Chapter 17
Observing farming systems: Insights from social systems theory

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Abstract *In Denmark, agriculture is becoming increasingly specialised, and more and more actors are becoming involved in farm decision making. These trends are more or less pronounced in other European countries as well. We therefore find that to understand modern farming systems, we have to shift the focus of analysis from individual farmers to communication and social relations. This is where Luhmann's social systems theory can offer new insights. Firstly, it can help observe and understand the operational closure and system logic of a farming system and how this closure is produced and reproduced. Secondly, it provides a theory of functional differentiation and structural couplings that opens up for a new approach to look at sustainability by way of decoupling, recoupling and new forms of coupling.*

Introduction

In this chapter we will introduce our usage of *Luhmann's systems theory* and actor network theory (ANT) to observe farming systems, especially to see how farms are organized and how decisions are made, but also to see and understand some of the problems of sustainable development of food chains. Both theories are analytical and can be used to observe and understand different aspects and development pathways of farming systems, but they are not normative theories describing better ways to decide or organise. Luhmann's systems theory offers, with some modifications, the opportunity to see farms as autopoietic systems and to observe functional differentiation (specialisation) and structural couplings (coordination) between systems in food networks. ANT provides us with a perspective to observe and understand the very heterogeneous corpus of a farm consisting of natural, technical, economical and social elements and interactions.

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Normally these two theoretical bodies are seen as very much in opposition to each other. However, what binds them together is their foundation in semiotics and communications, where relations are not causal but interpretations of causes. Luhmann's systems theory sees systems as communicative systems where utterances get their meaning through their relations to other utterances, and in ANT elements become agents through their network relations. Readers of rural sociology and human geography journals will be familiar with the widespread use of ANT, especially in relation to studies of agri-food networks, whereas Luhmann's systems theory is only rarely referred to. This chapter is meant as an appetiser to these theories and their application to farming systems, and as a source of inspiration on where to proceed if you would like to learn more. In accordance with this, the chapter begins with an introduction to our background for choosing Luhmann's systems theory and ANT and combining them. This is followed by a brief introduction to how we have operationalised these two theories to observe farming systems, with examples of insights we have obtained by applying this theoretical framework to see and understand farms as systems and the transformation processes going on within farming systems. The last section is devoted to a more comprehensive analysis of the increasing problems of developing sustainable food networks, drawing especially on Luhmann's notions of functional differentiation and structural couplings.

Why Luhmann's systems theory and ANT?

Through our involvement in a research group on 'farming systems studies' during the last 20 years, we have been researching sustainable development of farming systems in Denmark based mainly on longitudinal case studies involving private farms.

In relation to these studies we have seen a development that has increasingly challenged our common theoretical and conceptual understanding of a farm as a coherent unit of organisation, with a farmer and his family living on a farm in the middle of his farmland, making decisions on how to produce food and maintain the production capacity.

In Denmark farm sizes have increased dramatically. From 1990 to 2010 the number of fulltime farm enterprises has decreased from about 34,000 to about 12,000 (Landbrug og Fødevarer 2011). There are a range of characteristics in this development of agricultural production and food systems which pose increasing demands on the abilities of farmers and other actors to handle knowledge and complexity, and which are also highly challenging to our theoretical understanding of farming systems (Noe and Alrøe 2003).

We have seen that the farms have become still more specialised, so that almost all Danish farms now are specialised in one branch (such as pig production), and often only in parts of a branch (such as piglet production), compared to the situation in the 1960s, where almost all farms were mixed farms.

In connection with this specialisation, developments in knowledge and technology have lead to an increase in the number of different technical solutions. The revolution in computer technologies has especially given options for individually tailored solutions for automation and rationalisation of work tasks and routines on farms. An example of this is the different milking systems from automatic milking systems (AMS) to milking carousels, which have formed the basis for very different dairy farming systems (Noe and Kristensen 2003).

At the same time, we have witnessed that more and more people and organisations from outside the farm have become involved in the operations within the farm as well as in decision making, knowledge exchange and learning processes. Examples of this are the veterinarian who is responsible for the reproduction control, the inseminator who is responsible for the breeding strategy, and contractors who are responsible for the arable production. Moreover, when we look at what we normally consider as strategic decision making, more and more farms have established 'farm boards' involving for example the bank advisor, other advisors, and managers from other businesses.

We have also witnessed that the focus of farm management has gradually shifted from maintaining coherence between internal processes on the farm and reproduction, to managing relations with external actors and systems, inputs and sales, specialised advisors, financial partners and handling active capital.

These developments have led to a tremendous increase in productivity and efficiency of agricultural production, especially in terms milk yield per cow, number of piglets per cow, and number of hectares managed per labour units (Landbrug og Fødevarer 2011). At the same time we have witnessed the development of Danish agriculture which is moving away from multifunctional farming. Former semi-natural areas such as permanent grassland are either abandoned for agricultural production or transformed into intensive agricultural production. The landscapes are gradually reshaped to fit into the production systems, forming very large fields by removing all the hedges, roads and biotopes that disturb the operations. Due to specialisation the number of crops included in crop rotation has been reduced, which among other things has resulted in an increased use of pesticides.

These development trends are not unique to Denmark. They are common to more or less all the western European countries, although there are different development pathways. In the 1980s there was a huge debate on how to define family farming in opposition to the rising numbers of industrialized farming systems, and a discussion of the values related to these different systems (see e.g. Gasson and Errington 1993; Djurfeldt 1996). In terms of the processes of industrialisation and structural development, Denmark can be seen as an extreme case, compared to most other European countries, but also as a possible future scenario for them.

In our *farming systems studies* we have realised that we increasingly have to include descriptions of the involvement of other people, contractors and capital, and not only what we used to include, like buildings, machinery, land husbandry and labour, in order to describe and understand the organisation and flow of operations of a farming system. The boundary of what belongs to the farming system and what belongs to its environment becomes increasingly difficult to draw or define, especially in a biological and physical sense.

This development raises questions like: How can we understand farming systems in more and more network-like food production systems? What is a meaningful way to draw the boundaries between system and environment in order to be able to hold, observe and understand this development? How can the individual system or farm enterprise handle this seemingly increasing chaos, and what are the necessities of reducing complexity? On a larger scale, what does the specialisation and differentiation of agriculture and food production mean for the challenge of developing a multifunctional and sustainable agriculture that not only considers efficient food production, but also the environment, climate, landscape and rural development?

In our search for ways to describe and understand farm management and farm development, we have found the combination of Luhmann's systems theory and actor network theories fruitful. In the following we introduce some of our work in this area.

Farming systems organisation and farm management

In this section we will look at the challenges to farming systems organisation and farm management given the increasingly *complex network organisation* of food production. As described, we have observed a growing involvement of external actors in farm operations and decision making, such as advisors, veterinarians, financial partners, contractors, input suppliers, and operators and maintainers of new technology and equipment. This growing dependency on external actors has not only challenged the management of the farming system to cope with this increasing complexity, but also our understanding of a farming enterprise as a system organised through internal relations between objects and subjects within the farm. A key theoretical question is how the internal order, the organisation that keeps the system from breaking down, is sustained and developed in farming systems that have to cope with a more and more *complex surrounding world*.

Mapping the relational structures of farming systems

The first step in addressing the question of organization is to look at the relations that make up the network of a farming system.[1] In addressing this question, we find it useful to use the language of *Actor Network Theory* (ANT). ANT focuses on the heterogeneous relations between the entities of the social, biological, and technical domains of the world (Latour 1997). Its strength lies in the general and open mapping of the relational structures of networks, and this approach is well suited to address the heterogeneity of agri-food systems.

[1] We use the notion 'farming system' and not farm, for two reasons. The first is that the notion of a farm is widely associated with a well-defined physical unity of farmland, buildings, animals, machinery, family and labours, but in reality the organisation of agricultural production is much more complex. The second reason is that new forms of arrangements and organisations of agricultural production are emerging, involving new sources of capital and new forms of cooperation and coordination, which is not covered very well by the notion of a farm.

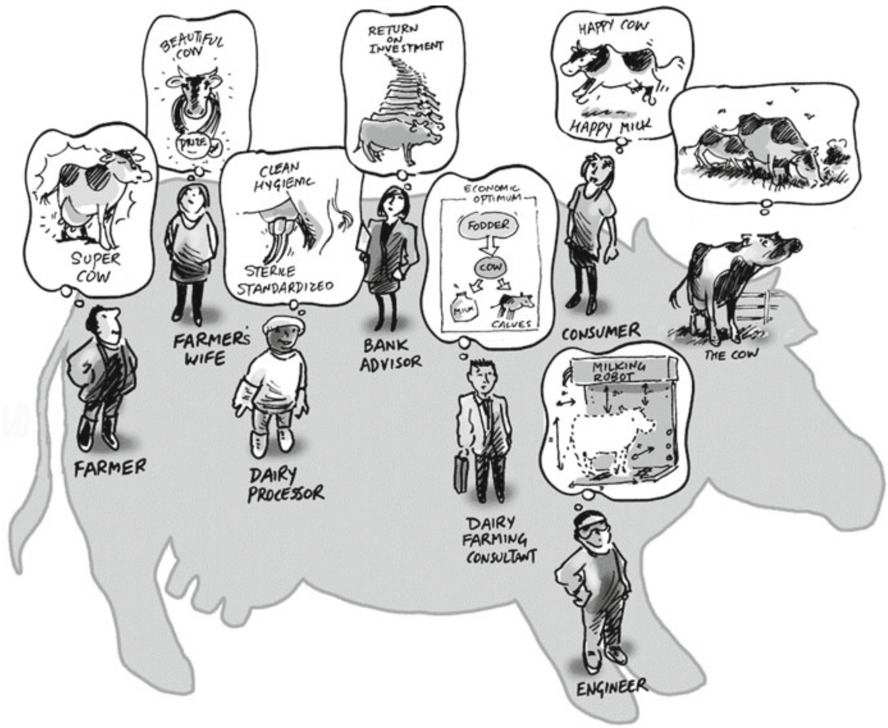

Fig. 17.1 Building on the understanding of ANT, a cow can be conceptualized very differently by the different people involved in the system. Depending on how the cow is enrolled into the project of an actor, different elements and potentials will be emphasized and developed

ANT strives to take a comprehensive semiotic view on human interaction and organisation (for a detailed discussion of ANT and semiotics, see Noe and Alrøe 2006). As Law puts it:

> I simply want to note that actor-network theory may be understood as a *semiotics of materiality*. It takes the semiotic insight, that of the relationality of entities, the notion that they are produced in relations, and applies this ruthlessly to all materials – and not simply to those that are linguistic. (Law 1999:4)

The perspective we get from understanding farm enterprises from an ANT approach is that the entities enrolled get their forms and performances through their relations (Law 1999:4). This means that the way the individual actor or element enters into the dynamics of farm processes and operations is not determined by the objects, but by the agency it obtains through the interactions. To illustrate this, there is a *surplus of possibilities* for how a cow can be enrolled in a farming system (Fig. 17.1). A particular cow could eat grass from the field on one farm and on another farm stay in the stable and eat concentrate. Theoretically, the same cow may produce 12,000 kg milk in one system and 7,000 kg milk in another. The same kind of difference can be explored for the other entities that are enrolled, such as wheat varieties, computers, etc.

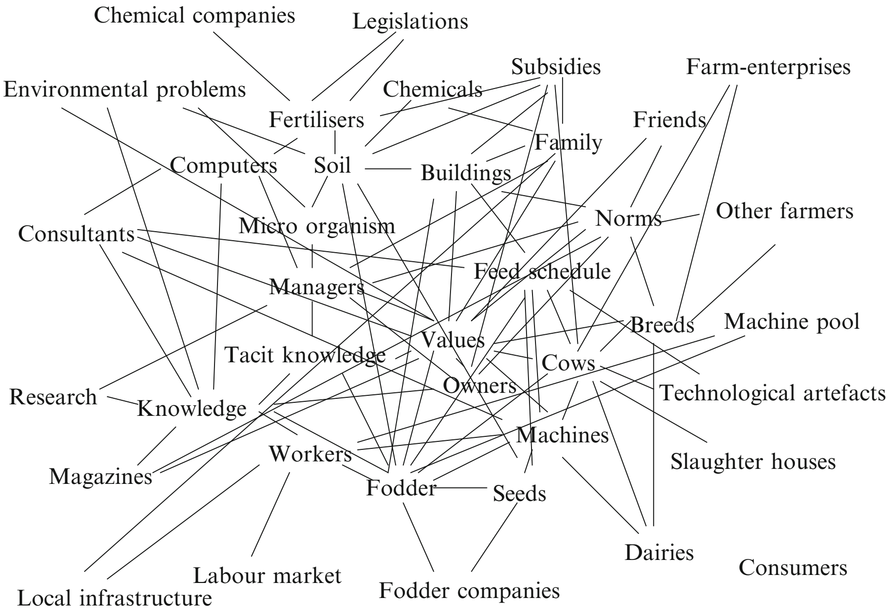

Fig. 17.2 A farm seen as an Actor Network, that is, as a complex network of relations between the elements enrolled as actants in the network of the farming system. This encompasses both elements that we commonly regard as belonging to the farm but also elements that are organised by other actor networks like a harvesting machine owned by a machine pool. The *lines* illustrate these interactions and are just examples, and in reality the actor networks of farming systems are much more complex than this. As an empirical approach the actor network can be explored by taking some of the key actants on the farm as the point of departure and exploring the way interactions are formed with other actants (Illustration from Noe and Alrøe 2006, reprinted with permission from Imprint Academic)

In the language of *semiotics* and ANT there will, as a continuous process, be a '*negotiation'* between the object and the representation. Let us again use a cow as an example to illustrate this relationship. The representation of a cow in a particular farming system could be that it is an actant that can produce 14,000 kg milk per year. The cow, as an object, will 'negotiate' with this representation either by producing the amount under the present circumstances or by striking back, e.g. by not fulfilling the expectation or by getting serious health problems. On the other hand, the negotiation process also affects the object, and thereby it can add to the range of possibilities of the object through for instance selection of genetic breeds that code for high milk production.

This means that a farming system is not defined by what elements and actors are parts of it, but by what role they play, or in ANT language, by how and in what relations they enter as actants in the network.

In a *farming system* seen from an actor network perspective, there are many objects that are translated and enrolled as actants into the Actor Network of a farming system, e.g. dairy cows, various kinds of machines, fields, sunshine, rain, computers, various kinds of plants, labour, family labour, experience, skills, knowledge, values and goals (Fig. 17.2). The kinds of objects that are enrolled or not enrolled as actants into the network, and how they are enrolled, depends on the characteristics of the enterprise, e.g. whether the commercial consultants or the consultants of the farmers' unions are enrolled and to what kind of performances they are enrolled. Empirically the actor network is far too complex to include all actors and relations, but in our experience a good analytical strategy is to start with the key actants of the system, for example the cow if it is a dairy farm: What kind of milking systems are enrolled (AMS, carousels or other systems) and what are the interactions between milking system and cows, who is involved in milking, and what skills are involved. What kind of fodder is offered to the cows, what foddering systems are in place? What is the interaction between the cow's fodder system, fodder quality, milking system and labour? Often just by looking at the interactions between these four elements of a dairy farm, one is able to detect the major differences between how dairy farms are organised, and also whether the strategy of the farming system is coherent.

Given the many possibilities linked to each object, one may easily realize how important it is for the coherence of the production strategy and the economical results of the farming processes that the interactions in the actor-network are negotiated in accordance with the strategy of the farming system.

The self-organisation of a farm through selection of meaning

Luhmann's theory of social systems is based on a theory of biological organisation developed by Maturana and Varela (1980, 1987). The central idea of Maturana and Varela is that biological organisms are open for material flow, but *organizationally closed* and *self-referential*, that is, they are *autopoietic*. It is the organism itself that constructs its own components and reproduces its own organisation. That the autopoietic system is self-referential means that every input for organisation is produced by the system itself. A good example to illustrate what is meant by self reference is pain. It is the sensory cells that produces the nerve impulses that makes us feel pain if we hit a needle, and not the needle itself. Without the sensory cells and our nerve system there will be no way the needle could cause our reaction.

Luhmann has adopted this foundational systems theoretical idea about autopoiesis and closure to social systems as *communicative systems*.[2] Luhmann defines a system as the difference between the system and its environment. The communication itself determines what belongs to the communication system and what belongs to its environment.

> Autopoietic systems are systems that are defined as unities as networks of production of components that recursively, through their interactions, generate and realize the network that produces them and constitute, in the space in which they exist, the boundaries of the network as components that participate in the realization of the network. (Luhmann 1990:3)

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[2] We are aware that many authors, not least the founders of autopoiesis theory Maturana and Varela, have augured against the use of the notion of autopoiesis on social systems. For a more comprehensive discussion on that see Noe and Alrøe (2003, 2006).

Luhmann distinguishes between three kinds of autopoietic systems: *biological systems* operating in life, *psychic systems* operating in thoughts, and *social systems* operating in communication. Both psychic and social systems operate in meaning. None of these system definitions fits readily to heterogeneous social systems such as a farming system. From an ANT perspective we have the insight that the negotiation process of a farm is not only communicative or cognitive; that it is continuously taking place in all *interactions* between actants enrolled in the farming system.

But still Luhmann's theory of autopoietic systems provides some fruitful notions for the study of farming systems as self-organizing systems. To apply Luhmann's ideas of social systems and organisational closure from autopoietic systems theory on farming systems, such as a farm enterprise that consists of a complex network of social, technical and biological relations, it is necessary to develop an understanding of system closure that goes beyond communicative closure and self-reference.

In Luhmann's terminology, *meaning* is linked to the fact of complexity that every operation enforces a selection:

> Meaning is a representation of complexity. Meaning is not an image or a model of complexity used by a conscious or a social system, but simply a new and powerful form of coping with complexity under the unavoidable condition of enforced selectivity. (Luhmann 1990:84)
>
> The phenomenon of meaning appears as a surplus of references to other possibilities of experience and actions. … Reference actualizes itself as the standpoint of reality. It refers however, not only to what is real (or presumably real), but also to what is possible (conditionally real) and what is negative (unreal, impossible). The totality of references presented by a meaningfully intended object offers more to hand than can in fact be actualized in any moment. Thus the form of meaning through its referential structure, *forces* the next step, to *selection*. This inevitability of selection enters into consciousness of meaning, and for social systems, into communication about what is meaningful. (Luhmann 1995:60)

Heterogeneous systems such as farms may be organized in numerous ways according to different goals and purposes, e.g. organic or conventional production. The farm as a heterogeneous social system must select a meaning in the surplus of possibilities offered by each object that is mobilised into the system/network, to be operational at all. But the network or system needs a kind of meaningfulness to make a situation of coherence possible and likely. According to Luhmann the production or reproduction of such system meaningfulness must be an internal process of the social system, in this case the farm. The encompassing world offers a surplus of meaningfulness, and the system has to select and develop its own to be operational and settle on a coherent strategy.

The farm as a heterogeneous social system is not only *forced to select* in the *contingency* of the objects that can be mobilised into the farming processes like pigs or cows, but also in the contingency of the potentiality related to each object that is enrolled; e.g. a computer can be enrolled as device for the yearly accounting or as part of a daily steering system. Any decision making system faced with such a degree of contingency needs to reduce complexity, both internally in terms of which elements are enrolled, and with regard to its environment in terms of what is important to observe and what is not. Otherwise it will break down immediately due to the overload of possibilities. The formation of a farming system needs a first choice to be made: an operational closure in terms of a selection of possibilities within the

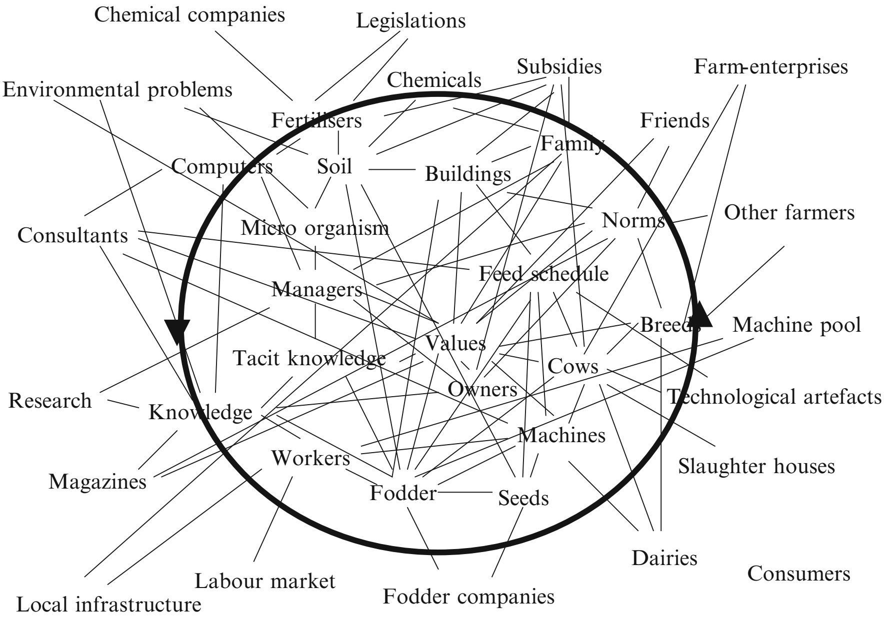

Fig. 17.3 A farm as a self-organizing system. The *circle* is meant as a symbolic illustration of the operational closure of a farming system. It is not a literal distinction between elements that belong to the system and to the system's environment, but a symbolic representation of which negotiations of interactions between actants are possible and which are not possible (Source: Noe and Alrøe 2006, reprinted with permission from Imprint Academic)

autopoietic system and a closure towards the possibilities left out. In other words we use the notion of operational closure for farming systems as description of the distinction between what is possible and what is not possible to consider within the system. Like a cell creates its own *operational closure* in terms of is cell membrane, open for material diffusion but closed in terms of its own operation of production and reproduction, a farm needs to create itself through the selection of possibilities open for internal operation (Fig. 17.3).

The self-organization of social systems as autopoiesis is then a process of *reducing complexity* by *selection of meaning*. The selection of meaning must be a system-internal and self-referential operation by which the system draws its own operational boundaries.

System rationality or the inner logic of the system

Another characteristic of an autopoietic system is that it has its own internal *system rationality* or logical schema at its disposal. Autopoietic systems are operationally closed systems. This means that the system must produce its own input for operation.

For instance the needle does not produce the feelings of pain while the person who feels the pain does. The nerve cells are only transmitting impulses, and it is in the mind that this disturbance is translated into pain. So, it is the internal schema of the system and not the specific quality of the perturbation that defines how a system reacts to a certain perturbation. The ability to be irritated by the needle (to feel pain) is a quality of the system and not of the needle.

> The environment is a world horizon that corresponds to the system's internal horizon. Therefore, a system's rationality cannot be clarified by referring to a superordinate, encompassing system. (Luhmann 1995:474)
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> Translated into the language of causality, this idea decrees that a system must control its effects on the environment by checking its repercussions upon itself if it wants to behave rationally. A system that controls its environment in the end controls itself. (Luhmann 1995:475)

The notion of self-reference also leads to a general understanding of observation, namely, that it is the internal complexity of the system that is limiting the capability of the system to observe itself and the capability to observe the encompassing world. This is in line with the biosemiotic understanding of each biological species having its own subjective or phenomenal world, or Umwelt, in the tradition of Jakob von Uexküll (1982).

As illustrated by the example of the needle above in autopoiesis theory, influences from the environment can only be irritations, and it is an ability of the system to become irritated it is the system that determines its reaction to them. This is of course not always as reflex reaction; if I'm hit by a needle I will presumable react before knowing it, but if the doctor is giving me an injection I will feel the pain in another way and react differently. Over time, the system may change its structures of expectation and thereby establish structural couplings with its environment, corresponding to the classical ideas of learning and adaptation. A *structural coupling* is "the specific form in which the system presupposes specific states or changes in its environment and relies on them" (Luhmann 1991:1432). In this way structural couplings reduce and facilitate influences from the environment.

According to Noe and Alrøe (2003), the ontological understanding of a farming system as a self-referential autopoietic system expands the possibilities for observing and understanding the complexity of farms. For example to observe the rationality and values around which a farming system is organized; explore what kind of internal and external observations are involved in the management; and observe whom and what is involved in the management processes. All these aspects are adding to the exploration of farm management based on the inner system logic (Noe 1999).

Insights in types and styles of farming

Experienced extension practitioners will know that what could be a good advice for one farm could be a disaster for another. Our personal experiences from working with extension practitioners are that they often explain these differences as good and bad farmers, depending on their own view on farming. But systems theory leads us to see a deeper explanation. Every operation and object is woven into the *network of semiotic relations* of the farm; and farm management is a continuous process of negotiations of coherence in all the involved network relations. This explains why there is not just one optimal strategy for production that all farming systems should strive for. Every farming system will have to make some initial choices to become an organisation (to obtain operational closure). This means on the one hand that it can start to operate and on the other hand that a lot of potential possibilities are omitted.

The negotiation of internal coherence (operational closure) is not only a matter of negotiation (in the semiotic sense described earlier) between the actors that are closely linked into the farming process, but also with the machinery, advisory systems, suppliers, etc. This negotiation process therefore needs to be a co-evolutionary process between various organisations. The '*styles of farming*' can be seen as an approach to study the development of farm management strategies into clusters of different types or 'styles' (van der Ploeg 1994). A social systems approach can add to this the understanding that the clustering around certain internal production logics can be seen as a necessary reduction of possibilities in the structural couplings between the different organisations and actors involved. An insight we have used to study, among other things, farmers' use of decision support tools (Langvad and Noe 2006).

Finally, this autopoietic understanding of farms implies that the coherence of a farm cannot be explored by studying only the elements that are enrolled into the system. The coherence needs to be studied from the perspective of the system or network, that is, it is the strategy of the farming system to achieve coherence and closure that needs to be studied.

Insights in farmers' reactions to legislation and support

People involved in regulation of agriculture will know that farms do not always react in the expected way to new legislation and incentive structures. This could be seen as a cognitive problem: the farmers do not have the right knowledge, or they have the wrong attitudes. Knowledge and attitudes do of course play a role, but Luhmann's social systems theory helps us to understand the strength in the resistance towards reacting in a specific way.

Applying the autopoietic understanding of farming systems, *the system has to produce its own input to react to changes in the environment*. As it is described above, it is the internal logical schema of the system and not the specific quality of the perturbation that defines how the system reacts to a certain perturbation. For example, if the milk price is going down, the farming system first of all has to be able to recognise that there is a decrease in milk price. Secondly, the recognised difference must be interpreted by the system: Is it due to a decrease in the quality of the delivered milk, or to temporary price fluctuations? Or is it a sign of a permanent decrease due to decreased demand or harder competition on the world market? How these observations are made by the system will vary from system to system, and needs to be investigated as an empirical question. It could be the bank advisor who raises the problem, it could be the cowman. Finally, the reaction by the system to this situation will again depend on the system itself: some will just carry on, believing that the situation will improve again, others will start working harder, some will change their strategy, and again others will give up dairy farming.

This means the different farming systems (with different farming styles) will be sensitive to different perturbations. If the farming strategy is organised around market opportunities, even small changes in price relations could lead to changes in the internal operations. If the strategy is organised around high yields, even large changes in price relations may not change the internal operations.

The sustainability challenges of differentiation and specialisation

Specialisation can be seen as a necessary consequence of *the increase in complexity*. Developments in research, technology and society create an increasing range of possibilities, and at the same time other possibilities are closed. Specialisation leads to a reduction of the environmental complexity that the system needs to deal with; but at the same time this means that the single farming system moves further and further away from the perspective of multifunctional and sustainable agriculture. In this section we will apply the insights of the previous section in exploring the challenge of multifunctional and sustainable agriculture. As a background for this, we will first provide a brief narrative that describes the specialisation and differentiation of Danish agri-food systems. Similar developments have taken place and are taking place in other countries, though within different timeframes and with variations due to the different structures of agricultural production.

Increasing differentiation and specialization of agri-food systems

When we look at the development of industrialized agri-food systems, there are at least two major parallel historical developments which are mutually conditional, but which it is analytically appropriate to separate:

- *Vertical differentiation* into more links of the food chain through specialisation of operations into autonomous organisations.
- *Horizontal differentiation* into separate branches of agricultural production.

The *vertical differentiation* can be described as two processes. One process is the genesis of more links in the food chain. Take for instance the production of pig meat, where piglets and fattening of pigs have increasingly become divided into two different farm enterprises, selling and buying piglets at market prices, and the slaughtering and processing of pig meat have been separated into two or more different independent enterprises.

The other process is the increasing separation of links in the food chains. For instance the input suppliers and dairies in Denmark were originally cooperatives organised by the farmers around the needs and problems of processing and selling the products of the farms. But these cooperatives have grown into very large and highly independent companies that focus on optimizing their own business operations, buying and selling raw products at the global marked, and investing in companies in other countries.

While there has been a long historical process of vertical specialization and differentiation within agriculture, the *horizontal differentiation*, in particular at the level of primary production, is of relatively newer date. Until the mid-1960s almost all Danish farm holdings were mixed farming systems with a balanced production between plant, cattle, pig and poultry production. Livestock fodder was produced on the farm, fields were used for grazing, and manure from the livestock production was spread on the fields of the farm. A number of simultaneous developments, including mechanization and the development of agrochemical components, made a horizontal differentiation possible. Within a decade (1965–1975) there was an almost total specialisation and functional differentiation in different production branches, and the mutual bindings or structural couplings between the different productions branches diminished. Simultaneously, the professional and political organisations in the fields of pigs, cattle, poultry, eggs and plant breeding evolved as independent organisations.

If we look again at pig production, there was at first an internal differentiation between plant production and meat production at the farm, and gradually the two operations became more independent of each other and increasingly driven by different optimization rationales. The main purpose of the plant production was now not necessarily to feed the pigs, and the pig production did not necessarily have to adjust to the productivity of the plant production. Many factors have influenced this development of specialisation and functional differentiation (Noe and Alrøe 2012), and this is well described in literature (see e.g. Goodman et al. 1987; Goodman and Watts 1997). Seen from a social systems theoretical perspective, the fundamental driving forces behind this development is the logic of reduction of complexity.

Reduction of complexity and the challenge of sustainability

According to Luhmann's social systems theory, the specialisation and differentiation of agriculture and food production is an unavoidable consequence of the increase of complexity. Here we will analyse why and how this poses challenges to the development of a *multifunctional* and *sustainable agriculture*.

The driving force behind the organisational specialisation and differentiation is the striving for *reduction of complexity*. The single organisational system reduces the range of complexity that it can be disturbed by, enabling it to handle the remaining complexity and even increased complexity, within the selected range. Reduction of complexity in the single organisational system, through differentiation and specialisation, thus forms the basis for the ability of the network to handle increased complexity overall. Complexity is only reduced from an *internal systems perspective*, and marginalisation of complexity may therefore be a better expression.

The two forms of differentiation of organisational systems within agriculture and food described in the previous section are based on different forms of reduction (or marginalisation) of complexity in systems operations:

- reduction in the complexity of consecutive operations (vertical)
- reduction in the complexity of parallel operations (horizontal)

As described above, these two movements in terms of reduction of complexity free the focus of the production systems to optimize internal operations. It frees piglet producers to become more and more efficient in producing piglets, dairy farmers to produce more and more kilos of milk from each cow, the abattoir to reduce costs of slaughtering the individual pigs, etc. This increase in efficiency can be seen very clearly in the increase in productivity that has happened over the last 50 years.

However, with this reduction of the internal complexity, these organisational systems also reduce the complexity of their environment (their Umwelt or phenomenal world in the semiotic sense), that is, the systems reduce the types of differences in the encompassing world that are allowed to disturb them, and there is an increasing degree of de-coupling.

The first form of reduction, which is related to the vertical differentiation into more links in the chain, means that the farm businesses seemingly have to worry less and less about what consumers think, because the relation with the consumers are more left to the processors, and even increasingly to the retailers using private labels. The farming system's environment is constituted by the processors and who will pay the highest price for its products.

This vertical differentiation therefore makes it possible to de-couple some of the quality dimensions that were previously mediated through the food chain; *quality dimensions* that may have been associated with long-term sustainability (Noe and Alrøe 2011). When you buy pork meat in the supermarket you have to look carefully to see where it has been produced. Unless you buy special products, there are no links between what you buy and how the pigs are produced, like the housing condition of the piglets, nutrient emissions, use of fossil fuels, changes in soil quality, etc. This type of *decoupling* can therefore be one of the causes of the sustainability crises because of the lack of a feedback mechanism between producers and consumers linked to the products (Noe and Alrøe 2012).

The second form of reduction, which is related to the horizontal differentiation into parallel production branches, means for example that pig meat production systems no longer have to worry about soil fertility and a sustained production of animal feed. The development within the agrochemical industry means that arable farming systems no longer (at least in the short term) have to worry about the sufficient supply of manure, crop rotations that match the availability of nutrients in the soil, etc. Recycling of nutrients is often much more difficult and harder to control than the use of inorganic fertilisers. The horizontal differentiation allows a decoupling from processes like recirculation of nutrients and organic material and crop rotations that are to increase soil fertility, processes that are of central importance for the long-term sustainability of agricultural production.

Insights into addressing sustainability problems through new structural couplings

The reductions of environmental complexity entailed by processes of horizontal and vertical differentiation reduce the possible disturbances (or irritations) to the system. Thus individual agricultural activity has to cope with fewer disruptions through responses in *the internal organisation and management* of the system. However, as mentioned above, there will also be an extension of disturbance possibilities and possible couplings within the specialised area of the system. A logical consequence of these differentiation processes is that the agricultural praxis is generally moving away from a position that can handle the *plurality of perspectives* involved in the semantics of sustainability; and away from a condition where they are sensitive to irritations that are expressions of the various dimensions of sustainability.

An example to illustrate this problem is the decomposition of humus in agricultural soil as a result of monocropping and heavy mechanical treatment of the soil, resulting in a loss of carbon in the form of greenhouse gas emissions that contribute to global warming. The humus content of the soil is crucial for the natural fertility of the soil, but the agrochemical components in terms of fertilizers and micronutrients makes a decoupling from the soil fertility possible, and allows farm enterprises to not be disturbed by changes in the humus content and therefore not to include these concerns in the decisions of internal operations. Only if the greenhouse gas emission is *reintroduced as a major disturbance* in terms of governmental economic or legislative means, or as a special market quality, can the concerns of the humus contents be reintroduced into the operations of the systems.

Based on a Luhmannian systems theoretical analysis we are led to the conclusion that the sustainability crisis can be seen as a more or less unavoidable product of the processes of specialization, differentiation and decoupling that take place, and that the general societal development moves us away from perspectives that can observe and handle the complexity of a sustainable development of agriculture and food production.

According to Luhmann the complexity reduction in the differentiated systems is symmetrical with the increase of complexity in society (in terms of the functional differentiation of society, see Luhmann 1995:23–28), and these reductions are irreversible. Therefore the sustainability problem cannot be resolved by a return to a former, more ideal state. A systems theoretical approach to deal with sustainability problems will be to seek to reintroduce the various concerns in terms of re-couplings between the systems in form of *new structural couplings* (Noe and Alrøe 2012).

One way of doing this is through new structural couplings to general perspectives in society (function systems, in Luhmann's terms), which farm enterprises produce to reintroduce changes in the surrounding world to their environment, for instance through forms of ethical accounting. A second way is through new structural couplings between organisations, which can handle other dimensions than price and quantity. For instance couplings that are mediated by labels such as the organic label, or new couplings in alternative food networks based on agreements within the network, which provide new options for *co-evolution*.

The further development of social farming systems theory

The investment in getting into social systems theory is large, but once you are there, we definitely find that it is worth the effort. For more than 15 years we have been applying Luhmann's social systems theory together with actor network theory. In this chapter, we have argued that the binocular use of these two theories has provided a range of insights into the development of farming systems and how it may be observed and studied. We hope that this short introduction to our work has stimulated the readers' interest and curiosity to what these theories can contribute to studies of farming systems and sustainability. And we hope that it will inspire some of the readers to take up the challenge and to contribute to the further development of 'social farming systems theory'.

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