern industrial agriculture become visible (Altieri *et al.*, 2015; Frison, 2016) the historical replacement of knowledge - and the resulting loss of local and eco-sensitive knowledge – puts the modern farmer of today in a weak position for developing new strategies to combat these adverse effects (Morgan and Murdoch, 2000).

Conservation Agriculture (CA) is by FAO described as: "an approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment"(FAO, 2015). A practice showing promising results about high productivity while reducing fuel and labour costs (Kirkegaard *et al.*, 2014). The central idea of the agricultural strategy is to reduce the disturbance of the soil making use of natural mechanism (eco-system-services) to create better soil health (structure, carbon content, nutrient and water holding capacity). The agricultural strategy is founded in three central principles i) continuous minimum mechanical soil disturbance, ii) permanent organic soil cover and iii) diversification of crop species grown in sequences and/or associations, which are all important in combination to secure a well-functioning CA system (ibid). However, this practice places demands on farmer knowledge and local adaptation in order to provide successful results (De Wildt-Liesveld, Bunders and Regeer, 2015).

2. Presentation of selected work conducted with farmer group

From ongoing qualitative studies of a conventional farmer group practicing CA initiated in 2014 knowledge and actor-driven objectives are identified as a starting point for transition to sustainable management of land, coexistence with other rural activities and urban populations' use of space. A number of methodological and theoretical approaches all centred around the understanding and involvement of actors' perspectives has been conducted through continuous participation in group meetings, facilitation of workshops and individual visits and interviews. The work has been funded by the EU ERA-NET Plus program on Climate Smart Agriculture (https://www6.inra.fr/climate-cafe).

The aim of the "Climate Change Adaptability of cropping and Farming systems for Europe (Climate Café) project is to evaluate traditional and more novel regional adaptation and mitigation strategies along a North-South climate gradient in the EU in order to propose new farming system designs combining expert knowledge (researchers, experiemnts and models) with farmer and advisor views presented in Adaptation Pilots representing regional cropping and farming systems located across EU (consortium countries). Novel cropping systems are designed and evaluated based on multi-criteria economic and environmental analyses.

The farmers in the Danish Adaptation Pilot are all situated in the eastern area of the country, Region Zealand, which is the most densely populated region dominated by arable crop

production and a high coverage (~64 pct.) of agricultural land (Klinglmair *et al.*, 2015). Agricultural systems of the region are characterised by rotations dominated by annual cereal and low intensity of animal husbandry. Limited use of animal manures and perennial cropping for fodder purposes and export of residues (primarily cereal straw) to local power stations, reduce the carbon soil inputs. Hence, soil carbon content is continuously declining with an average of 1-2.5 pct. (Adhikari *et al.*, 2014).
Based upon a general concern about unsustainable exploitation of land resources leading to soil degradation and implications for food security and local agriculture integrity the farmers investigated are gathered around the CA strategy. Local adaptation of conservation agriculture principles is their solution to sustainable future cropping systems involving application of modern agricultural technologies to improve production, lower cost but also helps maintain ecosystem functions and services. The farmers regard it as a win-win situation with potential improvements compared to traditional practices (ploughing) in both agricultural, environmental, economic and social terms.

The farmer network is about 15 years old and initiated as a response to limited Danish experience with CA leaving the practitioner with uncertainty of advisory support, regulation and access to newest findings. Presently, the network consist of more or less the same members (all full-time farmers) and operates without advisors or other experts involved. The members of the group meet approximately once every three months to share experiences and challenges in their individual farm management. Table 1 illustrates the individual farms, practices and years with CA.

Table 1. Examples of Danish farms involved in the network

Farm	Soil[1]	Area[2]	Animals	Crop rotation	CA[3]
A	5-7	300	No	Spring barley, clover (grass seeds 2 years) winter wheat.	20
B	3-5	1200	No	Spring barley, grass, winter barley, rapeseeds, winter wheat.	15
C	5-6	370	8000 pigs	Beet, barley, wheat, rapeseeds, faba beans.	13
D	4-7	350	1500 pigs	Spinach, wheat, rapeseeds, wheat, spring barley.	14
E	6	160	No	Barley, wheat, rapeseeds, barley, wheat	9
F	5-7	83	No	Rapeseeds, wheat, barley, barley.	42
G	6-7	260	No	Winter rapeseeds, wheat, faba beans, wheat, spring barley.	15
H	7	300	No	Rapeseeds, spring barley, faba beans, winter wheat.	10
I	2-7	200	460 sows.	Rapeseeds, winter wheat, spring barley.	20

[1]Soil types are: 2 = coarse sandy soil; 3 = fine sandy soil; 4 = sandy soil with clay; 5 clay soil with sand; 5 = clay soil; 6 = heavy clay soil; 7 = humus soil. [2]Owned *and* rented land in hectares. [3]Years since shift to conservation agriculture.

As shown in the table the farms vary in relation to physical conditions, management and personal experiences. Despite being located in a relatively small geographical area the local contexts between the farms vary considerably due to among other things different historical management (eg. removal of straw, tillage practices, choice of crop rotation and coverage), which places different demands on the farmers' current and future management.

In order to gain knowledge about the innovations and barriers towards more sustainable agricultural practices the research group has worked with the farmer group through several methodological approaches all centered around farmer involvement in research. The approaches presented in this paper are the following: a future workshop from the action-research tradition; the FarmDESIGN tool used in farm co-designing evaluation and support for planning processes; and the actor-network analysis with dynamic networks of relationship between social and natural components.

2.1 Future Workshop

The Future Workshop (FW) approach was developed by the Austrian writer and journalist Robert Jungk with the main aim to activate a basis, which was able to develop a proposal for a desirable future through a joined critique of the establishment (Jungk, R. and Müller, 1987). It was regarded as a method to support the political struggles of community groups for better enforcement of their interests enabling a better future.

The research group invited the farmers to a full day FW event focusing on changing or transforming the actual situation of farming practices in Denmark towards a higher degree of sustainability. The workshop was divided into three phases: i) during the first phase, the farmers listed all negative aspects of their daily lives (Negative by definition). In our case, narrowed down to their daily practices as farmers engaged in CA. ii) During the second phase features and elements of an imagined ideal situation were listed (Visionary by definition). iii) During the final phase they were encouraged to propose strategies of action to move towards their goals (Personal acts to be taken).

Each phase was facilitated by a timekeeper and a moderator to secure high activity level by all participants. A brainstorm event was initiated by an individual session where as many post-its as possible were written by each farmer and put on a wall to get insight into each other's criticism/visions/actions creating a common understanding (picture 1). All post-its on the wall were grouped into themes in plenum. Afterwards, each farmer was asked to vote on the two most important post-its in his or her opinion including the possibility to vote for the same post-it twice. In cooperation with all participants the facilitator was able to identify the most shared issues among the participants (picture 2).

Picture 1. Creating the wall of individual statements (brainstorm). Picture 2. Grouping brainstorm post-its in plenum and the following voting to select the most shared statements.

The FW enabled an articulation of many problems and ideas identified by the farmers. Few examples of the preliminary causal chains identified by the farmers are pictured in table 2.

Table 2. Phase two: Future Workshop post-its to create common targets and actions.

Goal	**Targets**	**Actions**	**Actors**
Seeding in healthy soils	Security; produce; sale; functionality	Farmer knowledge sharing; on-farm experiments; profitability; law and legislation	CA NGO's (DK and EU); researchers; consultancy; machine companies and developers
Acknowledgement from society	Positive journalists, politicians; consumers, schools	Media branding; professional communication; events; education package	CA NGO's (DK and EU); homepage and newsletters; demonstrations; academia links
Soil as provider of healthy foods	Political regulations; qualified CA consultancy	Outreach to policy makers; specialised consultants; farmers school task force	CA front runners; local and national politicians; civil servants; colleagues

A central issue taken from the workshop outputs was the lack of merit of the environmental friendly initiatives that farmers perceive their own CA practices to be. A strong lack of understanding and support of the potential of this system from other farmers, rural population, urban citizens or politicians experienced by the farmers on their respective farms. Another key obstacle articulated at the FW was a lack of knowledge on the factual merits of the CA system in both research and consultancy. The farmers explained that the long term effects on reduced tillage, the biological understanding of diversity, creation of new equilibria in the soils microbiome etc. is too difficult to feed on the shorter 4-years political cycle (until next election) agendas. Furthermore, farmers found the policy and regulatory environment constraining because of a generally negative attitude towards agriculture among political decision makers. Farmers called for further research on the impacts on their farming practices combined with increased outreach towards consumers, educational institutions and politicians. The latter supported by more professional lobbying for regulatory mechanisms and standards based on more localized data (see table 2).

All participants strongly underlined their frustration around lack of understanding and respect from the surrounding society. The farmers do not see themselves only as commodity producers but also providers of quality food and managers of the eco-system. In their perspective future global food demand draws upon local natural resources, ecological processes and farmers' knowledge of them. They are completely confident that CA practices show the right path for future more sustainable strategies but is not able to convince neither farmer colleagues, local consultancy or even the rural citizens. To survive in their business high productivity are required. However, from a public goods perspective fewer external inputs are expected while producing the same output and/or higher-quality outputs. In their views less farm profitability will result in a situation where sustainability will become even more challenging. They highlight the declining share of value added in the food chain over the past decade and regard this as a joint responsibility. The third phase advocating for actions on the shorter term verified lack of belief in communication ability with a lot of attention to changes for other players in the value chain(s).

The farmers group clearly expressed the value of meeting and sharing knowledge to identify strengths and weaknesses on their CA practices as well as identification of core personal competencies according to the rest of the group. Thereby, their local farm location, financial or social capital are used to respond to the opportunities and also threats found in the external environment. However, it was identified that the farmers could personally benefit from more detailed information on their specific farm operations, cropping strategies, market decisions. The groups variety of competences also turned out to be beneficial when discussing individual farm challenges and opportunities. Lack of access to qualified consultancy therefore opened up for other possibilities to qualify the sharing of knowledge among the group members.

2.2 FarmDESIGN

With a Describe Explain Explore Design (DEED) cycle idea (Falconnier et al, 2017) for further collaboration with the individual farmers while facilitating farmer group member interactions the research group decided to test the FarmDESIGN computer model using its constituent database (Groot, Oomen and Rossing, 2012) combined with comprehensive individual farmer interviews. Model-based support might be useful in the search for farm system analysis including potential choices and complicated soil-plant-atmosphere interactions evaluating an array of crop and cropping options while taking into account farmer livelihood, safeguarding system sustainability by e.g. increasing the organic matter build-up in the soil and reducing nutrient losses. At the same time the model allow the research to be adjusted according to actor-driven objectives as a starting point and joint involvement of non-academic actors as well as scientists (model development) in a process of knowledge co-creation and mutual learning. A comprehensive input database in FarmDESIGN created the basis for the model within categories like biophysical environment, socio-economic setting, crops, animals, buildings, inputs, etc. (figure 1).

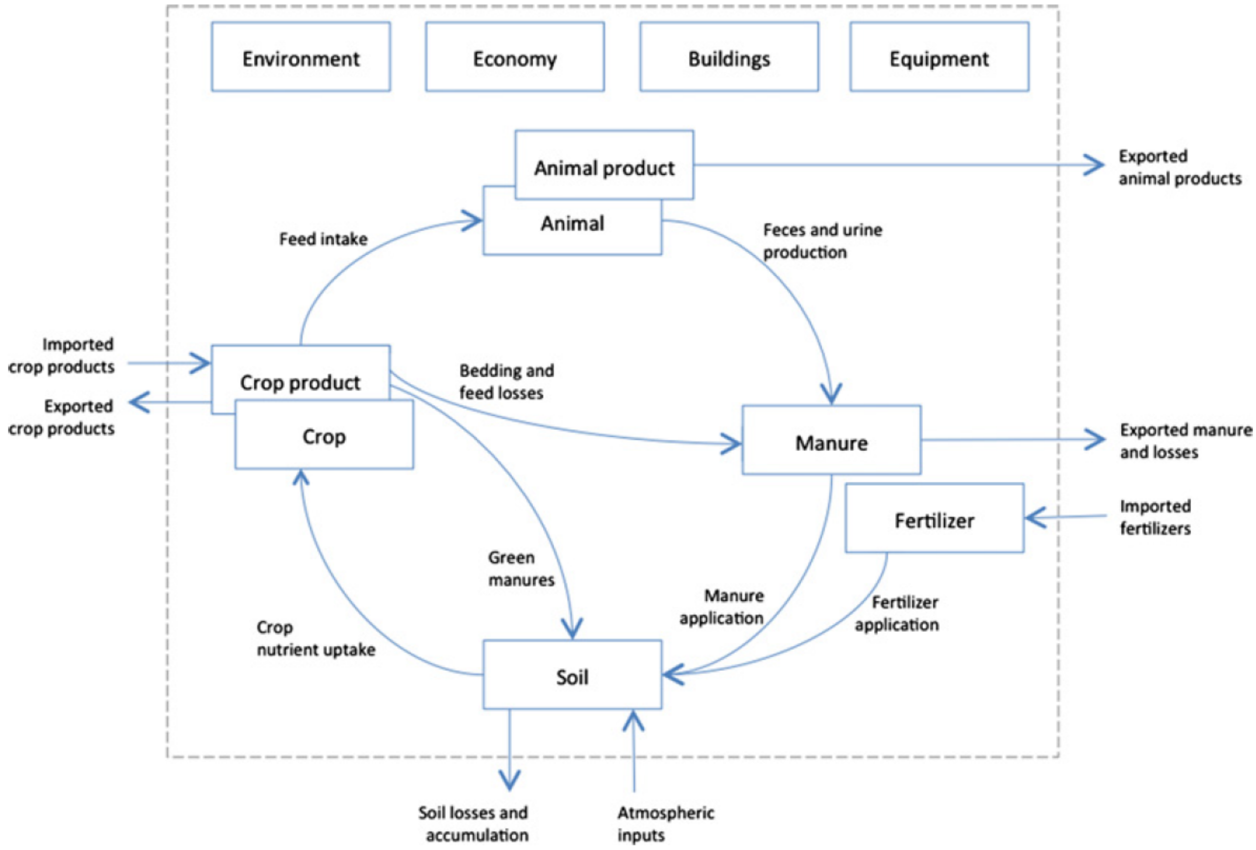

Figure 1. Illustration of the FarmDESIGN model with boxes indicating farm components, arrows material flows quantified by the model and the dashed lines the farming system boundary with the external environment (From Groot et al. 2012).

With special emphasis towards one of the most respected farmers in the group a workshop around the FarmDESIGN outputs from his current practices and optimization options suggested by the model was conducted on his farm with all farmers in the network represented. Before the workshop the research team and a specific farmer meet to clarify inputs and outputs to be presented at the workshop. The workshop was initiated by an outdoor field tour around the farm and nearby natural area reinforcing general discussion on current farm practices opening up for the following discussions about suggested optional transitions made by the model. Thereafter the model principles was introduced to the group with a lot of clarifying questions and experiences challenging model standards providing opportunity to build on common understanding. The debate ranged from long-term strategic planning over longer time-spans (several years) to yearly more tactical planning and short-term operations.

The visual output from the model played an important role for the communication of results. Very fast the farmers obtained an overview of the well-known farm operations looking at the calculated carbon flows to, through and from the farm. Positive effects of current CA practices on soil carbon mitigation were identified by the model (figure 2). The 828 kg C/ha/year number at the bottom right of the figure indicate net-sequestration, which was strongly recognized by the farmer colleagues. One of the farmers refereed to the Danish Ministry of Food and Environment estimations around 100 kg C/ha/year for reduced tillage and up 325 kg C/ha/year for direct sowing. The farmers in the group were sceptical towards model overestimations, also due to lack of complete transparency to database numbers. However, others highlighted the effect of successful production of clover seeds introducing perennials in the rotation (Table 2) while reducing the need for artificial fertilizer N inputs.

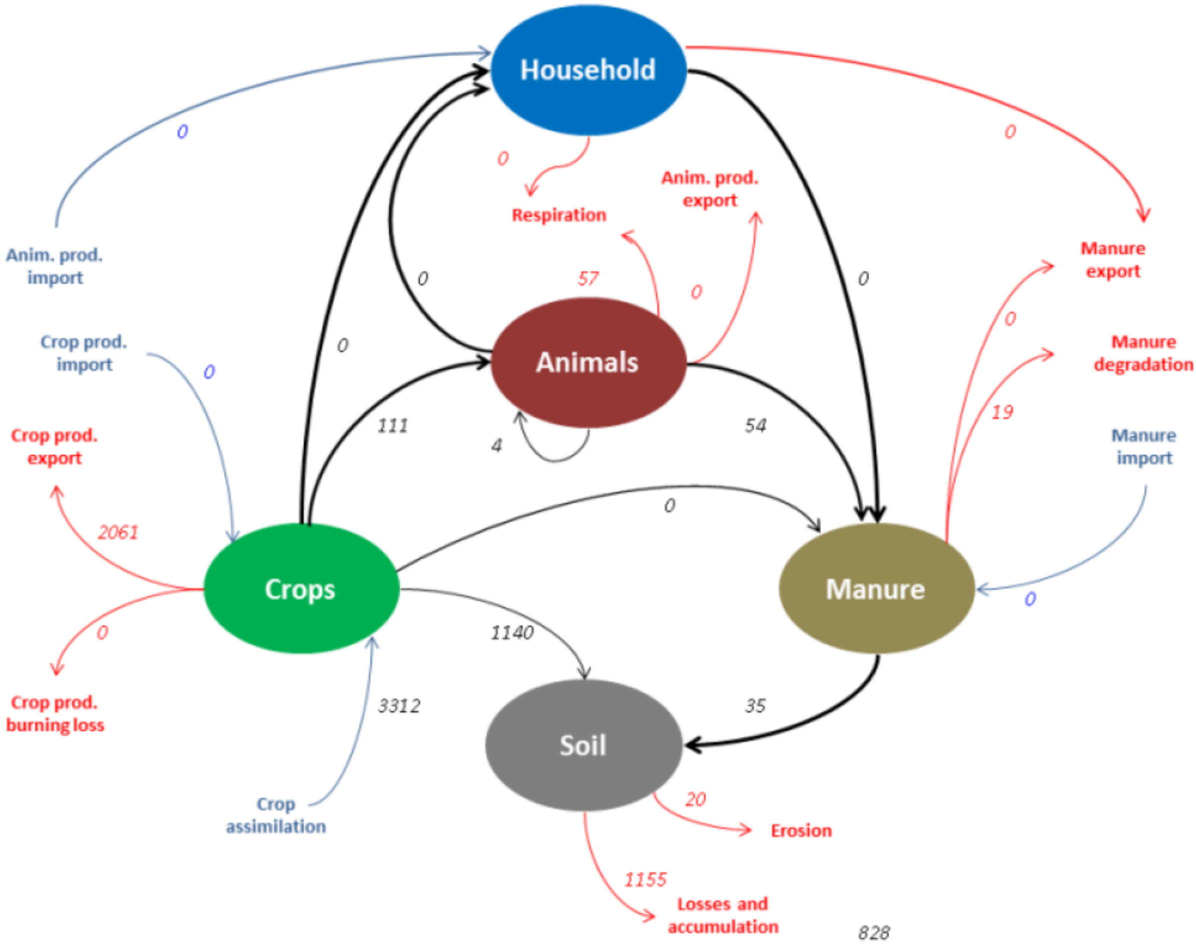

Figure 2. Illustration of the visualized carbon (C) flow (kg C/ha/year) output from the FarmDESIGN model calculated on basis of the actual farm input deriving from farmer interview and the model's constituent database.

From the workshop discussions it was clear how farmers' informal knowledge differs from the formal knowledge that underlies the model simulations. Some of the model functions were regarded by the farmers as more or less "black boxes", difficult to understand (and explain). The fact that scientists had the key to open the box fostered misunderstanding and scepticism in the co-design process rather than creativity, learning and knowledge integration. The model approach was intended to facilitate knowledge sharing but in the end too many specific questions on details to be specified reduced the scaling out potential to other farmers in the group. It is concluded that the FarmDESIGN model created valuable overviews but did not work as a motivational driver behind potential farmer transitions in the current situation.

2.3 Actor-Network Theory

The learnings from the FarmDESIGN model indicating that formal evidence based knowledge might be an obstacle for farmers engagement raises the question whether it is possible to integrate informal knowledge and understanding of the analysis of the individual farmers practices into scientific research.

The Actor-Network Theory (ANT) was developed by Bruno Latour, Michel Callon and John Law in the 1980s and is used to perform sociological analyses of science and technology. The theory introduce the perception that everything in the social as well as natural world exists through complex and dynamic networks of relations (Latour, 1996).

Through qualitative interviews with the individual farmers of the farmer group about their practices and perceptions on Conservation Agriculture an Actor-Network diagram was developed (figure 3).

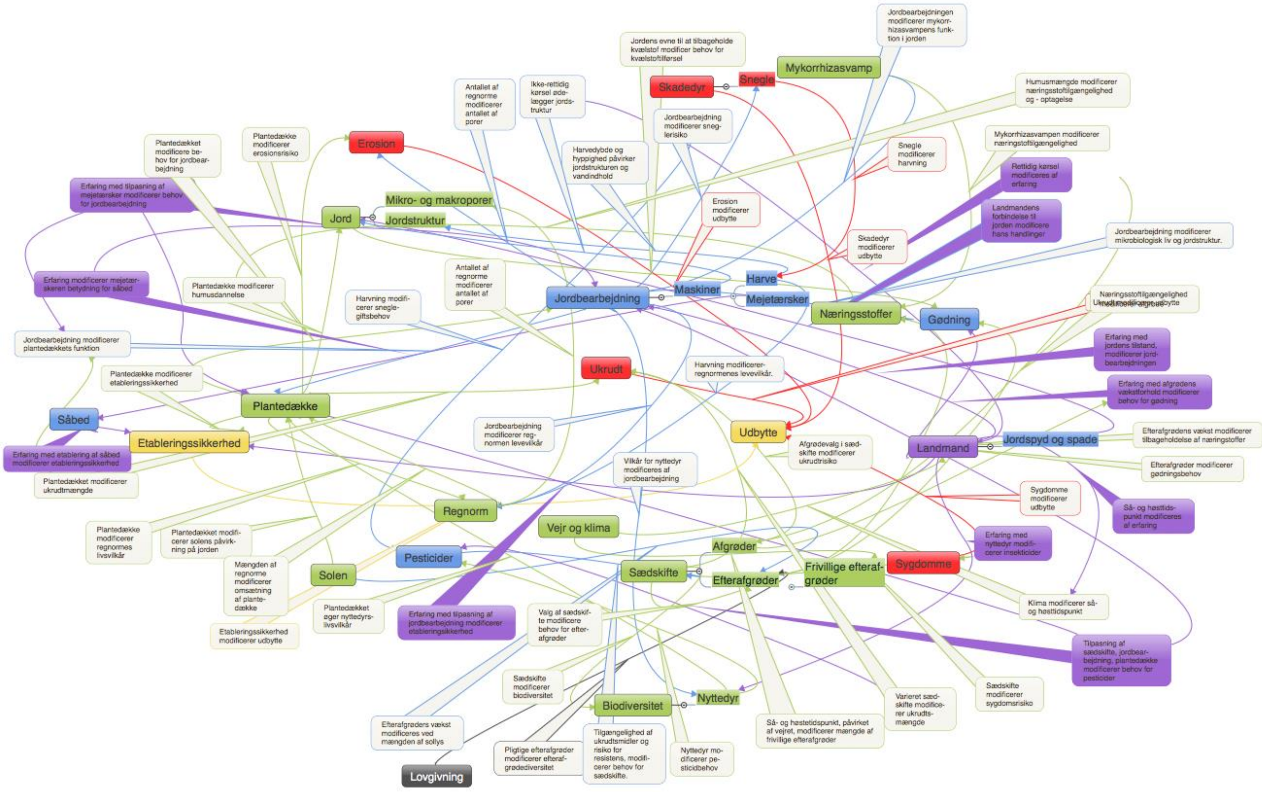

Figure 3: Illustration of the compiled connections between components of the agricultural system as expressed by farmers. The names of the human and non-human actors in the network (boxes) is in Danish. The colors indicate different groups of components eg. biological components, agricultural tools, threats, outputs etc. while the speech bubbles indicate the interrelations between the components.

ANT was used to visualize the complexity and interconnectedness of the farming system as experienced by the farmer including both social, economic and natural/technical aspects. As for the FarmDESIGN model the ANT analysis showed multiple interconnections between components. However, the number of components as well as their nature (being functions, activities, objects, concepts etc.) exceeded and differed from the components in the computer-model. The ANT analysis allowed a socio-technical perspective on the farming system. Thereby the network turned out to be more comprehensive with not only mechanical relations as in the FarmDESIGN model increasing the complexity.

The network illustrated in figure 3 is a compilation of the interrelations as expressed by all ten farmers. This indicates that not every farmer necessarily registrar all of the relations. Therefore, the analysis showed that the complexity of the farming system is individual depending on the context, knowledge and experience of the farmer.

Unlike the FarmDESIGN model ANT take its starting point in the knowledge of the farmers avoiding disagreement and black boxes regarding data and calculations performed by the model. Instead the analysis intended to visualize farmers' informal knowledge to the best possible extent. However, the informal knowledge can be difficult to handle in research as it unlike the formal knowledge is dynamic, local, personal and holistic (Šūmane *et al.*, 2016) challenging the perceptions of truth and consistency, which are central parameters in the scientific discipline. However, the concrete analysis showed that the informal knowledge could raise question to existing formal knowledge by involving the complexity and local differences present in practice, point out knowledge gaps in science and contain important new ideas or innovations.

2.4 Summary of farmer group activities

The three approaches investigated for farmer inclusion was used for different purposes revealing various potentials. The FW was used to facilitate the articulation of requests and ideas of farmers for a sustainable development of the sector including a session for formulation of actions needed. In order to facilitate initiation and evaluation of concrete actions in relation to farming practices the co-design tool FarmDESIGN was used. The tool enabled a dialog between researchers and farmers on the outcome of the implementation of specific actions. However, the underlying data for converting actions to outcomes gave rise to disagreements among the farmers. In that connection, the ANT analysis was used to visualize the farming system with farmer's perception as the starting point. The ANT acknowledge the informal knowledge and its individuality as well as the socio-technical complexity of the agricultural system. The question is how to operationalize and make use of the informal knowledge in research. The preliminary experiences from the research is integrated into the coming work of the research group in a newly initiated EU Horizon2020 project (EU Research and Innovation program).

3. Further research

In the cross-disciplinary H2020 project "Redesigning European cropping systems based on species MIXtures" (ReMIX) researchers and other relevant actors from 13 European countries are investigating "the benefits of species mixtures to design more diverse and resilient arable cropping systems, making use of agro-ecology principles" in European agriculture (https://www.remix-intercrops.eu/).

Species mixtures or intercropping are old global methods that have earlier been an integrated part of every farming system (Altieri, 2004). Along with the access to chemical and technological inputs species diversity in cropping systems has decreased (Tilman *et al.*, 2002; Brooker *et al.*, 2015) Intercropping can be perceived as an eco-functional intensification (Jensen *et al.*, 2015; Raseduzzaman and Jensen, 2017), as it can potentially increase yields (Bedoussac *et al.*, 2015) while reducing the need for inputs (Hauggaard-Nielsen *et al.*, 2008). This is among other things due to the enhancement of ecosystem services, efficient nitrogen use, reduced pest and diseases and weed infestation levels - as well as reduction of nitrogen emissions to the environment. These benefits are not just interesting from an environmental perspective but also in relation to productivity and resilience in the farming system now and in the future (Altieri *et al.*, 2015; Frison, 2016)

Aligned with the EIP MAA actors especially farmers are involved in both the design and implementation of new innovations through a range of co-designing methods. The actor involvement is initiated through Multi-Actor Platforms (MAP) across Europe being physical units producing, gathering and distributing demand driven local knowledge regarding intercropping principles and species mixtures.

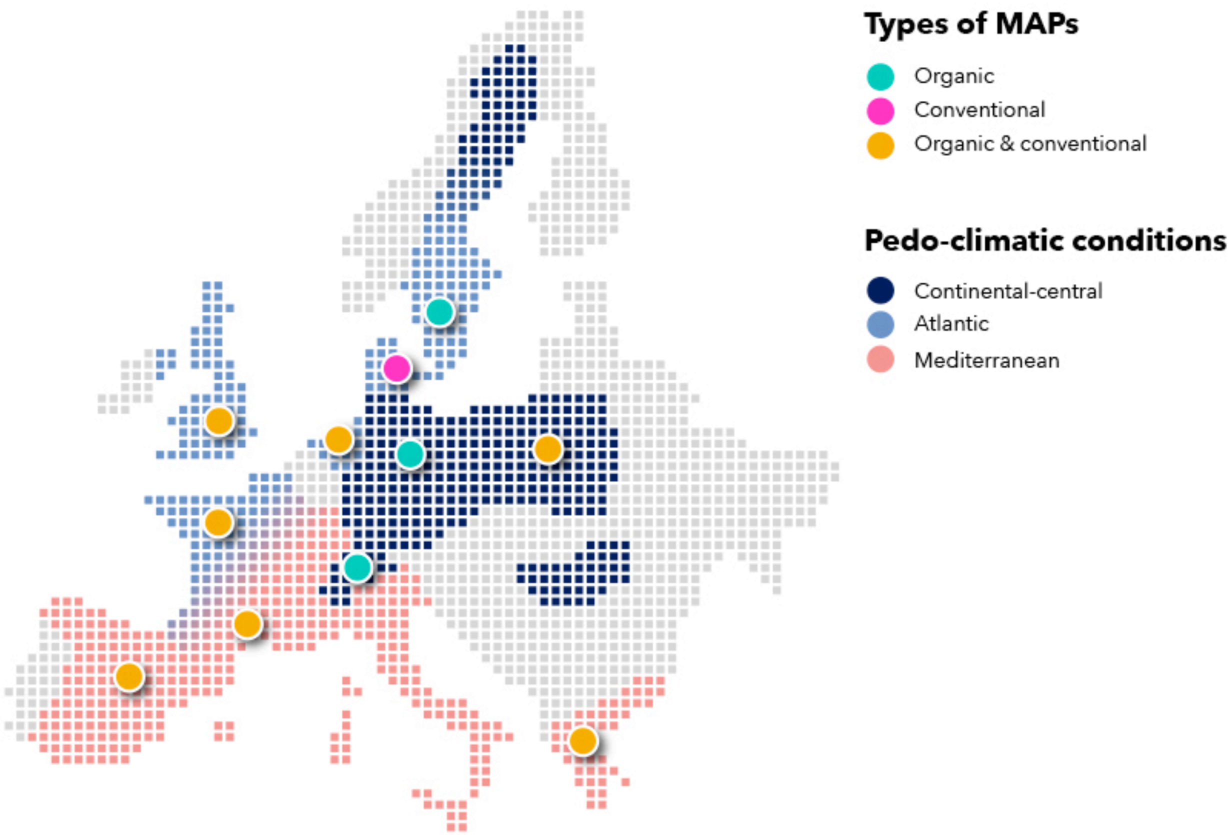

Figure 4. Illustration of the 11 ReMIX Multi-Actor Platforms (MAP) located across Europe.

Based on the presented experiences recently initiated ReMIX research activities in Denmark points towards three main strategies for increased knowledge sharing and co-designing. The research include i) classical demonstration of plot trials and field operations using farmer equipment headed by consultancy company and university researchers The aim is to monitor and challenge the tradition consultative approach where farmers visually realise challenges and opportunities through advisory dissemination with no control over the type of solutions ("doctor-patient" relationship). The second activity includes ii) local experiments of intercropping strategies performed and evaluated by farmers including knowledge sharing with local farmers and community. 10 farmers identified through a demonstration day at the above mentioned plot trial will test a freely delivered cover crop mixture at their individual farms. Researchers will learn from following these farmers both at the field and through interviews mapping their current knowledge, pros, cons, considerations and knowledge sharing around the use of mixed cover crops. Finally, the research includes iii) facilitation of farmer's group of innovative farmers discussing possibilities for local adoption of intercropping and other agroecological principles through workshop, games, social media etc. The aim is to test and evaluate alternative ways of knowledge sharing through concrete activities in a focus group. Drawing on the results from all activities the goal is to provide concrete suggestions for institutional changes that can foster an increased share of innovations and knowledge among farmers and thereby support a transition towards more diversified agricultural systems in Europe.

By acknowledging the influence of various actors (farmers as well as actors representing other parts of the sector) the MAA approach encourage a systemic perspective on the agricultural sector. Socio-technical system analyses (Gells, 2005) of the agricultural sector are used in the ReMIX project to identify some of the key obstacles (technical solutions, structures, traditions, law, values etc.) for transition towards more diversified agricultural systems and to provide an overview of country specific barriers and possibilities for further application of intercropping principles in the agricultural production. Apart from revealing the lock-in situations involvement of actors representing those parts of the agricultural sector creating lock-ins for targeted transitions is the first step to overcome present demanding obstacles (Geels, 2005). Acknowledging the classical agronomy and food science the socio-technical perspective however require the inclusion of social sciences challenging the cross-disciplinary capabilities of the researchers.

Due to differences in both local natural and social conditions the variation span among the ReMIX MAPs is significant. Furthermore, the MAA call for demand-driven research increasing the diversity among the MAPs and the investigated issues associated. Creation of useful and transferrable knowledge and experiences from the outcome of research attached to very different conditions and demands across the member states is an essential however challenging task which have to be accomplished in the ReMIX project. In this sense the ReMIX project also work with the use and legitimacy of local in opposition to generic knowledge and how it is possible to create valuable knowledge or translations of knowledge across geographical and social contexts.

The suspected outcome of ReMIX is to obtain a better understanding and concrete recommendations for co-designing processes and knowledge exchange assisting innovation and transition towards future sustainable agricultural management providing public goods.

4. Commons and agriculture

The assumption behind the presented research is that a participatory approach to agricultural research and planning can help to promote more successful sustainable transitions in Danish and European agriculture. Stronger linkages to public goods and a more prominent role for farmers can open up for more integrated solutions for management of the commons. This rely on the perception that a common platform of knowledge and goals between society and the ones who have to carry out the transition is a prerequisite. The involvement of farmers also creates an opportunity to gather important knowledge while facilitating farmers learning and realization pushing the actors forward in a transition process. Agriculture is intertwined with public goods which depend on farmers' collective knowledge. The traditional strong scientific advancement of agronomy and food science might benefit from including the contribution of farmers to rural development through social innovations (capital).

However, involvement of the agricultural sector might not be sufficient to initiate a sustainable transition that meets the interest of the broader society eg. compensation for negative externalities such as biodiversity loss, mitigation of climate change, water and air pollution, and in particular the depletion of natural resources, including soil quality. As market prices do not reflect the public goods, which society rely on the farmers to deliver public investment and regulation are needed to meet the common interest of society.

EU spends > €50 billion on the Common Agricultural Policy with the primary goal to support European food security and farmers' income, but also to improve the environmental impact of agricultural production. 30 pct. of the direct payment is distributed as Green direct payment requiring farmers to diversify crops, maintaining permanent grassland and dedicating land to ecological beneficial elements (EU, 2017). A new CAP reform is expected during the next couple of years and a break with the one-size-fits-all regulation has been proposed due to the great differences in farms and farming practices across Europe. The suggestion is to partially decentralize the administration of direct payment by allowing member states to choose the measures relevant for the individual state. Meanwhile a new Danish legislation for fertilization will become effective from 2019 taken into account the local differences by differentiating the permitted allocation of fertilizer according to the sensitivity of the area.

New tendencies in European and national regulations are pointing towards increased focus and acknowledgement of local differences. A more decentralized planning and regulation however requires more understanding of local conditions and inclusion of local actors. In this respect, many questions remain unanswered. How can we create a platform for a multi-actor debate and formulation of common goals and solution for European land-use and food production? And how can regulation take into account both local and social differences among farmers while maintaining the pressure for sustainable transition of agricultural production?

Along with the intensified land-use for agricultural food production there is a need to develop and maintain a farming landscape with multiple functions and services – being ecological or social - to enhance public goods and to reveal more options for adaptation to environmental and socio-economic changes. In order to support such development the authors of this paper suggest a stronger emphasis towards multiple forms of expertise from academics, practitioners, businesses, land managers and the public to make valuable contributions to the knowledge base. A fruitful compilation of these sources of knowledge is challenging and requires a cross-disciplinary approach. However, the increased complexity and urgency of the challenges surrounding the agricultural sector call for mutual enrichment of scientific and nonscientific knowledge to combat future challenges managing the commons.

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