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Synthesis, part of a Special Feature on Multicriteria Assessment of Food System Sustainability

Sustainability assessment and complementarity

Hugo F. Alrøe [1] *and Egon Noe* [1]

ABSTRACT. Sustainability assessments bring together different perspectives that pertain to sustainability to produce overall assessments, and a wealth of approaches and tools have been developed in the past decades. However, two major problems remain. The problem of integration concerns the surplus of possibilities for integration; different tools produce different assessments. The problem of implementation concerns the barrier between assessment and transformation; assessments do not lead to the expected changes in practice. We aim to analyze issues of complementarity in sustainability assessment and transformation as a key to better handling the problems of integration and implementation. Based on a generalization of Niels Bohr's complementarity from quantum mechanics, we have identified two forms of complementarity in sustainability assessment, observer stance complementarity and value complementarity. Unlike many other problems of sustainability assessment, complementarity is of a fundamental character connected to the very conditions for observation. Therefore, complementarity cannot be overcome methodologically, only handled better or worse. Science is essential to the societal goal of sustainability, but these issues of complementarity impede the constructive role of science in the transition to more sustainable structures and practices in food systems. The agencies of sustainability assessment and transformation need to be acutely aware of the importance of different perspectives and values and the complementarities that may be connected to these differences. An improved understanding of complementarity can help to better recognize and handle issues of complementarity. These deliberations have relevance not only for sustainability assessment, but more generally for transdisciplinary research on wicked problems.

Key Words: *complementarity; food system sustainability; implementation; indexation; integration; multicriteria assessment; Niels Bohr; perspectivism; sustainability transformation; sustainability transition*

INTRODUCTION

Sustainability is a key concern for modern society and better and more sustainable food systems is crucial to these concerns. To develop food system sustainability, there is a need to make overall assessments of the effects of food systems on environment and nature, animal welfare, human health and well-being, etc., and to bring those assessments into practice.

The semantic (or discourse) of sustainability emerged around 1980, less than four decades ago, and it has since grown to have an immense public, political, and scientific importance. However, unlike other semantics, like nature conservation, animal welfare, and hunger reduction, sustainability is a paradoxical perspective, in the sense that this semantic wishes to comprise the whole, but must rely on a multitude of scientific perspectives (Noe and Alrøe 2015). Therefore, there is no one overall perspective from which sustainability assessment can be made. To establish itself as a functioning semantic in society, sustainability therefore has to take the form of a multiperspectival or polyocular semantic based on observations of the observations of different specialized perspectives. Moreover, there is no one fixed idea of sustainability; new concerns arise continuously in society and new perspectives emerge in science, such as, notably, climate change in the mid-1980s, which must be included, and the observation of sustainability can never be exhausted or concluded. This inherent paradoxicality of sustainability as a semantic and as a scientific perspective, but not, e.g., as a social norm, forms an unsteady ground for the field of sustainability assessment.

Nevertheless, a wealth of sustainability assessment methods has been developed by science. However, because of the paradoxicality and complexity of sustainability, there are some fundamental methodological issues in sustainability assessment that need to be addressed. In particular, there are two major problems in sustainability assessment that are yet to be resolved. We call them "the integration problem" and "the implementation problem."

The integration problem concerns the surplus of possibilities for integration. Assessing the overall effects is crucial to the sustainable development of food systems, but also a challenge because food systems cannot be fully assessed from any one single research perspective (Thorsøe et al. 2014). In the last decades many sustainability assessment methods have been developed that are presented as integrated, "holistic," or multicriteria tools for observing and assessing sustainability because these tools integrate a range of different indicators pertaining to sustainability (e.g., Ness et al. 2007, Van Passel and Meul 2012). The problem is that these methods are very different in scope and way of integration, they produce different assessments, and none of them can claim to have the right answer (e.g., Reed et al. 2005, Schader et al. 2014). This problem becomes very visible when we look at the indexes that are typically produced by sustainability tools as a means of integrating the multiple assessments and indicators that the tool utilizes. Whether the tool produces one overall index (typically a number between 0 and 100) or a range of indexes presented in a diagram, any difference will be obvious and call for an explanation.

Often such differences are not seen, however, because only one tool has been applied to any one instance. But efforts are made to shed light on the differences and make the assessment results more comparable, such as the global Sustainability Assessment of Food and Agriculture Systems (SAFA) guidelines initiative (see, e.g., Schader et al. 2014), and to categorize the different sustainability assessment tools and provide guidance on how to

[1]Department of Agroecology, Aarhus University

choose the most appropriate tool for each situation (Ness et al. 2007, Gasparatos and Scolobig 2012, Van Passel and Meul 2012, Marchand et al. 2014, Schader et al. 2014).

Unexplained differences and disagreements between different approaches and sustainability tools will not be helpful in bringing sustainability assessments into practice, because they turn public debate into nothing but a rhetorical game. However, there is a deeper implementation problem, which concerns methodological questions of how to bring complex assessments into food system practices and lead to sustainability transformations or transitions (we use these terms interchangeably, cf. e.g., Olsson et al. 2014). This implementation problem has been recognized as a key problem in assessments of food system sustainability (e.g., Triste et al. 2014). Sustainability assessments are complex and typically made by experts, whereas sustainability transformation involves changes in a range of practices involving different actors. And the implementation problem, the problem of getting from sustainability assessment to sustainability transformation, is connected to the methodological choices made in making overall sustainability assessments. (In the following we will talk of "sustainability assessment and transformation" or use only "sustainability assessment" to include both, as in the title of the paper. This reflects our understanding of assessment as part of a larger process of problem solving and transition, and as will become clear, this is crucial to the purpose of the paper.)

A common approach to the implementation problem is to focus on stakeholder involvement and public participation to facilitate the transition toward more sustainable practices, technologies, and organizational structures (e.g., Fraser et al. 2006, Videira et al. 2010, Von Korff et al. 2012). It is generally agreed that better decisions are implemented with less conflict and more success when they are driven by stakeholders; that is, by those who will bear their consequences and carry out the actions for change (Beierle 2002, Voinov and Bousquet 2010). The last decades have thus seen the development of a range of participatory assessment techniques and participatory practices aimed at promoting sustainability (e.g., Gregory 2000, Palerm 2000, Tippett et al. 2007, Walker 2007, Thabrew et al. 2009). However, in many cases the results have been disappointing, and disillusionment has grown among practitioners and stakeholders who have felt let down when the many benefits that have been claimed for participation are not realized (Frame and Brown 2008, Reed 2008). The challenge emerging from the scientific literature is thus that whereas research and experience suggest that stakeholder involvement is crucial to the successful implementation of methods of sustainability assessment in food systems development, there seems to be deeper issues at play than whether or not to involve stakeholders.

Hypothesis and aim of this paper

We pose the hypothesis that the "stubborn" problems of integration and implementation in sustainability assessment are, at least to some degree, determined by issues of complementarity. We use complementarity in the radical sense of Niels Bohr, meaning that two observations of an object, such as the determination of the position and momentum of an elementary particle, exclude each other in a way that prevents getting the full picture of the object, so that we are left with complementary phenomena that cannot be combined. Such complementarity is deep; it is based in the very nature of the object and the observational and experimental possibilities. (Complementary in this radical sense is very different from complementary understood as "supplementary" in the sense that different assessment methods can supplement each other in a way that makes it possible to combine them and use them in a harmonious manner, e.g., Rotmans 2006).

The reason for posing this hypothesis is that we, in our own research experiences with assessments of food systems, have often found conflicts that are not merely conflicts of interest, but more fundamental cognitive conflicts caused by incompatible perspectives and values (cf. Alrøe and Noe 2011, 2014*a*, Thorsøe et al. 2014). And we have found that Bohr's complementarity from quantum physics offers a model for such stubborn and insurmountable cognitive delimitations (in line with Barad 2007).

The question of complementarity in sustainability assessment and transformation has, as far as we know, not yet received any attention. Yet we believe it to be an important question, because complementarity in this sense cannot be overcome through, e.g., involving more stakeholders, introducing new methods of negotiation of interests and values, constructing new methods of integrating sustainability indicators and methods, or making more detailed and complex assessments. Genuine cases of complementarity, if such cases exist in sustainability assessment, must be handled in a different way that takes into account the fundamental epistemological issues at play. We therefore aim to analyze issues of complementarity as a key to understanding crucial challenges in sustainability assessment and transformation, and as a tool for better handling problems of integration and implementation.

THE COMPLEMENTARITY PRINCIPLE

Niels Bohr modestly characterized his principle of complementarity as a "general viewpoint," but in fact he argued for a revolutionary change in our philosophical understanding of the scientific description of nature (Folse 1985, Barad 2007). Bohr claimed that the paradoxes found when viewing quantum physics from the viewpoint of classical physics had led to an unavoidable fundamental revision of the conceptual basis on which the scientific description of nature rests.

Complementarity was at the center of Bohr's famous debate with Einstein over the completeness of quantum mechanics, whereby he stated that the lesson from quantum physics, "discloses ... an essential inadequacy of the customary viewpoint of natural philosophy for a rational account of physical phenomena of the type with which we are concerned in quantum mechanics," and that, "the finite interaction between object and measuring agencies conditioned by the very existence of the quantum of action entails ... the necessity of a final renunciation of the classical ideal of causality and a radical revision of our attitude towards the problem of physical reality" (Bohr 1935:697).

Quantum physical complementarity arises where the necessary interaction with the observed object cannot be disregarded, because the observed objects are sufficiently small that the quantum of action becomes significant. Popularly speaking, the position of a particle cannot be observed without the radiation involved in the observation influencing the momentum of the particle. More correctly, measuring the position will make the momentum indeterminate, and vice versa (cf. Barad 2007).

The complementarity view was suited to embrace the characteristic features of individuality of quantum phenomena, and at the same time to clarify the peculiar aspects of the observational problem in this field of experience. Bohr emphasized that even though quantum phenomena are very different from classical physics, the accounts of quantum experiments must be expressed in an unambiguous language, which in this case means that the experimental arrangement and the results of the observations must be described in ordinary language making use of the terminology of classical physics.

Complementarity "implies the impossibility of any sharp separation between the behaviour of atomic objects and the interaction with the measuring instruments which serve to define the conditions under which the phenomena appear. ... Consequently, evidence obtained under different experimental conditions cannot be comprehended within a single picture, but must be regarded as complementary in the sense that only the totality of the phenomena exhausts the possible information about the objects" (Bohr 1949:210).

Bohr further advocated that the very word "phenomenon" be applied exclusively to refer to the observations obtained under specific circumstances, including an account of the whole experimental arrangement (Bohr 1955). When two different observations of the same object mutually exclude each other, we end up with "complementary phenomena" in Bohr's sense. The reasons for such mutual exclusion are to be found in the conditions for observation as they are determined by the structures of the observing system(s) and the observed object. In short, complementarity for Bohr means simultaneously necessary and mutually exclusive (Barad 2007).

The generalization of complementarity

Bohr believed that the demands of complementarity in quantum mechanics and of relativity in the theory of relativity were both a result of novel aspects of the observation problem, namely the recognition that observation in physics is context-dependent because of the existence of, respectively, a minimum quantum of action and a maximum velocity of propagation of all actions (Faye 2014). Because of these universal limits it is impossible, in quantum mechanics, to make a sharp distinction between the behavior of the object and its interaction with the means of observation and, in the theory of relativity, to make an unambiguous separation between time and space without reference to the observer. Bohr was thus acutely aware of the epistemological lessons to be learned from the new physics. Moreover, it is clear that Bohr intended to establish complementarity as a contribution to the general philosophical clarification of the principles underlying human knowledge, and in no way restricted to the analysis of only the specific paradoxes that arise in the quantum mechanical description of atomic systems (Folse 1985).

From 1935 to his death in 1962, Bohr's overriding philosophical goal was to bring the epistemological lesson of complementarity to fields other than atomic physics, such as biology, psychology, and anthropology (Holton 1970, Folse 1985, Favrholdt 1999). He wrote, for example, about the complementarity between molecular dynamics and organism behavior (or between mechanistic and teleological accounts) in biology, between thoughts and sentiments (or between descriptions of reasons to act and feelings of free will) in psychology, and between justice and mercy in ethics. The latter suggestion gave rise to our work on value complementarity, which we will describe in detail further below. Others have worked with the extension of complementarity to, e.g., mathematics (Otte 2003), biological and social structures (Pattee 1978), matter-symbol complementarity in biosemiotics (Pattee and Rączaszek-Leonardi 2012), political science (Rasmussen 1987), and consciousness (Jahn 2007).

Karen Barad (2007) argues against the method of generalizing complementarity by analogy, entertained by others, and even often by Bohr; instead, she follows the deeper philosophical implications of Bohr's thinking, and we agree in this approach. Bohr was convinced that complementarity teaches a lesson about the use of concepts for describing all phenomena. The quantum of action, which is the key to the necessity of complementarity in quantum physics, is important only to quantum physics. A generalization of complementarity must therefore be based on Bohr's broader lesson from quantum physics, that "'phenomena' are the ontological inseparability of objects and apparatuses" (Barad 2007:128), and that, "Not only, of course, have we learnt that every observation involves a disturbance of the phenomena; we have furthermore realized that the whole concept of observation requires a separation between the object and the means of observation." (Bohr 1931, as cited in Favrholdt 1999:521). (Bohr later renounced talking about the "disturbance of phenomena by observation," in favor of "observations obtained under specified circumstances, including an account of the whole experimental arrangement" Bohr 1955:53).

Following Bohr's general lesson, we can say that the three fundamental conditions for observation are (1) the separation of the observer (in a general sense, including the observational apparatus) and the observed object, (2) the interaction between the observer and the observed object, and (3) the observer's representation of the observed object (Alrøe and Noe 2011). A phenomenon, in Bohr's sense, involves all these three conditions of observation. Because of the ontological inseparability of the object and the conditions for observation, every observation must construct a separation, a cut that delineates what is observer and what is observed (see further in Barad 2007).

To clarify the understanding of observation and representation here, we employ the powerful semiotic framework of Charles S. Peirce, which lays out an elaborate theory of representation and signs (e.g., Nöth 2011). In particular, Peirce distinguishes between the immediate object, "the object as the sign represents it," and the dynamical object, "the really efficient but not immediately present object" (Peirce 1998:482). There is no position from where we can observe the dynamical object as it is in itself, but every perspective adds to the number of immediate objects that refer to, point at, or hint at the dynamical object (Alrøe and Noe 2014*a*). It is important to note here that the Peircean notion of immediate object is congruent with the Bohrian concept of phenomenon. Peirce's sign is triadic, a sign represents an object to an interpretant, and the representation mediates not only ideas, concepts, or cognitions, but also the feelings, wishes, desires, and actions resulting from the interpretation of the sign (Nöth 2011). Representation is thus to be understood not only in a semiotic sense, but also in an interacting, or intra-acting and performative (cf. Barad 2007), sense. If we, on this basis, are to formulate the principle of complementarity in more general terms, it states that complementary observations are observations of the same (dynamic) object that mutually exclude each other because of the conditions for observation, and which both, or all, contribute to the representation of that object.

A general, methodological form of complementarity

Based on the above generalization of the notion of complementarity, we are able to formulate new conceptions of complementarity that are more generally applicable in science. All empirical sciences share the common "problem of observation," the problem of devising a framework suitable for the unambiguous description of the phenomena in question, given that observation cannot take place without interaction. In cases where this interaction cannot be ignored, the conditions for defining the observed system as it is (without interaction) precludes the conditions necessary for observing it (with interaction), and Bohr considered these two distinct modes of description as complementary, each pursuing a goal necessary for the employment of the other (Folse 1985). We consider this a methodological form of complementarity, which can be applied to science in general. Jürgen Habermas has used the term "cognitive interests" to characterize such methodologically distinct processes of inquiry (Habermas 1987), and more generally we can speak of the complementarity between two modes of science, one characterized by a detached observer stance focusing on describing the world as it is and producing general knowledge, and the other characterized by an involved observer stance focusing on enabling action and change in concrete contexts (cf. Alrøe and Kristensen 2002). This fundamental methodological complementarity is one of the forms of complementarity that we will elaborate on in the following in connection to sustainability assessment. For lack of a better term, we will call it "detached-involved observer stance complementarity," or "observer stance complementarity" for short.

Complementarity and perspectivism

According to Bohr, complementary phenomena are due to the mutual exclusion between different observations that contribute to the representation of an object, and this complementarity is determined by the very conditions for observation in the form of the structures of the observing system(s) and the observed object. Bohr's complementarity viewpoint can thus be seen as a form of perspectivism (cf. also Peña 1991, Chevalley 1994). The elaboration of this connection between complementarity and perspectivism can help clarify the basis for a generalization of complementarity, and thereby help illuminate possible issues of complementarity in sustainability assessment.

A perspective is here understood as that which determines what an observer can observe and what it cannot observe, and perspectivism can be characterized plainly in a few sentences: There is no outside perspective on the world; all knowledge comes from a certain perspective; all learning happens in concrete perspectives on the world, which are part of the world, and which can themselves be made objects of observation (Alrøe and Noe 2011).

Perspectivism has had a long but marginal presence in philosophy, with roots in Kant and Nietzsche (Palmquist 1993, Anderson 1998, Hales and Welshon 2000). Over the last decades the cognitive understanding of science, where the focus is on scientific models and representation rather than theories and truth, has been growing and developing in philosophy of science (e.g., Giere 1988, Cartwright 1999, van Fraassen 2008). Recently, an explicitly perspectival philosophy of science has been developed (Giere 2006, Wimsatt 1994, Alrøe and Noe 2011, 2014*a*, Callebaut 2012). This implies that all scientific knowledge is created in scientific perspectives, and that scientific knowledge, representations, and measurement outcomes (data) are perspectival (van Fraassen 2008).

Scientific perspectives determine what the observing systems of science can observe and what they cannot observe. A discipline, or more often a subdiscipline or "research school," is an example of a scientific perspective. Scientific perspectives are both cognitive and social communicative systems, which are autopoietic. That is, they create and reproduce their own meaning through internal processes; they produce their own methods, theories, and instruments for observation, and thereby also their own inputs in the form of observations and data (cf. Luhmann 1990, 1995, Alrøe 2000). As part of this reproduction a scientific perspective harbors certain concepts, theories, classifications, instruments, problems, and values that delimit and focus the observational field, and make possible the observation of certain phenomena and aspects.

The connection between complementarity and perspectivism is important for two reasons. First, the elaboration of the structure of the perspective can help illuminate the conditions for observation that may give rise to complementarity. Second, clarification of the autopoietic closure of scientific perspectives involved in, e.g., sustainability assessment and other cross-disciplinary research activities and the characteristics of their conditions for observation can help point out issues of incommensurability and complementarity between these perspectives (the notion of incommensurability will be discussed later). Examples show that an explicitly perspectivist framework can help to reveal the perspectives in play and how they determine the observations made (Alrøe and Noe 2014*b*, Læssøe et al. 2014, Thorsøe et al. 2014).

In general we may speak of perspectival complementarity and the possibility that different scientific perspectives may be complementary. But we think such general notions of complementarity can be made more precise by investigating what exactly it is that makes the observations from one perspective preclude observations from another perspective, and we believe such elaboration can clarify how these instances of complementarity could be handled.

To be more concise, an observation is a relation between observer and observed (cf. Alrøe and Noe 2011, 2014*a*); a relation that at the same time establishes the perspective as the frame of the observation and the phenomenon as the result of the observation. In line with Bohr, these three can and should not be treated separately; phenomena, including scientific data, etc., must always be treated as observations from a certain perspective (Bohr's "very conditions" of observation including the whole experimental arrangement). And complementary observations, complementary phenomena, and complementary perspectives are therefore three different entry points to the same set of both necessary and mutually excluding observational relations.

OBSERVER STANCE COMPLEMENTARITY

The fundamental methodological form of complementarity that we characterized as observer stance complementarity in the previous section stems from the difference between a detached and an involved observer stance. In sciences that work with complex research worlds, research approaches that take a detached observer stance to describe the world as it is, are very different and in fact incompatible with research approaches that take an involved observer stance to facilitate change and development (Alrøe and Kristensen 2002).

For instance, there are two very different forms of farm research. One form focuses on monitoring farms as they are "on their own" so to speak, to get a better image of how they function and to be able to model agriculture on an overall level by incorporating detailed knowledge of the internal processes of the farm. To do this kind of research it is important that the researchers keep detached and do not interfere with how the farm is managed, because this would bias the results. The other form focuses on how to help improve the function of farms by making research based tools and procedures that can help make the management more effective and responsive to problems in the production. To do this kind of research it is important that the researchers get involved in how the observations and decisions at the farm are made. These two kinds of farm research are mutually exclusive, but they are both needed to get a full understanding of farms.

The crux is that the mutual exclusion between these two kinds of farm research is due to the individuality of the farm as a self-organizing (autopoietic) system (Noe and Alrøe 2003, Noe et al. 2015), similar to the situation in quantum physics due to the individuality of quantum phenomena (see above). Sustainability assessment and transformation always involves social systems that have their own perspectives, with meaning, values, and logics. Therefore, it is important to be attentive to observer stances and the possibility of observer stance complementarity. We analyze three examples of observer stance complementarity that are relevant to the assessment of food system sustainability.

Cognitive interest: description versus development

In a study of the choice of sustainability assessment tools at the farm level, Marchand et al. (2014) determined key characteristics of different tools. They define two types of tools: (1) complex, expert-based "full" sustainability assessment tools and (2) simpler, participatory "rapid" sustainability assessment tools. Full assessment tools make use of detailed farm data and/or expert information, they need trained advisers and/or expert visits to gather the data, and they take a long time and are expensive to carry out. Rapid assessment tools make use of the farmer's knowledge or readily available data, allow an audit by the farmer or an adviser, and they are relatively short in duration and less costly. These constraints about data, time, and budget affect additional characteristics, such as output accuracy, data correctness and availability, user-friendliness, compatibility, transparency, and complexity.

The full assessment tools are suitable for monitoring sustainability aspects of farming systems. They have high output accuracy and can potentially be used for certification. But the user-friendliness for a farmer or adviser is rather low, because of the time-consuming, expensive data gathering and complex data processing. The rapid assessment tools are more oriented toward communicating and learning. They are suitable for use by groups of farmers to help raise awareness, trigger farmers to become interested in sustainable farming, and highlight areas of good or bad performance. They are more user-friendly and less complex than the full assessment tools, using transparent and understandable indicators based on management options. But they have rather low output accuracy.

An important point is that full descriptive assessment methods, which produce general knowledge, are methodologically complementary to rapid developmental assessment methods, which focus on enabling action and change in concrete contexts, because of their basis in a detached and an involved observer stance, respectively. In this respect they can be seen as two mutually excluding forms of sustainability assessment based on different cognitive interests. Full assessments are directed at monitoring (description) and must be general and not site-specific, because they need to be tested, well documented, and standardized. Rapid assessments are directed at learning (development) and must be concrete and site specific, because each site harbors specific perspectives and values. The two approaches exclude each other because the rapid assessments do not allow for full, well-documented descriptions, and the full assessments do not provide individual directions for actions and change. Furthermore, it is not possible to find some optimal middle form that incorporates the strength of both full and rapid assessments; combining both functions within one tool has proved to be ineffective (Triste et al. 2014).

Marchand et al. (2014) conclude that these two approaches have complementary strengths and weaknesses and should be used in a complementary way (in line with the overview of complementarities between different sustainability assessment methods in Van Passel and Meul 2012). And they recommend first choosing a clear and well-defined function, either monitoring or learning, as a basis for selecting or developing a sustainability assessment tool.

This suggestion for complementary use of sustainability assessment tools is not connected to a deeper analysis of the basis for the complementarity. But the suggestion shows recognition of the deep methodological differences between full sustainability assessment tools, focusing on detailed description and monitoring, and rapid sustainability assessment tools, oriented toward communication and learning. We argue that this is not a case of complementarity in a loose or shallow sense, but a deep observer stance complementarity that cannot be overcome methodologically.

Assessment position: from without versus from within

Usually, sustainability assessment tools are developed and directed by scientists and other experts from outside the systems of food production and consumption. Even when, as in the example of the rapid, developmental tools above, the assessment operates with an involved observer stance, it is typically directed by outside experts. For instance, Schader et al. (2014) identified two prevalent perspectives on sustainability in assessments of food system sustainability: The business or farm perspective describes whether the farm is able to sustain itself for an extended period of time. The societal perspective assesses whether a farm contributes to a sustainable development of society. Any one tool has to choose a perspective for selecting the proper indicators, and the different assessment perspectives may well lead to contradictory impact assessment results. This is clearly a case of observer stance complementarity due to the use of different perspectives, or observer stances, observing the farm from within or from without. But the assessment is still directed by outside experts.

The second example presented here shows a more radical approach that takes the involved observer stance one step further, by accommodating the idea of food systems as self-organizing social systems with their own perspectives, with meaning, values, and logics, and thereby their own observer stance from within. The MultiTrust project (2011-2014) investigated methods to make and communicate balanced overall assessments of the effects of organic food systems on society, environment, and nature to help organic actors develop the organic food systems in accordance with the organic principles and in synergy with societal objectives (Alrøe and Noe 2014*b*). The focus on organic food systems made it obvious that the sustainability assessments had to be tailored to the food system because the organic understanding of sustainability (based on the principles of organic agriculture, IFOAM 2005) is quite different from some of the other understandings of sustainability (cf. Alrøe et al. 2006).

Based on the realization that both sustainability assessments and food systems are inherently value-based, and that a key to successful implementation of such assessments therefore is to make values and perspectives explicit in a participatory process, the project focused on the question of how to communicate values. The conclusions from a multistakeholder workshop on how overall assessments may benefit the development of organic food systems were the following: (1) assessments should be driven by user needs, (2) assessments must be used in chains, and (3) assessments should focus on tangible initiatives (Alrøe and Noe 2014*c*).

These conclusions have quite far-reaching consequences for the development of participatory assessment tools:

1. For assessments to be user driven, there has to be an option for discussing and influencing the criteria, i.e., values used for assessing, on which the assessment is based. But often criteria are determined by expert ideas about what is important. And generally the existing sustainability assessment tools are quite inept in exposing and handling values.

2. Most tools have focused on single entities like farms, businesses, sectors or countries, or single products, and not on the interaction between links in food chains or food systems. But transitions toward better and more sustainable food systems require synchronized changes in practices across food chains and systems.

3. The focus on tangible initiatives, or “good examples,” such as a farm biogas plant or a retail packaging reduction plan, points in another direction than the typical assessment tool, which is focused on entities or products. Tangible initiatives are easier to communicate across different actors and stakeholders because they provide concrete and palpable objects that are amenable to common understanding.

As a result of this line of work, the MultiTrust project proposed a cooperative communicational platform for developing more sustainable food chains (see an animated sketch of this tool on https://youtu.be/UF15_4knPUA). The proposed tool works by revealing and communicating the value-laden criteria used by different actors in the food chain, i.e., producers, processors, retailers, consumers, etc., for selecting goods and taking new development initiatives (Alrøe and Noe 2014*c*, see also the discussion in Kastberg 2015). Communicating about values (in the form of criteria) and concrete initiatives enables the actors in the chain to know in what direction other actors are moving and coordinate their own decisions and actions accordingly. For instance, producer criteria and initiatives may influence consumer choices, and the criteria and buying strategies of consumers may influence strategic producer decisions. Sustainability transformation of food systems is a complex undertaking that requires mediation of values (cf. Noe and Alrøe 2011) and synchronization of actions. If any link, be that production, processing, sale, or consumption, lags behind, the transformation is stopped in its tracks.

The form of observer stance complementarity found here is between making assessments from without and from within. But this example is a radically different approach to assessment of food system sustainability from assessments directed by outside experts (illustrated above), because here the assessments enter only in the place and form required by the actors in the food chain. The food chain determines what is needed in the form of assessments to assist sustainability transformation, and the proposed tool can help to do this by enabling mediation of values and determination of the criteria needed for a relevant and consistent assessment.

Use of knowledge: risk versus precaution

The third example shows how the complementarity between observer stances is related to a derived form of complementarity in the use of knowledge in assessments of food systems. In 1998-1999 a major survey was carried out to assess the overall consequences of phasing out the use of pesticides in Danish agriculture. The so-called Bichel assessment included the modeling of a 100% conversion of Danish agriculture to organic production as one approach to phasing out pesticides (DEPA 1999, Alrøe and Kristensen 2001). This work illustrates a significant methodological issue in sustainability assessment research. A total transition to organic agriculture implies radical changes to the present agricultural systems, and although the models implemented in the survey were based on all the available scientific knowledge, the work revealed insufficient knowledge in many areas. This, in turn, made it clear that the modeling could not be done without an inquiry into the limits of scientific knowledge.

The Bichel assessment therefore involved a lively discussion about the role of the precautionary principle and the distinction between risk assessment and precaution. Risk assessment is concerned with the calculation of proportional risks and benefits from available scientific knowledge, whereas the precautionary principle prescribes acting before conclusive scientific understanding is available in front of possible irreversible damage. The two are mutually exclusive and the choice between them is connected to different conceptions of human knowledge and control and different views of nature and the relation between human and nature.

The principle of precautionary acting arises out of an awareness of the human dependency on the environment, together with recognition of the growing human influence on the environment and the fact that the consequences of this influence are to some degree unknown and uncontrollable. Furthermore, there is an important distinction between a separative or distinctive conception of the human relationship to nature, which sees humans as basically separate from nature, and a systemic conception that sees humans as basically an integral part of nature (see below). Organic agriculture has the latter view, which is more congruent with precaution toward environment and nature.

The use or nonuse of the precautionary principle is a complex issue that involves ethics and politics as well as views of knowledge, control and nature. "Precaution above all requires a society able and willing to invest in the future, the need for which cannot be 'proven' in advance, but must remain a matter of faith" (Boehmer-Christiansen 1994:57).

But the comprehensive work in the Bichel assessment on modeling the overall consequences of a 100% conversion to organic agriculture identified the precautionary principle as one of the key questions to be resolved before an assessment of this radical transition could be made. The precautionary principle enters into the practices and regulations of organic agriculture, and it enters into environmental law and societal decisions in some countries, but it is not possible to integrate precaution into a model-based assessment approach. In the Bichel assessment, despite that it was considered a key issue and that precaution was recognized as a fundamental principle in organic agriculture, it was left as an add-on, as a commentary on the results of the modeling.

The point of this example is twofold. First, that the choice between a detached and an involved observer stance also involves different views on the limits of scientific knowledge, the role of local ecological knowledge, and normative principles such as the precautionary principle. Second, that the involved observer stance, i.e., including the precautionary principle, contains substantial methodological challenges compared to common science-based assessments from a detached observer stance.

The observer stance complementarity in question here is thus a complementarity that involves not only the complementarity between from without and from within, but also, following from this, the complementarity between risk assessment and precaution as a methodological challenge for sustainability assessment. "The precautionary principle applies *to* sustainability assessment as well as *in* it" (Gibson et al. 2013:186 [emphasis in the original]).

VALUE COMPLEMENTARITY

In our search for possible issues of complementarity in sustainability assessment we have, in addition to observer stance complementarity, found a number of issues that we characterize as "value complementarity." Values are in general a key component of scientific perspectives (Alrøe and Noe 2011), and in sustainability assessment values are even more crucial because there can be no assessment without value (Gasparatos 2010, Thorsøe et al. 2014). In his efforts to generalize the complementarity principle, Bohr suggested the complementarity between contemplation and volition, between justice and mercy, and between values of different cultural traditions (Bohr 1955, 1961 as cited in Favrholdt 1999). Following these leads and many years of experience with assessment of food systems, we propose that value complementarity is an important and widespread form of complementarity in sustainability assessment.

Assessments are inherently value based; they are always judgments of better and worse in some sense, though these values are often more or less hidden. For instance, indicators are chosen as measures for certain aspects of food systems because they are "important to us" in certain ways. Hartmut Bossel (2001) has suggested the term "orientor" for the way an indicator is important: "It does not make much sense to develop indicator systems without explicit reference to the orientors about which they are to provide information. But that means starting by first analyzing the fundamental interests or orientors of the system for which we want to define indicators." (Bossel 1999:26). More generally, sustainability assessment relies on multiple specialized assessment perspectives, each of which is based on built-in and mostly hidden values, which are embedded in the methods and tools used (Gasparatos 2010). At a very basic level, the values are built into indicator scores, which transform judgements of good and bad (the orientors) in relation to different indicators into numbers from 0 to 1 based on functions of indicator measures.

The different values in different assessment perspectives may be incompatible, and this may lead to issues of complementarity. In fact we argue that there is a special form of complementarity, which we call value complementarity. Value complementarity differs from the methodologically focused observer stance complementarity that we described in the previous section (and the original complementarity of quantum mechanics) by focusing on the normative conditions for observation. In methodologically based complementarity two observations mutually exclude each other because of the conditions for observation as they are determined by the structures of the observing system(s) and the observed object. In value complementarity the mutual exclusion of two observations of the same object stems not primarily from the methodological options for observation but from different values that determine what observations are relevant or desirable in one perspective compared to another. (Secondarily, there may well be methodological constraints involved in value complementarity, but the primary cause is a difference in values.) The determination of what observations are relevant or desirable is exactly what takes place in the construction of assessment tools in terms of embedded values (Gasparatos 2010), and in the construction of indicators in terms of orientors (Bossel 1999).

The reason for the incompatibility that leads to mutual exclusion and value complementarity can be understood from a relational conception of value (cf. Noe and Alrøe 2011, Læssøe et al. 2014). In a relational perspective, value relations are primary entities that belong neither to the subject nor to the object (Pirsig 1999, Barad 2007). Because of the relational nature of values, there are limits to how values can be combined and integrated. A value relation is a basic form of preference, and we may think of value incompatibility as a sort of path dependency, when one path has been chosen out of two possible, the other path is no longer available or possible.

We believe value complementarity is of key importance in sustainability assessment, though these constraints are not generally recognized at the moment. To identify possible issues of value complementarity, we may look to conceptual analyses of value-laden concepts in science such as food quality, soil quality, sustainability, animal welfare, justice, health, etc. Often these philosophical analyses reveal different meanings of such key scientific concepts that are connected with different scientific perspectives such as disciplines, subdisciplines, and research schools. We analyze three examples of value complementarity that are relevant to the assessment of food system sustainability.

Animal welfare: naturalness versus care

Among other suggested value-laden and conceptual differences in animal welfare (e.g., Fraser 2008), we find two very different and conflicting perspectives that can be characterized as naturalness versus care, of which pursuit of naturalness is found particularly in the context of organic agriculture, outdoor pig production, and other alternative forms of production (Lund 2006, Alrøe et al. 2001, Vaarst and Alrøe 2012). In a naturalness or natural life perspective, animals are seen as basically natural creatures that are kept and bred in artificial conditions, and therefore free range and other nature-like production systems are preferred. Research studies focus on the conditions and behavior of the animals compared to natural conditions and natural behavior, often referring to inherited instincts and the possibilities for natural behavior such as caring for offspring and moving around. Observations are made on, e.g., feather picking, tail biting, and stereotype behavior such as repeated movements of the head (weaving) and pacing the enclosure. The values that underpin naturalness is that freedom is good for the animals and exertion of natural behavior is a sign of good animal welfare.

In a care perspective the important thing is whether the animals are healthy and function well in the production system. Research studies focus on disease and whether the necessary treatments and interventions to reduce the source of illness are made, such as hoof trimming, sectioning, cleaning and disinfection. Observations are also made on the level of fear, indicating how the animals react to human contact. The values that underpin care is that humans are responsible for controlling the welfare of production animals, and that absence of disease and functioning well in the production system are indications of good animal welfare.

The values of naturalness and care are connected to freedom versus control, and they exclude each other in the same way that justice and mercy exclude each other. The more you pursue animal welfare as naturalness the more difficult is it to control and take care of their well-being, and vice versa. This is the source of value complementarity in assessments of animal welfare, a value complementarity that shows up as very important in, for example, sustainability assessments that compare organic and conventional production systems, because naturalness plays a key role in organic production usually not found in conventional systems.

Nature quality: authentic versus rich nature

Nature is a prolific and diverse concept, but in relation to the issue of nature quality the main conflicting perspectives can be characterized as authentic versus rich (cf. Tybirk et al. 2004). Two overarching conceptions of the relationship between man and nature are the "distinctive" conception that sees man and nature as basically separate, and the "systemic" conception that sees man as basically an integrated part of nature (and vice versa). The distinctive and systemic conceptions of nature largely correspond to two major schools in conservation biology: compositionalism and functionalism (Callicott et al. 1999).

Within these two basic conceptions of nature, there are three "archetypical" normative views of what good nature is (Alrøe and Kristensen 2003, Tybirk et al. 2004). Within the distinctive conception of nature we find two views: the culturist view of nature (often connected with conventional agriculture and a religious history of human dominance over nature), which values nature that is controlled, well-ordered, cultivated, and useful to man; and the naturalist view of nature (mostly connected to natural history and conservation biology), which values the wild and authentic nature, untouched and uncontrolled by man. The systemic conception of nature gives rise to an ecologist view of nature (mostly connected to ecology and organic agriculture), which values the rich, but not untouched, nature that provides intimate and mutually benign relations between humans and nature. Whereas the culturist and naturalist views disagree on what good nature is, they may agree on dividing land into (nature poor) cultural land and authentic natural land. But the ecologist view will disagree with this division and insist on a nature rich, though not authentic, cultural land. In connection with sustainable food systems, research studies on nature quality as authentic nature will look in the small biotopes in hedges and ditches, where biodiversity in the form of rare and threatened species may be found. The prevalence of common species on agricultural land will be of little interest. And mostly they will want to look elsewhere, in nature areas that may be afflicted by agricultural activities. Research studies on nature quality as rich nature will look in the fields, where biodiversity in the form of robust and plentiful species may support soil fertility and crop growth, and for common species that may enrich recreation in the countryside.

The values of authentic and rich are thus connected to entirely opposite conceptions of man's relation to nature, and this is the source of value complementarity in assessments of nature quality. This value complementarity shows up as very important in, for example, sustainability assessments that compare organic and conventional production systems because the view of nature mostly differs between these two systems and between their connected research system. One of the basic ethical principles of organic agriculture thus says directly that agriculture should cooperate with nature and that the production should emulate and benefit from nature's systems and cycles, and help sustain them (IFOAM 2005).

Sustainability: three perspectives on growth and sustainable development

There are other well-known conflicts around key value-laden concepts that are important to the assessment of food system sustainability; concepts such as soil quality (Schjønning et al. 2004), health (e.g., between preventing illness and building resilience), food safety (e.g., between the precautionary principle and evidence-based risk assessment), and food quality (e.g., between standardization and diversity, such as local and seasonal food), and not least the concept of sustainability itself. Our last example here concerns value complementarity on an overall level of sustainability assessment compared with the previous examples, namely three different perspectives on growth and sustainable development: growth without borders, growth within limits, and growth and ecological injustice (cf. Byrne and Glover 2002, Byrne et al. 2006).

Growth without borders
From a neoliberal economic perspective, globalization does not present a problem. On the contrary, globalization is seen as an improvement of the possibilities for free market forces to allocate resources, which in this view is economically and socially ideal and a prerequisite for liberal democracy. The solution to world poverty and environmental problems lies in growth and open markets, because growing wealth will furnish more than enough capital to repair whatever damage the growth may have caused. This position can be characterized as having a "weak" conception of sustainability. It presupposes an independent, always growing economic system as well as well-distributed benefits from the system. The field "environmental economics" recognizes that there are market failures with respect to the environment and advocates institutions to internalize external costs, so that markets can settle on optimal levels of pollution and ecological losses. From this perspective, sustainable development is measured by a single economic indicator: growth in the value of society's collected capital. The price for this simplicity is an assumption of substitutability, that all natural resources and environmental goods can be replaced with produced goods or, in other words, that there is no critical natural capital.

Growth within limits
Other economic perspectives endorse stronger conceptions of sustainability. For example, many believe that the economic system is dependent on a finite, vulnerable, ecological system and that there are only limited possibilities of substituting natural capital with manufactured capital (Daly and Farley 2003). The field "ecological economics" is a pluralistic, transdisciplinary alternative to market liberalism that considers ecological limits and the scale of the material and energy flows to which the economical processes connect. A key argument from the ecological economics perspective is that sustainable scale, just distribution, and an efficient allocation are three distinct, but interdependent, problems requiring different policy instruments (Daly and Farley 2003). Sustainable scale here implies that the throughput associated with economic activities remains within the natural capacity of the ecosystem to absorb wastes and regenerate resources.

Growth and ecological injustice
A third position comes from the field "political ecology," which does not see development and efficiency as solutions, but as the primary sources of social and ecological problems (Byrne and Glover 2002). Political ecology opposes both globalization and ecological modernization because both presume trade is essentially an economic issue. Political ecology, on the other hand, situates trade within a political frame as a contest between resources taken as "commodities" and taken as "commons," a contest, in essence, of ecological justice, which is concerned with the fair distribution of the common environment between the inhabitants of the planet (Low and Gleeson 1998). From this perspective, sustainable development in the form of ecological modernization has primarily been the agenda of the wealthy. Sustainable development is seen not as a remedy for problems created by globalization, but a reform program that currently tends to advance a globalization agenda. Together, globalization and sustainable development spur a replacement of commons valuation with commodity valuation that benefits multinational corporations and exploitive commodity interests, while simultaneously undermining sustainable commons systems and community governance.

Such differences in the interpretation of sustainability have important implications for sustainability assessment tool choice and the decision-making processes (cf. Ness et al. 2007). The three perspectives on growth and sustainable development presented here: economic growth and substitutability versus critical ecological limits versus fair distribution of the common environment, are based on values that are clearly, at least in some ways, incompatible. The assumption of substitutability goes directly against the ideas of critical ecological limits and planetary boundaries, and the simple goal of maximum economic growth goes against the fair distribution of the common environment. (The idea of critical ecological limits may be compatible with the fair distribution of environments, but one may still be blind to the other.) These issues of value complementarity occur at the very top level of any sustainability assessment and are therefore of critical importance to the construction and results of tools for sustainability assessment and transition.

DISCUSSION

In the introduction we outlined two major problematics of sustainability assessment that are still unresolved today, the problem of integration and the problem of implementation, and suggested that the principle of complementarity could help clarify and better handle these problematics. We have now investigated how the principle of complementarity may be generalized from its original formulation in quantum physics, and described two specific forms of complementarity in sustainability assessment of food systems, observer stance complementarity and value complementarity. As we have indicated, the differences, conflicts, and constraints that we connect with issues of complementarity have often been known to some degree and in some form. But the principle of complementarity can help understand how fundamental these problems are (or not), and thereby what can and what cannot be done about them.

We discuss whether these issues of complementarity can indeed help explain and deal with problems of integration and implementation in sustainability assessment, and what the further implications of thinking in terms of complementarity are. Although the problems of integration and implementation are separate problems, they are not independent, and in the discussion we will also point out cross-cutting issues.

The integration problem and value complementarity

Sustainability assessment tools integrate a range of different indicators and fields of assessment, and the integration problem concerns the surplus of possibilities for integration. Value complementarity points out that different assessments may be incompatible because they are based on different and incompatible values.

Integration and levels of assessment
We have analyzed examples of value complementarity at two different levels, specific issues about animal welfare and nature quality and complementarity issues concerning sustainability at an overall level. It is clear that in relation to problems of

integration in sustainability assessment, the overall value complementarity found in the different understandings of growth and sustainable development concern the choice of a framework for integration, whereas the specific issues of value complementarity concern integration choices within a certain framework. However, it is also clear that the specific issues of value complementarity are not independent of the overall complementarity between different meanings of sustainability. For example, the different values connected to nature quality, which we characterized as distinct (man and nature separate) versus systemic (man and nature integrated) are connected to sustainability as growth without borders versus growth within limits.

At present, such connections and differences between values at different levels of assessment, and in different fields of assessment, are difficult to elucidate in sustainability assessments because values are mostly hidden when the tools are applied. There is a need for normative transparency and better ways of handling values in sustainability assessment tools to enable developers to compare values across levels and fields and thereby ensure normative consistency in the integration processes. This is also important with regard to the implementation problem because it will enable users to compare their own values with the built-in values in the tools, which can assist tool choice and help steer their transformation to more sustainable practices.

Complementarity and food system dilemmas

To instigate sustainability transformations we need to handle, on the one hand, disagreements and complementarities due to differences in perspectives and values and, on the other hand, systemic dilemmas where actions that promote sustainability in one area have negative effects in other areas because of internal structures and dynamics in the system. (In sustainability assessment such systemic dilemmas may also be considered a form of indicator interaction, see, e.g., Binder et al. 2012). In some cases these two can be difficult to discern. But even though they both pose important constraints, they must be handled quite differently. An example of a systemic dilemma is found in organic pig farming, where the goal to increase animal welfare by establishing free range production systems may jeopardize environmental goals because of problems of controlling the deposition of animal manure in these systems and the leakage of nutrient due to the pigs rooting up the fields. However, this dilemma is distinct from, e.g., the example of value complementarity between naturalness and care that we described above. Such dilemmas may be more or less difficult to handle, but they can be addressed by way of system innovation, and they do not necessarily pose the kind of unsurmountable problems that complementarity does.

Indexation as a machine to hide information

In sustainability assessment a solution to the problem of complexity, which is also a part of the implementation problem, is often attempted by way of indexation. Indexation is a prime example of how integration can work against the clarification of values in overall assessments. Indexation is a process whereby different kinds of assessments in different fields of sustainability are weighted and combined, or integrated, into a number, usually on a scale from 0 to 100. (As such, indexation is a further move toward the quantification of values, which sustainability assessment is based on in the form of indicator scores.) The result of indexation may be one index, such as the Ecological Footprint and the Happy Planet Index, or, more typically in food system assessment, a range of indexes for different overall fields of sustainability that are presented in a diagram (see, e.g., Marchand et al. 2014, Peano et al. 2014). Multicriteria assessment is thus an alternative to the simple indexes that retains the visibility of different fields or areas of assessment. Yet this is still based on indexation within each of these areas.

Indexation can thus be seen as a very efficient integration machine. But this integration machine works by hiding information in form of, e.g., the perspectives and values involved and the limitations of the scientific knowledge used, which are all necessary parts of the cognitive context of sustainability assessment. Thereby, indexation also efficiently hides any occurrence of value complementarity and hinders the recognition and handling of value complementarity issues.

Indexes are simple and therefore very efficient in communicating sustainability assessments. This can ideally assist implementation. But indexation also hides all the value differences and nuances in the plurality of perspectives and criteria, as well as any complementarities, dilemmas, etc. And by providing a specific answer it closes off continued communication. In this way indexes can also exclude stakeholders and at the same time hide the reasons for why they should not be excluded.

The implementation problem and observer stance complementarity

The implementation problem concerns the difficulties of bringing complex sustainability assessments into practice and thereby instigating sustainability transformations. Observer stance complementarity points out that different approaches to sustainability assessment may be incompatible because they are based on different and incompatible modes of science that can be characterized as detached and involved.

Assessment, participation, and observer stance complementarity

Triste et al. (2014) provide a systematic reflection on the development and implementation process of a particular sustainability assessment tool, the Monitoring Tool for Integrated Farm Sustainability (MOTIFS), a study of a type that has scarcely been performed before. MOTIFS was developed with the aim of becoming widely adopted by farmers and farm advisors, but this result was not achieved, despite a participatory tool development process, which involved a wide range of stakeholders. This lack of implementation is not uncommon. “Adoption of sustainability assessment tools in agricultural practice is often disappointing,” as Triste et al. note.

Triste et al. (2014) analyze the barriers and success factors that influenced the general adoption of MOTIFS, and point to the tool development process as a critical success factor for adoption. For example, MOTIFS aimed to be a communicative monitoring tool suitable for social learning, but, “This multifunction aim created tensions that are reflected in indicator choices. The objective of monitoring resulted in the development of indicators with a high-precision measurement. However, to be suited for learning purposes, indicators need to be understandable and transparent.” (Marchand et al. 2014)

According to the thesis in the present paper, such tension is to be expected since the different functions of monitoring and learning are subject to observer stance complementarity.

The reflection process by Triste et al. showed three clusters of lessons learned for sound tool development: (1) institutional embeddedness, addressing the researchers' role in the development process and the need for shared process visions and objectives in an adaptive learning process, (2) stakeholders' ownership, pointing out that farmers must recognize and accept their responsibility in achieving a more sustainable agricultural practice, and (3) tool functions, stating that different tool functions require different specifications concerning implementation settings and end users.

On this basis, Triste et al. (2014) suggest actions to take for researchers involved in sustainability assessments. They recommend research and development of better guidelines on what tools are relevant for which end users and what purposes, complementary use of tools, and the development of flexible tools for varying situations. But they recognize that the scientific basis for this is still weak. Referring to a number of other authors, they also recommend learning from stakeholders and end users. Active stakeholder involvement can stimulate the sense of ownership, increase awareness of problems and acceptance of measures required to solve problems, improve decision making by accounting for diversity in viewpoints and knowledge, increase support for the assessment outcomes, and enable mutual learning. However, organizing and managing good stakeholder involvement is a big challenge. There can be significant differences between designers' and users' interpretations of a problem, and it is important that researchers and experts do not monopolize knowledge. Participation should be institutionalized and end users should be involved early in the process to support tool design that fits the intended purpose and end users.

Although the complementary use of tools and the diversity of viewpoints is among the explanations given by Trieste et al. (2014) for the lack of adaptation of MOTIFS for practical use, the deeper analysis of complementarity that we have provided here can help substantiate these discussions in the scientific community. In particular, a greater awareness of the complementarity between detached observer stances aimed at description and monitoring and involved observer stances aimed at development and learning would help understanding the barriers to implementation experienced in the case of MOTIFS and in other cases.

Lack of understanding of this methodological complementarity could be a reason why many complex, scientific assessments do not lead to the transformations in practice that are expected. Seeing the implementation problem as (at least partly) a problem of complementarity may particularly help explain why many participatory assessment approaches do not result in the expected sustainability transformations in practice (cf. Reed 2008). No degree of participation in an assessment that is based on an observer stance from without the food system (be that a farm, a food chain, or, e.g., the organic food system) will change that assessment to an observer stance from within the food system.

Implementation, stakeholder perspectives and complementarity

If the explanation of the implementation problem as (to some degree) due to observer stance complementarity is correct, the implementation problem cannot be resolved by developing still more advanced and complex assessment methods, if these approaches employ a detached observer stance that is directed by the norms of science. End users such as farmers and advisors wish to adjust or select indicators depending on the goals and the context-specific needs, conditions, and characteristics of the farms (Marchand et al. 2014). New approaches must be found that provide ways for how stakeholder perspectives and values can actually enter into the sustainability assessment processes (as attempted by the MultiTrust project).

There are multiple kinds of actors and stakeholders in food systems with very different values and goals, and the existing sustainability assessment tools are generally inept in communicating values. It is therefore not a simple or straight-forward case to carry out communication processes with the relevant stakeholders, which make values and perspectives explicit in sustainability assessments. Key questions are how values in the form of orientors or normative criteria are built into multicriteria assessment tools in the selections and condensations made (cf. Gasparatos 2010), how they can be exposed, and how these built-in values relate to the values of food systems, societal goals, and the interests of different stakeholders (cf. Gregory 2000). There is a need for normative transparency to be able to address both issues of value complementarity and observer stance complementarity.

In response to the widespread disappointment in the results of stakeholder involvement (as described in the introduction), we conclude that participation in itself is impotent. Participation will not lead to successful implementation of sustainability assessments unless the participation involves stakeholder perspectives in the form of explicitly incorporating their values and in the form of assessments from within instead of from without.

Complementarity between assessment and transformation

In line with the above discussion, sustainability assessment and sustainability transformation can be seen as two mutually excluding, but necessary, ways of addressing the goal of sustainable development of food systems. In assessment processes, focus is on showing how sustainable, e.g., a type of farm or a food sector is, and to do this science takes a detached observer stance. Here, the weight is on means of perception (measurement procedures, instruments, etc.) and ways of representing the object (models, diagrams, etc.). In transition processes focus is on making, e.g., a farm or a food chain more sustainable, and to do this science takes an involved actor stance. Here, the weight is on the means of operation (initiatives, interventions, changes of practices, etc.).

This does not mean that transition processes are necessarily blind processes without assessment elements, or that assessments can never lead to transition processes. The point we want to make here is that, paradoxically, these two fundamental modes of sustainability science are in their essence complementary by virtue of their different cognitive interests and observer stances. It is not possible to find some optimal middle form that incorporates the strength of both forms. This is what is now becoming recognized in the analyses of, and reflections upon, the use of different sustainability assessment tools (e.g., Marchand et al. 2014, Triste et al. 2014). Science is essential to the societal goal of sustainability, but for science to have a constructive role in the transition to more sustainable structures and practices in food systems, and elsewhere, it needs to be acutely aware of the importance of different perspectives and the complementarities connected to the difference between detached and involved observer stances.

Further implications of complementarity and perspectivism

Complementarity and other perspectival differences

Different scientific perspectives are autopoietic social systems that create and reproduce their own meaning. They specialize in observing specific phenomena or observing the world in specific ways. Disagreements between scientific perspectives are therefore not necessarily due to one being right and the other wrong, but may often be due to differences in perspective (Alrøe and Noe 2011). Perspectival differences are a key problematic issue in interdisciplinary research on wicked problems (such as the problems of food system sustainability), which often leads to failure because of a lack of mutual understanding and respect between disciplines and, often, the hegemony of a single discipline. The solution to such problems is a greater awareness of the role of perspectives in science and in interdisciplinary and transdisciplinary research (cf. Alrøe and Noe 2014*a*).

A further complication is that tools that aim to describe the world as it is, from a detached observer stance, are often considered "more scientific" than tools that aim to support development of the system from an involved observer stance (cf. Alrøe and Kristensen 2002). Such hegemonic ideas are detrimental to interdisciplinary research (Alrøe and Noe 2014*a*). The realization that approaches aimed at description and development represent different modes of empirical science that can be equally scientific, though they differ in cognitive interest and purpose, is thus a necessary step toward better handling such issues of complementarity in sustainability assessment.

The differentiation of science into specialized scientific perspectives is an important reason why it is often difficult to communicate across scientific perspectives, in terms of what Thomas Kuhn (1996) called incommensurability. Each scientific perspective has its own phenomenal world, its own representation (as defined above) of the world entailed in theories, models, concepts, classifications, observation apparatuses, and examples. This perspectival understanding is a deeper reason of incommensurability than language differences, which Kuhn stated as the reason for incommensurability, because it is tied into the specific observational apparatus and the specific forms of interaction with research objects provided by it (cf. Alrøe and Noe 2014*a*).

We must expect different scientific perspectives to sometimes bring forth mutually excluding representations of the research object, which none the less all seem important to our understanding; that is, complementary phenomena in Bohr's sense. Incommensurability means that it is impossible to incorporate representations of the (presumed) same object from one perspective into another because of differences in the theoretical framework, concepts, etc. Still, the different observations may be performed concurrently and supplement each other to give a fuller, if multifaceted, representation of the object. In contrast, complementarity means that the observations exclude each other because of the observational conditions, and "allows us only to make a choice between the different complementary types of phenomena we want to study" (Bohr 1949:223). For instance, doing farm development research from an involved observer stance excludes doing monitoring research on how that farm performs "on its own" from a detached observer stance because of the interactivity (or intra-activity in Barad's terms) of observation and the individuality of farms.

Complementarity and problem solving

Perspectival disagreement, incommensurability and complementarity may all be problematic in cross-disciplinary research activities (and science-based sustainability assessment and transformation is, in effect, cross-disciplinary research), but very little has been done to investigate what complementarity means for cross-disciplinary research. Even less has been done to identify differences between perspectival disagreement, incommensurability, and complementarity and to investigate how to handle these different forms of constraint in cross-disciplinary research. We think such work could prove very helpful in addressing the key problems of integration and implementation in sustainability assessment and transformation, because even though these different differences between perspectives (perspectival disagreement, incommensurability, and complementarity) may all pose important constraints, these constraints must be handled quite differently.

When problems of complementarity are confronted in sustainability assessment, they are typically recognized as very difficult problems that involve a choice between different and in some way incompatible perspectives, approaches, or methods, but not as problems of complementarity in the radical sense that we have explored in this paper. This means that such problems are handled in different, but all inadequate or abortive ways, such as: (A) disregarding (or overlooking) the differences and pretending (or believing) that the methods of observation are not incompatible, (B) choosing one method and ignoring, dismissing, or countering the other(s), and (C) trying to mix or combine or merge the different methods or construct an in-between method.

An improved understanding of complementarity as a general issue in science can help in two ways:

1. It can help understanding the fundamental cognitive character of complementarity, which means that complementarity cannot be overcome by methodological advances, only handled in better or worse ways, and focus attention on how to handle issues of complementarity better.

2. It can help distinguish between issues of complementarity and other problematic issues, and thereby between problems that may be resolved and those that may not, and focus attention on how to better recognize issues of complementarity.

CONCLUSIONS

Sustainability is a paradoxical perspective because it strives to comprise the whole to sustain life and well-being, but it must rely on a multitude of perspectives, perspectives that may be complementary and therefore mutually exclude each other. In fact, we have shown that complementarity plays an important role in understanding two key problems of sustainability assessment, the problem of integrating different assessments and indicators and the problem of implementing assessments in practice. Unlike many other problems of sustainability assessment, complementarity is of a fundamental character connected to the very conditions for observation. Therefore complementarity cannot be overcome methodologically; only handled better or worse.

We have identified two forms of complementarity in sustainability assessment and transformation. Value complementarity concerns a basic ontological path dependency. Two values, such as naturalness and care in animal welfare, or sustainability as growth without borders and growth within limits, may be located on different paths that cannot both be taken at the same time. Observer stance complementarity concerns a basic epistemological condition. Two perspectives, such as assessment for monitoring and assessment for learning and development, or assessment from within a food chain and assessment from without, may exclude each other because of the conditions for observation and representation.

Science is essential to the societal goal of sustainability, but these issues of complementarity impede the constructive role of science in the transition to more sustainable structures and practices in food systems. Participation in itself is impotent. The agencies of sustainability assessment and transformation need to be acutely aware of the importance of different perspectives and values and the complementarities that may be connected to these differences.

An improved understanding of complementarity can help to better recognize and handle issues of complementarity. These deliberations have relevance not only for sustainability assessment, but more generally for transdisciplinary research on wicked problems.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/8220

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