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REVIEW ARTICLE

Transforum system innovation towards sustainable food. A review

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Abstract Innovations in the agri-food sector are needed to create a sustainable food supply. Sustainable food supply requires unexpectedly that densely populated regions remain food producers. A Dutch innovation program has aimed at showing the way forward through creating a number of practice and scientific projects. Generic lessons from the scientific projects in this program are likely to be of interest to agricultural innovation in other densely populated regions in the world. Based on the executed scientific projects, generic lessons across the whole innovation program are derived. We found that the agricultural sector requires evolutionary rather than revolutionary changes to reshaping institutions. Measuring sustainability is possible against benchmarks and requires stakeholder agreement on sustainability values. Results show the importance of multiple social views and multiple stakeholder involvement in agricultural innovation. Findings call for flexible goal rather than process-oriented management of innovation. Findings also emphasise the essential role of profit in anchoring sustainable development in business. The results agree with concepts of evolutionary innovation. We conclude that there is no single best solution to making the agri-food sector more sustainable densely populated areas, but that the combination of a range of solutions and approaches is likely to provide the best way forward.

Keywords Sustainable agriculture · Innovation · Transition

Contents

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1 Introduction

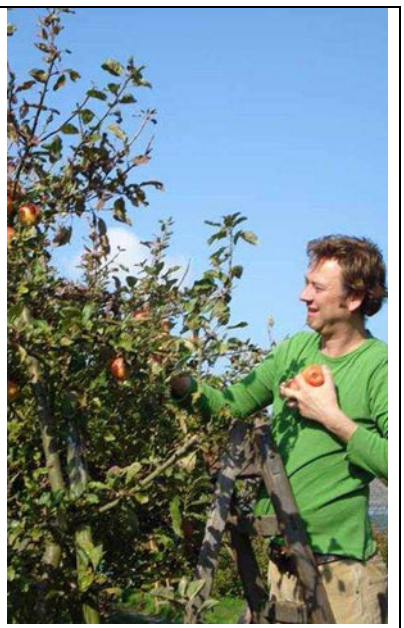
The low-lying plains in river deltas have long supported human agriculture. The earliest western civilisations

emerged in the deltas of Tigris and Euphrates, and of the Nile. This has resulted in large and densely populated areas around the world such as the Osaka–Kyoto region in Japan, the Boston–Washington–New York conurbation in the USA and the Rhine delta consisting of the Netherlands and parts of Belgium and Germany. These regions have in common that they combine dense urban populations with some of the most fertile arable lands on the planet. The dense urban infrastructure makes it impossible to grow staple crops at a large scale in these regions. In fact, people living in cities may lay claim to rural areas, for example for recreational purposes that do not necessarily agree with the use of heavy harvesting equipment or large stables. The growing population and increasing affluence leading to an anticipated doubling of the demand for high-quality foods by 2050 make it essential that the densely populated regions contribute to the global food supply (Tacoli 2004; FAO 2009), as part of a range of initiatives to ensure food supply in the future (Sachs et al. 2010). Besides offering problems, the unique interweaving of urban and food production functionality also has benefits. The agricultural industry has easy access to highly trained professionals, and there is ample opportunity to develop short distribution chains. A good example of these developments can be found in Dutch agriculture, where short distribution chains allowed the opportunity for farmers to interact with consumers (see Table 1) and where a high-tech animal-friendly egg-laying coop was developed to fit into the landscape (see Table 2).

The Dutch agricultural sector consists of some of the most productive and advanced agricultural producers in the world (Arnade 1998; Roseboom and Rutten 1998); with €58 billion (10% of Dutch GDP), it was the second largest exporter of agricultural produce in the world (UN 2008). With its relatively small land area of 41.528 km^2 and dense population of 400 persons/km^2 (compared to, e.g. France, land area 674,843 km^2; population density 116/km^2; or the USA, land area 9,826,673 km^2, population density 34/km^2) , the Netherlands is one of the most agriculturally intensive and most densely populated countries. However, like agriculture in other densely populated regions, Dutch agriculture is currently surpassing its limits. Overspecialisation, environmental damage and competition for space between agricultural land use and public and recreational land use have resulted in competing claims on the scarce rural resources (Wiskerke and Van der Ploeg 2004). As a consequence, in the densely populated metropolitan area of the Netherlands, Dutch agriculture has met its physical and social limits. These limits put the Dutch agri-industrial sector at risk of losing its societal 'licence to produce', its regulatory 'licence to operate' and its economic 'licence to sell' (Casimir and Dutilh 2003; Veldkamp et al. 2009). The Dutch agricultural sector requires innovations in the near future to be

Table 1 The 'MijnBoer' case

DIRECT LINKS BETWEEN PRODUCER AND CONSUMER



Consumers are increasingly insisting that the products they buy are sustainably produced. Consumer's food options are often limited to those products on the shelf in the supermarket. When it comes to purchasing policy, supermarkets are guided in particular by price. As far as supermarkets are concerned producers are interchangeable, because price is the only important criterion for selecting producers. The 'MijnBoer' ('My Farmer') initiative establishes a direct link between producer and consumer.

In the project, farmers in the vicinity of Amsterdam use alternative distribution channels to offer their products directly to the consumer. This way, they establish a direct link with their customers. One of the distribution channels for the 'MijnBoer' products is Marqt, a new supermarket formula, totalling nearly 700 m^2 of shopping area. At Marqt, the producers keep the ownership of their products even on the shelf. As a business model,

Marqt receives a percentage of the farmers' sales, instead of earning a profit by reselling the farmers' products. Consumers can consult a website (www.mijnboer.nl) to get some background on their purchases, such as where the'MijnBoer' products come from and how they are produced. Consumers are welcome to visit the farm for a demonstration. This increases their awareness of the food and how it is produced, and their willingness to pay a fair price for the quality and sustain ability of the products, and answers to the consumer demand for authentic, tasty and high-quality food produced along sustainable lines, and it gives producers a chance to invest.

Table 2 The 'Rondeel®' case

IMPROVEMENT OF ANIMAL WELFARE IN A HIGH-TECH POULTRY STABLE

Current chicken-husbandry systems have many problems concerning animal disease risks, environmental pollution and animal welfare. In response to public demand for animal welfare, food safety and animal health an innovative, sustainable chicken husbandry system called "The Rondeel ®" was developed. Entrepreneurs, research institutes and societal organisations jointly developed this sustainable housing system. The design criteria that were used included environmental impact (e.g. reduced ammonia emissions and an efficient chicken manure drying system), chicken health and welfare (including indoor facilities in case of fowl pest), fit within the landscape, and business efficiency (e.g. modern packaging machines). A coalition of poultry farmers, the Animal Protection Foundation, a chicken coop constructor, a coop building company, research institutes, an egg-dealer and the retailer was created to together develop the business model that could turn the chicken husbandry system into a success. A visitor centre has been set up to inform consumers about how the chickens live and how the eggs are produced. Rondeel® eggs are on the shelves of major national supermarkets. The extra investments for coop design and construction should be recouped in due course.

socially, environmentally and economically sustainable (cf. Elkington 1999). Lessons learned from initiatives to bring along such 'sustainable innovation' are likely of relevance to other regions in the world that face similar issues. Therefore, this paper uses the case of a Dutch innovation program to derive generic lessons for sustainable innovation for agriculture in densely populated, urban areas.

The innovation program used as a case in this paper is TransForum, which was established in 2004 by the Dutch government as an innovation program to develop and test new, sustainable perspectives for the Dutch agriculture. The TransForum program set out to develop a tailored approach to supporting sustainable innovation in Dutch agriculture. It was informed by innovation theories and allowed for adjustments after observations of the first tranche of projects. This approach has been outlined in detail by Veldkamp et al. (2009) in a previous edition of this journal. Where Veldkamp and colleagues presented a vision of how to organise innovation for sustainable agriculture, they could not yet state to what extent the proposed ideas would be successful in practice. Since 2009, a large number of projects have been completed. At this stage, it has therefore become possible to analyse actual results from the scientific research supporting sustainable innovation in agriculture.

To understand such outcomes in the relevant context, first an overview of the program is given. This will be followed by an analysis of the outcomes of the program, from which generic principles to support sustainable innovation in the agri sector are derived and discussed.

2 Framework of the research program

TransForum adopted five guiding ideas for working towards sustainable (in the sense of addressing environmental, social and economic concerns) development (Veldkamp et al. 2009). These ideas were rooted in specific convictions about the nature of the agri-food sector. In terms of system type, we see the Dutch agri-food sector as a socio-technical system (e.g. Schot et al. 1994; Rip and Kemp 1998). This means that, in our conceptualisation of the agri-food sector, the physical, the social and the technological aspects of the system are included. When applied to the agri-food sector, this includes aspects such as:

- Soil, climate, water (physical aspects).
- The presence of multiple actors with specific values of interest; societal discourses about the agri-food sector, laws governing the agri-food sector and institutions that shape, and are shaped by the agri-food system (social/societal aspects).
- Innovative animal husbandry systems, new modes of genetic modification, but also more intangible 'technology', such as the integration of agricultural and care services and the development of and experimentation with new institutions that are beneficial to change (technological aspects).

More specifically, with regard to its system behaviour, the agri-food sector is essentially considered as a complex adaptive system (e.g. Holland 1996; Kay 2002), in the sense that, as a whole, the system behaves in an evolutionary way,

reacting to slow changes in its societal and physical context, while at the same time, many aspects of its behaviour emerge from the actions and interactions of the actors within the system. Complex adaptive system behaviour can include sudden system reconfigurations from one system state to another and is inherently unpredictable (Kay 2002).

Managing systems like the agri-food sector requires specific modes of learning and management. The presence of multiple, interdependent actors in combination with the inherent unpredictability of those systems limit the options for steering the agri-food sector. Traditional policy analysis, where scientists analyse a problem and offer technological solutions, is no longer viable (Steyaert et al. 2007). Scientific knowledge turns out to be only one kind of knowledge and complex societal issues require a more integrated approach, in which knowledge is used and produced by scientists, entrepreneurs, non-governmental organisations (NGOs) and policymakers alike (cf. Funtowicz and Ravetz 1993; Ison et al. 2007). Indeed, there should be an emphasis on concerted action (Ison and Watson 2007) by the actors involved, despite their mutual differences (e.g. animal welfare organisations vs. intensive animal farmers). This requires a transdisciplinary process, in which all actors involved learn from each other and construct new knowledge and solutions (Ison et al. 2007).

The above conceptualisation of the agri-food sector gave rise to the following five guiding ideas for sustainable agricultural development (Veldkamp et al. 2009):

1. Sustainable development is a dynamic system property. Sustainability is a multidimensional optimisation of people (or social), planet (or environmental) and profit (or economic) characteristics (Elkington 1999) in a societal context. There is no single optimal solution, especially since the sustainability indicators are being redefined in their specific context. This will result in an on-going dynamic optimisation process that will eventually involve the agri-food sector as a whole.
2. Sustainable development needs system innovation. The current agricultural practice has been optimised for large volumes and low costs. As such, it is not sufficiently equipped to be optimised for more complex and multidimensional sustainability aspects such as environmental impact and social effects. Therefore, innovations should introduce not only new products and services, in the sense of further agricultural optimisation, but should also introduce structural change such as new modes of production, the inclusion of non-agricultural goods and services, and the adoption of new accountability systems.
3. System innovation is a non-linear learning process. The dynamic and multidimensional nature of sustainable development creates a situation where a simple linear process from invention to market no longer holds. Societal demands increasingly put pressure on scientific inventions, to repeatedly interact with, rather than respond to, societal and institutional regimes.
4. Non-linear system innovation requires a multi-stakeholder approach. Non-linear system innovation implies that no single stakeholder has a solitary role in any single stage of an innovation. Instead, multi-stakeholder involvement is required at all stages of system innovation.
5. An integrative approach for sustainable development has to be transdisciplinary. A non-linear multi-stakeholder approach entails that a ranges of sciences interact with on-going innovation in practice, making this a clear case of a transdisciplinary approach.

Following these ideas, TransForum developed a series of innovative practice projects. TransForum provided financial support, but has also assumed the role of intermediary in the innovative practice projects. In the latter function, it has adopted a leading role in the practice projects following its vision of how to develop a relevant sustainable agricultural sector in a densely populated metropolitan area (cf. Senge et al. 1994).

An analysis of the practice projects shows that the five guiding ideas outlined above have been particularly successful in those situations where innovations for sustainability involved complex systems, or wicked problems (Peterson and Mager 2011). These ideas where thus most useful in those problems that involve, among others, incomplete knowledge, contradictory and changing solutions (Rittel and Webber 1973; Frame 2008). Solving parts of a wicked problem may create changes that affect or even worsen other parts of the problem. This makes wicked problems in practice (nigh) impossible to solve, and the best approach is to manage the issue rather than to aim for a definitive solution.

2.1 The supporting role of science

Besides practice projects, TransForum also supported scientific research. The role of scientific research in TransForum aimed at managing issues emerging from practice projects, especially those issues that by their nature went beyond the boundaries of a single practice project. Thus, there has been a continuous interplay between the practice projects and the scientific projects. In that interplay, science has taken three distinct approaches to interacting with practice (cf. Ison et al. 2007).

First, scientists have been involved in the practice projects as reflective agents. In this role, scientists closely monitored practice projects, aimed at validating the guiding ideas and providing principles for sustainable innovation in the agro-food sector (see e.g. Regeer 2010). Second, scientists have been involved in practice projects to provide scientific advice

and solve problems in the projects themselves, as such adopting a role close to that of scientific consultant.

A third role of science was through separate scientific projects, which were specifically developed to investigate *generic* issues of importance for practice. The scientific projects were aimed at delivering answers to questions arising across the practice projects. The resulting scientific projects were in part established in answer to issues raised bottom up from specific practice projects. Additional scientific projects addressed issues that were identified as being important to the successful implementation of innovation. This approach was more top down and worked from a priori insights about bottlenecks that frustrated innovation.

To structure the scientific projects, they were assigned to one of four themes that represent important phases in innovation in agriculture (Veldkamp et al. 2009): (1) Shared images of a sustainable future creating a drive towards sustainable development. (2) Inventions to promote sustainable production are needed. (3) Inventions need to relate to an institutional innovation environment. (4) Market and consumer demand to generate the required cash flow to anchor the sustainable development. The subsequent, new situations, lead once again to new images for the future, thus creating a continuous innovation cycle or spiral (Argyris 1994, Fig. 1).

The scientific projects within the themes were not specified a priori, but formulated in response to knowledge demands from the practice projects. The resulting scientific portfolio was therefore more closely tailored to questions emerging from practice, than being 'programmed' in a top-down manner, making the themes more like four 'thematic hotspots', instead of clearly delineated programmatic themes.

2.2 Reference framework of knowledge demands from the practice portfolio

Recently, Peterson and Mager (2011) conducted a post hoc analysis of 30 practice projects in Dutch agriculture. They identified various important issues that could not be addressed within these projects. These are the issues that can benefit from scientific study and come down to five major issues.

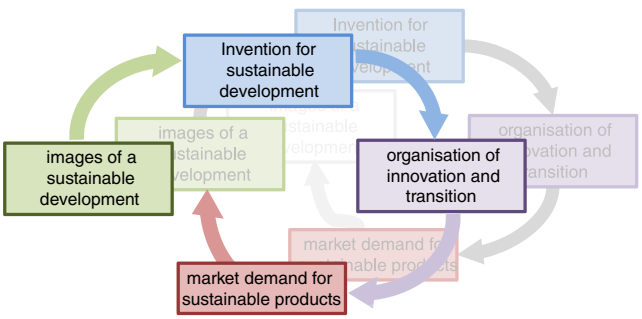


Fig. 1 Innovation spiral

- How to deal with the lack of power to influence the institutional environment

  Practical innovation projects are operating in an institutional environment the project has little power over. This makes innovations vulnerable to unexpected consequences of actions and random events. Most projects largely manage to work their way around such problems. In spite of the general success in coping with this issue, little generic knowledge how to interpret, assess and (if possible) to influence institutional regimes is present in most projects. This makes strategies to deal with the lack of power to influence the relevant institutional environment haphazard but at the same time necessary (cf. Midgley 2000).
- Measuring sustainability

  The debate how to define, measure and quantify sustainability still revolves around arriving at a 'golden standard' for weighing the relative importance of people, planet and profit dimensions. There is no agreement which sustainability indicators to be used in a dynamic situation.
- Insufficient realisation of importance of social and organisational issues besides technology development.

  Several projects depend heavily on the development of technologies. However, the organisation around these innovations and the implementation of inventions in institutional and societal contexts are often neglected as it is assumed these structures will 'conform' to technological invention. There is little generic knowledge on how to integrate the non-technological part of innovations with invention activities.
- Strictly defined project management structure

  Innovations require flexible and adaptive organisation; however, in many innovation programmes and projects, prescriptive subsidy regimes by the government, traditional management structures and the demand for projects to be accountable to the original project description, planning and deliverables are mandatory. Alternative management structures are insufficiently explored.
- Investment in actual production is not achieved

  Implementation of business plans and actual investment, let alone the realisation of promises, are often not fully realised. For innovation to be successful, there is a need for business development where profit, people and planet values are all anchored into the core of the business plan. These five issues can be used to generalise the relevance of scientific projects and their value for innovation in practice.

3 Methods and approach

The approach in choosing topics for scientific research was based on the unpredictable knowledge questions arising from innovation in practice. This makes an overview of the scientific portfolio of TransForum based on an a priori reference framework impossible. Instead, this reference framework emerged from the practice portfolio concurrently with the scientific research being conducted. Systemic action research has been adopted in developing the TransForum program, following four stages (Ison 2010): (1) Naming the system of interest, which in this case is the Dutch agri-sector as a case study. (2) Evaluating the effectiveness of the system as relevant to understanding the context, where the five principles have been shown to be highly relevant by Veldkamp et al. (2009). (3) Generating a joint decision-making process, which is the rationale behind the specification of scientific research based on practical issues (discussed in detail in Veldkamp et al. 2009). (4) Evaluating the effectiveness of the decision made. The latter of these has not yet been realised in full and will form the main effort of the remainder of this paper.

More explicitly, evaluation of the scientific projects will address answering the following specific questions:

1. What insights and action perspectives to support sustainable innovation emerge from the scientific portfolio?
2. How do these outcomes across the different themes relate to the practical issues raised in the practice projects?

To answer research question 1, the contribution of each scientific theme is analysed separately, starting with a brief description of the theme identity, followed by an overview of specific and overarching conclusions for that theme. Each theme was coordinated by one or two scientists, who were responsible for deriving the meaning of their theme. The interpreted meaning of each theme was reviewed by the coordinator of another theme and revised according to his/her the comments. Additionally, in 2010, the theme coordinators reviewed each individual project in their theme, to aggregate the meaning of individual projects. The reviews were discussed in the plenary meeting of TransForum and revised accordingly. Drawing from these individual project reviews, the coordinators of each theme then interpreted the contribution of their theme to managing emerging issues in practical innovation in the agro sector for the current paper. The current paper provides the generic insights of relevance, and action perspectives for future innovations projects that emerged from this analysis.

To answer research question 2, the outcomes of the scientific projects were interpreted against the raised issues from practice.

4 Results: insights and action perspectives from the scientific portfolio

4.1 Images for sustainable development

Images have a pivotal role in complex innovation processes: they can lead to support and action readiness amongst actors, but may also create societal opposition against innovation. Image management is essential to foster support within the own, multi-actor innovation team, and support for the innovative project from society at large. The study of images in innovation has yielded the following insights and action perspectives:

Insight Multiple discourses about sustainable agriculture coexist in the Netherlands; the agri-ruralist (farmer), utilitarianist (countryside as resource) and hedonist (country side as recreation ground) discourses are particularly different in this respect (Hermans et al. 2009). The weighing of people–planet and profit dimensions and even the valuation of performance on a single sustainability dimension is an inherently subjective and value-related decision. Each of the discourses offers a different view on people, planet and profit dimensions, as well as sustainability performance. The position of the stakeholder determines the value attributed to either dimension.

Related action perspective Studying discourses helps to understand how different stakeholders balance people, planet and profit dimensions of sustainability issues, but it does not provide clear action perspectives towards consensus, nor does it make it easier to discuss the underlying complexity (Beers et al. 2010).

Insight Different worldviews lead to different interpretations of sustainability. Among people adopting the utilitarian perspective, technology is seen as an important solution to sustainability issues. Other people view technology mainly as a source of problems. Indeed different consumer segments have different opinions and wishes related to sustainable food products. The realisation of different discourses confirms that the sustainable food market is not homogenous. It was shown that deliberate and focussed consumer segmentation could further specify the products to the most viable target group for business development. In complex adaptive systems simple images can take away attention from the more complex aspects of innovation, thus limiting insight in unexpected and counterintuitive dynamics of change.

Related action perspective Collaborative development of scenarios that visualise multiple pathways towards sustainable development should be applied to bridge differences (values, interests) between actors and their goals. This process can also be used to better understand the underlying system complexity and their associated dynamics, as it is

easier to talk about what can be visualised, than to use abstract concepts that are open to multiple interpretations (Vervoort et al. 2009).

Overarching insight Viewing sustainable innovation as a discourse organised around images helps the understanding of problems with measuring sustainability, and allows monitoring and framing of on-going discourses.

Overarching action perspective Apply image management to deal with different (societal) opinions on separate levels to shed light on unexpected and counterintuitive dynamics of change. Image management consists of three major elements: (1) Within an innovation project, action needs to be taken to guarantee sufficient diversity to be able to become aware of the different ways in which projects are seen. (2) On the interface with society, awareness must be actively developed of how different societal groups may impact the project, be it positively (e.g. The Roundel—see Table 1) or negatively (e.g. New Mixed Farm—see Table 3). (3) On the societal level collaboratively image creation of the future is needed. Images should include multiple discourses, even when that means including opponents (Beers and Veldkamp 2011).

4.2 Inventions for sustainable development

Classically, innovation was considered a technology-driven process. Although technological inventions remain important for successful innovation, it has become clear that in complex innovations the hardware provided by technology needs parallel and interactive development of new knowledge and competence in the innovation team (or software) and institutional embedding (or orgware):

Insight Measuring sustainability improvement remains difficult as specific inventions carry different social consequences. An important new development is that inventions in the life sciences are increasingly protected by patents; this is in contrast to the past where these inventions were freely available because of their origin in public domain. At present, there is a tension between breeder rights, allowing the free use of protected varieties as breeding parent, and the patent law, which is strictly protecting one or a few traits of a variety (Jacobsen et al. 2011).

Related action perspective Stimulate the practice of open innovation, with appropriate protection of intellectual property rights as an alternative for patents.

Insight While inventions are an essential part of innovation, they are not sufficient. New inventions can only lead to successful innovations if they stimulate entrepreneurship and ensure that a limited number of 'leaders' arise that inspire 'followers'. The inventions needed to achieve a more sustainable agriculture will be particularly dependent on these leaders.

Related action perspective Appoint entrepreneurs as leaders of innovation projects instead of scientists, policymakers of NGO representatives.

Table 3 The 'New Mixed Farm' case

LINKING UP FARMS TO MAXIMISE USE OF RESOURCES
Linked up cycles between farms and effective use of another's' waste flows has lead three farms to cooperate in the New Mixed Farm to establish 1) a closed poultry farm ranging from egg right through to chicken fillet, 2) a closed pig farm from parent sow through to meat pig and 3) an installation firm. The aim of the entrepreneurs is to reuse waste flows from each other's farms wherever possible and to convert these into high-grade products to generate additional social utility and profit; and to increase the efficiency of production through increases in scale and chain-integration efficiency. In doing so the New Mixed Farm developers thought to be responding to the wishes of its customers in the nearby metropolitan areas. An independent sustainability scan has revealed the potential sustainability gains. The environmental performance is above average with 60-80% less energy used, emissions of greenhouse gases 30-40% lower than on conventional farms and a 70% reduction in ammonia. The chain integration should result in substantial decrease in animal transport, and improved animal welfare; The concentration of enterprises at a single site did however result in a local increase in industrial traffic, ammonia, stench, and fine-substance emissions. This project clearly shows the challenges in involving the local community. Tensions between local supporters and opponents did not become visible until late in the decision-making process. Involvement and protests only gained power after the local consequences became clear. Change in political support also affected the ideas for the new mixed farm.

Insight It is increasingly common for inventions not to be linear but complex. Linear inventions follow the sequence of development of fundamental and strategic research followed by targeted application. For complex innovations, entrepreneurship should drive the innovation from the start. Inventions may have their origins in technology, but can also be driven by society. The latter has been the case with the development of organic agriculture, and more recently, the development of the energy-producing greenhouse and environment-friendly production at care farms with psychiatric clients. In such cases, technology development, if necessary, is much more targeted at solving specific problems that emerge at different stages in the on-going innovation, rather than being a single driving starting point for innovation.

Related action perspective In complex non-linear inventions, science and technology can no longer be the main leading driver for innovation. Development of software (new skills and knowledge) and orgware (favourable organisational and institutional conditions) should be at equal footing with science and technology.

Overarching insight Inventions are central to many new developments, including sustainable agriculture. But, although inventions are necessary, they are not sufficient for complex innovations. Entrepreneurial drive, skill development and knowledge development and institutional and societal influence should be taken at heart at every stage of an innovation project.

Overarching action perspective For complex innovations, focus on robust innovations in a changing societal situation where inventions should be used to support innovations instead of leading them.

4.3 Organisation of innovations and transitions towards sustainable development

Institutional contexts can both hinder and support innovation processes. Establishing a nurturing institutional context for innovation requires insights in the capacity and motivation of entrepreneurs. Successful collaborations between companies and entrepreneurs are needed, as well as new public–private partnerships and ways of tracking the larger development of sustainable food production. Insights for the specific institutional context of sustainable agri-food innovation are:

Insight Gradual and stepwise 'reconfigurations' are a more important transition trajectory in agriculture than revolutionary breakthroughs (cf. Geels 2002, 2004). Acknowledging the potential of self-organisation is essential. In a self-organising innovation, boundary-spanning actors such as innovation facilitators can be intermediaries that resolve the problems with institutional regimes. Actual regime change in agriculture requires a multitude of small-scale initiatives that yield evolutionary changes, while efforts towards revolutionary change tend to activate societal opposition (cf. Geels 2004). Innovation programmes act as spaces of experimentation and sensibilisation, creating new configurations of involved actors around a common awareness to explore possible directions for change. At the same time, they provide the kinds of resources (new knowledge, new contacts, venture capital and licensing space) that enable entrepreneurs to explore and learn from uncertain opportunities.

Related action perspective Create small-scale innovation spaces, to allowing for seeding stepwise innovations. Innovation programmes set up as experimentation space are well suited for this purpose.

Insight Networks are influenced positively by enduring focus on goal-directed aspects (e.g. a business case); an intermediate level of partner diversity; a mediating and facilitating knowledge infrastructure; sufficient levels of trust, early involvement, formalisation and commitment between actors.

Related action perspective Aim innovation networks and programmes at achieving shared goals. The process and innovation team composition should be organised to support goal achievement and should be highly flexible to accommodate this.

Insight Successful stakeholder configurations are based on the organisational, social and institutional dynamics characterising innovation and transition trajectories in the agro-food complex. The organisation and evolution of 'vital coalitions' of KENGi[1] partners enables transitional changes based on effective public–private forms of network management.

Related action perspective When designing innovation projects, ensure the presence of (1) a shared sense of direction based on a shared story line; (2) entrepreneurship and versatile leadership; (3) a responsible and process sensible form of government backing and (4) a transdisciplinary knowledge infrastructure which acts as a third party and acts as a boundary-spanning instance, while not taking over responsibility.

Overarching insight Identification of the institutional and organisational conditions hindering/facilitating the

[1] KENGi partners: Knowledge Institutes, Entrepreneurs, NGOs, governments and intermediaries (optional)

mobilisation is essential for the maturation of innovations and transitions. Large-scale, process-optimised, innovation efforts that are aimed at achieving revolutionary breakthroughs are of less relevance in the agri-food domain compared to accumulated small-scale initiatives.

Overarching action perspective Organise support for many small-scale projects to achieve evolutionary innovation in the agri-food sector.

4.4 Market demand for sustainable products and services

Sustainable innovation, independent of continued subsidies, will only be possible if the products and services that are brought to a consumer market provide sufficient cash flow to maintain business. Organising the demand for sustainable products is thus a key to lasting sustainable innovation. Organisation of demand should deal with creating chains that include rewards for being sustainable inside the chain, or because of increased consumer market spending on sustainable products. Insights and action perspectives from social marketing and product marketing are:

Insight When buying products, consumers tend to lump people and planet dimensions of sustainable development together into a single sustainability dimension (Van Dam and van Trijp 2011). Positioning of sustainable products and brands in shops can support sustainable consumption, through the in-store retail mix and assortment organisation.

Related action perspective Create a single 'sustainable' brand combining all sustainable product lines (fair trade, CO_2 neutral and organic). Carefully choose placement of the sustainable brand to increase consumer choice.

Insight Attitudes have only limited predictive power for sustainable choice. Attitudes are related to personal value structures and provide an opinion in the public debate. As such, they are important in the discourses at an abstract level, but not very important when it comes to actual consumer choice. Addition of peer pressure or social norms is likely to contribute to actual sustainable choice (e.g. Melnyk et al. 2011).

Related action perspective Interpret consumer attitude as relevant to the public discourse, but with limited predictive power for consumer choice.

Insight Corporate social responsibility strategies for increased sustainability are essential. Corporate social responsibility is supported by a proactive internal drive of a company or a reactive external driver (pressure on the company). Companies may freely switch between non-sustainable (usually price driven), reactive and proactive sustainable strategies. Sustainability incentives on companies should be applied continuously to maintain or increase sustainable business.

Related action perspective Maintain pressure on companies to keep moving towards more sustainable production. Do not interpret the move towards sustainable production as unavoidable or a stable endpoint for the development of a company.

Insight Multi-actor collaboration is necessary for the introduction of sustainable products. The ideal constellation of actors in such a process depends on a fitting management style and the phase of a project. Projects should actively combine specific actors that work best under a specific management style. Constellations of actors and the stake they support should be revisited through the stages of a project. Early involvement of consumers as stakeholders is essential to build in and anchor consumer values into products. Reframing from process (organic laying hen requirement in square meter) to goal (achieve natural hen behaviour) can be used to anchor multiple actor views in a product.

Related action perspective Create and update innovation projects to have management style and stakeholder composition (including end users) that fits the stage of a project.

Overarching insight Incentives to become sustainable are needed within the production chain, either by increasing efficiency (cost reduction) or by additional company benefits generated by increased consumer spending.

Overarching action perspective Collaborate with the sustainable sector as a whole to increase the overall sustainable market by adopting social marketing principles.

4.5 Generic

Emerging issues from practice projects that are not close to a single of the four thematic hotspots were studied to ensure the broad coverage needed for innovations in the agri-food sector. The insights from these generic projects tend to be at the intersections between the other themes:

Insight Innovation for sustainable development is an iterative process—a process that requires a vision and monitoring as guidance to the development (cyclical innovation model and self-organisation). Standardising 'sustainability' is not possible and regarding it as a final outcome of an innovation creates a barrier for further sustainable

Table 4 Insights relating to the five areas for further attention

	Dealing with the lack of power to influence the institutional environment	Measuring sustainability	Insufficient realisation of importance of organisation, knowledge and dealing with public opinion	Strictly defined project management structure	Investment in actual production is not achieved
Images		Complex, dynamic system approaches with multiple stakeholders include subjectivity in measuring sustainability	Different discourses may have a radical different outlook on the same issue (e.g. technology) where the benefits for one party as seen as risks by another		
Inventions	Movement towards patent as sole way of protecting intellectual property right is frustrating innovation		Non-linear innovations have multiple stages that involve technology development, but also societal involvement that makes technology leading principles not suitable for all projects		Entrepreneurial drive is required to bring invention to innovation.
Organisation	For the agro-sector, changing the institutional environment through the accumulation of many small innovations works better than attempting to create radical innovation			Innovation projects are most successful when the project team is somewhat diverse, but is focussing on a shared but dynamic goal. Project management should reflect and account for underlying institutional realities	
Demand			Attitudes are a better prediction of personal values and societal discourse than consumer choice	Innovations projects require different stakeholder roles (including end user) in different phases of development	Existing marketing knowledge on branding and placement can be amended with specific details for sustainable production. Adoption of sustainable business plans requires internal or external pressure on the company
Generic		Generic and final measures of sustainability do not exist as it is a dynamic and wicked issue			Ambitious plans require a lot of funding and generate many risks, making the business proposition of little interest to investors. In sustainable production the i mportance of profit is still often overlooked.

development. This renders measuring a definitive sustainability score practically impossible. Instead, improvement of sustainability should be benchmarked against the sustainability performance of alternatives.

Related action perspective Measure sustainability improvement by comparing people, planet and profit improvements of an innovation against a baseline scenario (Blonk et al. 2010).

Insight Many plans that promise huge sustainability improvement are overly ambitious and require a lot of resources and investments (in both money and effort). This makes that some of the most promising plans are less realistic in terms of organising support and controlling risks. In developing business propositions, mathematical models can be used to estimate risks and making these manageable.

Related action perspective Keep tight control over risks by starting small, providing proofs of concept, keeping track of risks and scale up accordingly.

Insight Profit is an essential condition for the creation of a successful sustainable business plan. An idealistic entrepreneur who does not look for profit will not achieve relevant sustainable development, an opportunistic entrepreneur focussing on profit but not planet and people dimension will also not achieve sustainable development. The relation between profit on one hand and the people and planet dimension on the other hand requires considerable attention and is often overlooked (Blonk et al. 2010).

Related action perspective Include profit indicators in sustainable business plans, while at the same time making sure to anchor sustainability indicators into these plans. Determine how to weigh profit, planet and people indicators against each other within the specific context.

Overarching insight In the context of innovation for sustainable agriculture, dynamic and temporary goals tend to lead to more rapid progress than more ambitious approaches.

Overarching action perspective Adopt intermediary solutions, with acceptable levels of invested resources. Work from intermediary solutions. Be careful with investing in expensive, long-term high-risk revolutionary innovations.

5 Analysis: contribution of science to the emergent issues from practice

Successful practice projects often worked within or were accepted by the existing institutional frameworks. The

Table 5 Action perspectives relating to the five areas for further attention

	Dealing with the lack of power to influence the institutional environment	Measuring sustainability	Insufficient realisation of importance of organisation, knowledge and dealing with public opinion	Strictly defined project management structure	Investment in actual production is not achieved
Images			Develop collaborative scenarios that depict a shared goal		
Inventions	Adopt open innovation where possible and suitable		Include resources to include knowledge and organisation development in the innovation project	Make the entrepreneur project leader	
Organisation	Create small-scale initiatives			Make the goal leading in innovation projects, not the process and procedures Include a dynamic mix of KENGi partners in an innovation project.	
Demand				Allow change of project team composition to fit stage of project, and include end-users at the relevant stages.	Apply social marketing to promote sustainable production as a sector
Generic		Measure sustainability performance by benchmarking and not as an absolute			Start small and invest according to success. Include profit as an essential criterion in all plans.

reviewed projects provided support for this approach in the broader situation of agriculture. The strategy to involve institutional actors and aim for evolutionary change by showing the power of a range of niche experiments is likely to be successful in the agri-food sector to a larger extent than orchestrated effort aimed at radical regime change. A risk is that changes in the institutional context (such as the shift from breeders' rights to patents) may disrupt on-going innovation practices, implying that vigilance to react to institutional changes at an early stage is essential.

Measuring sustainability remains indeed a difficult issue, especially since sustainability as a dynamic property cannot be set as a 'golden standard'. The research suggests how the measurement in such dynamic context can be facilitated by looking at the changes in adaptive systems where robustness of a solution is an indicator of sustainability. Sustainability improvements (but not endpoints) can be benchmarked, thus facilitating the quantification of the efficacy of sustainable development. It remains important to realise that the operationalization and weighing of different sustainability dimensions (people, planet and profit) are likely different between actors when measuring sustainable development. Agreement on how to measure a move towards sustainability remains an essential starting point to any practical innovation aimed at achieving sustainable development.

It is important to understand that personal values drive framing and interpretation of developments significantly. This requires the presence of actors that can reach out across different groups of people and form networks that make different views explicit and mediate between these views. On the other hand, these different views allow for segmentation of the sustainable product market. Additionally, it is realised that public opinion is only to some extent reflected in purchasing behaviour, while other factors like peer pressure should not be overlooked. In other words, we should not only consider the vote of consumer by their actions (Tiebout 1956) but also the societal dynamics created by their attitudes.

Strictly defined management structures are detrimental to sustainable development. Three ways to design innovation programmes are suggested to provide the necessary flexibility. The first option is an empirically supported plea for self-organisation, which would benefit from a largely unstructured experimentation space. The second approach suggests the definition of essential actors for each stage of a project. While this is somewhat more descriptive, it allows flexibility in specifying the actors and changing them when the project requires this. The third approach recommends moving away from restrictive procedures towards project goals as the main guiding principle in accountability of project success. These goals in themselves should be dynamic to account for on-going learning in the project.

When moving towards actual investment, the weighing and anchoring of the different dimensions of sustainability into a business model is an essential hurdle to take. Low profit margins make the profit dimension of central importance, yet in much of the sustainability debate, less attention is paid to making money compared to finding elaborate solutions for people and planet. All chain actors need to be involved using their own competences and the consumer market needs to be increased and segmented towards sustainable products. Anchoring of sustainability values in the core of a company remains a topic that needs to be carefully monitored, as companies may revert to less sustainable

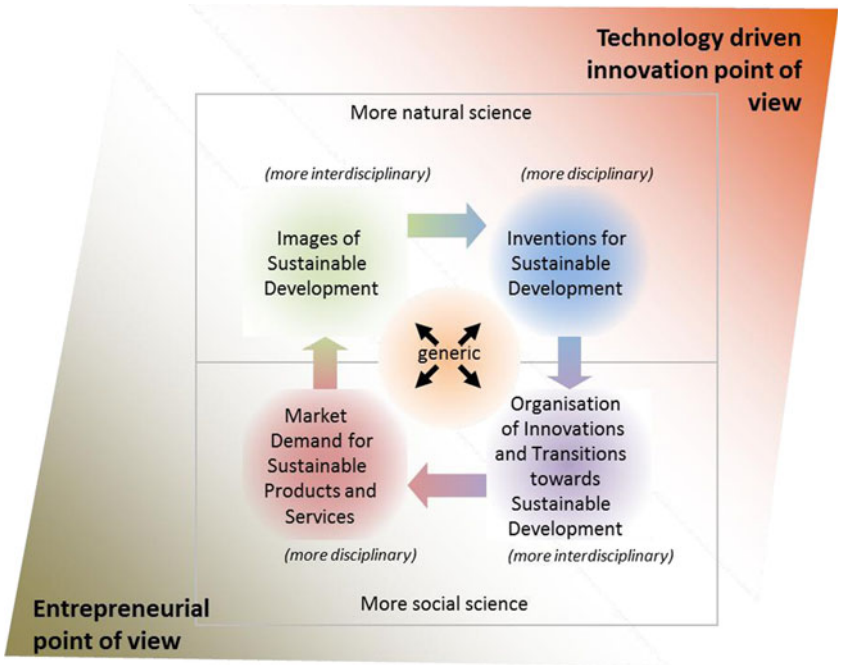


Fig. 2 Innovation playing field

practice if economic or social pressure demands this. Tables 4 and 5 provide an overview of these findings.

6 General discussion and conclusion

Several insights and action perspectives to deal with generic issues emerging from practice projects in sustainable innovation in agriculture have been presented. Underlying difficulties have been explored and lead to suggestions to improve future innovations in wicked problem spaces.

Across the different thematic hotspots, all topics raised from practice were covered, but no single theme dominated the research field, providing support for the design of the scientific effort of TransForum into themes. In retrospect, we observe that the four themes did not only cover distinct phases in the development of an innovation, but that each theme also embraced its own approaches, traditions and paradigms. Themes 1 and 2 were based more in natural science including studies in the best possible soil composition, and greenhouse construction, while themes 3 and 4 adopted more social science approaches focusing on multi-actor interactions and consumer behaviour. Themes 2 and 4 focussed more on disciplinary research based in agricultural technology and marketing; themes 1 and 3 adopted a more interdisciplinary research outlook in the environmental and sciences and in policy sciences (cf. Fischer et al. 2011; Fig. 2). It appears that this specific combination of disciplinarity and interdisciplinarity resulted in a fruitful mix of depth and focus (disciplinary) combined with broad competences in connecting research lines (interdisciplinarity) in a temporary interdisciplinary 'coalition of the willing'.

The iterative nature of the model originally proposed (Veldkamp et al. 2009) was in practice often amended with a joint space where views of all four themes were freely exchanged. In the same joint space, questions emerged which were deemed of universal importance, but did not necessarily fit with one of the four main themes. The areas of connection between the hotspots make sense, as emerging issues from practice projects were leading in the topics of study rather than strictly defined programmes. The connecting space, overlapping all themes is a logical consequence of the more diffuse situation that resulted from this approach (Fig. 2).

The emerging innovation field is most likely to be entered by agricultural entrepreneurs based on perceived market demand, a shared image and institutional situations, instead of the traditional view where innovations where approached from a technology development point of view.

The action perspectives aligned with existing research and tend to be rather specific and straightforward. Broader action perspectives for more complex interventions were frequently not found. This is likely due to the wicked nature of the more complex problems, allowing for almost unlimited ways to manage the problem in hand, which makes a single solution an illusion. Evidence that suggested action perspectives could be applied in other projects remain however scarce. This is partially due to the limited run-time of the TransForum program that did not sufficiently allow confirmation of all ideas in field tests, but may also relate to the wickedness of the faced problems. The changing context does not always allow for application and testing of all suggestions, and the greatest strength thus lies in providing meaning to the unique combination of circumstances in the wicked problem under investigation (see e.g. Nowotny et al. 2003) rather than pursuing elusive 'one size fits all' solutions.

This paper has generated a collection of tools and suggestions, aggregated across multiple projects, disciplines and paradigms. Continued effort applying and evaluating these suggestions applied to future innovation projects will be the true proof of our findings.

References

Argyris C (1994) Initiating change that perseveres. J Publ Admin Res Theor 4:343–355

Arnade C (1998) Using a programming approach to measure international agricultural efficiency and productivity. J Agr Econ 49:67–84. doi:10.1111/j.1477-9552.1998.tb01252.x

Beers PJ, Veldkamp A (2011) For or against innovation? The influence of images. In: van Latensteijn HC, Andeweg K (eds) The TransForum model: transforming agro innovation toward sustainable development. Springer, Dordrecht, pp 59–72. doi:10.1007/978-90-481-9781-1_4

Beers PJ, Veldkamp A, Hermans FLP, van Apeldoorn DF, Vervoort JM, Kok K (2010) Future sustainability and images. Futures 42:723–732

Blonk H, Scholten J, Broekema R (2010) Measuring the sustainability performance of agro-food chain innovations. TransForum, Zoetermeer

Casimir G, Dutilh C (2003) Sustainability: a gender studies perspective. Int J Consum Stud 27:316–325. doi:10.1046/j.1470-6431.2003.00323.x

Elkington J (1999) Cannibals with forks: the triple bottom line of 21st century. Business Capstone Publishing, Oxford

FAO (2009) Food, agriculture and cities: challenges and priorities. Retrieved 12-11-2011 from: http://www.fao.org/fileadmin/templates/FCIT/PDF/food-agriculture-cities_advocacy.pdf

Fischer ARH, Tobi H, Ronteltap A (2011) When natural met social: a review of collaboration between the natural and social sciences. Interdiscipl Sci Rev 36:341–358

Frame B (2008) 'Wicked', 'messy', and 'clumsy': long-term frameworks for sustainability. Environ Plann C Govern Pol 26:1113–1128

Funtowicz SO, Ravetz JR (1993) The emergence of post-normal science. In: Von Schomberg R (ed) Science, politics and morality: scientific uncertainty and decision making. Kluwer, Dordrecht, pp 85–123

Geels FW (2002) Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. Res Pol 31:1257–1274

Geels FW (2004) From sectoral systems of innovation to socio-technical systems: insights about dynamics and change from sociology and institutional theory. Res Pol 33:897–920

Hermans F, Kok K, Beers PJ, Veldkamp A, Mommaas H (2009) Comparing regime discourses and niche perspectives on sustainable agriculture, First European Conference on Sustainability Transitions: Dynamics & Governance of Transitions to Sustainability, Amsterdam, the Netherlands

Holland JH (1996) Hidden order: how adaptation builds complexity. Addison-Wesley, Reading

Ison R (2010) Systemic action research. In: Ison R (ed) Systems practice: how to act in a climate-change world. Open University, London, pp 267–281. doi:10.1007/978-1-84996-125-7_11

Ison R, Watson D (2007) Illuminating the possibilities for social learning in the management of Scotland's water. Ecol Soc 12:21

Ison R, Röling N, Watson D (2007) Challenges to science and society in the sustainable management and use of water: investigating the role of social learning. Environ Sci Pol 10:499–511

Jacobsen E, Beers PJ, Fischer ARH (2011) Invention for future sustainable development in agriculture. In: van Latensteijn HC, Andeweg K (eds) The TransForum model: transforming agro innovation toward sustainable development. Springer, Dordrecht, pp 21–40. doi:10.1007/978-90-481-9781-1_2

Kay JJ (2002) On complexity theory, exergy, and industrial ecology: some implications for construction ecology. In: Kibert C, Sendzimir J, Guy B (eds) Construction ecology: nature as the basis for green buildings. Spoon Press, London, pp 72–107

Melnyk V, Van Herpen E, Fischer ARH, Van Trijp HC (2011) To think or not to think: the effect of cognitive deliberation on the influence of injunctive versus descriptive social norms. Psychol Mark 28:709–729

Midgley G (2000) Systemic intervention-philosophy, methodology and practice. Springer, New York

Nowotny H, Scott P, Gibbons M (2003) Introduction: 'Mode 2' revisited: the new production of knowledge. Minerva 41:179–194

Peterson HC, Mager SE (2011) From motivating assumptions to a practical innovation model. In: Van Latesteijn HC, Andeweg K (eds) The TransForum model: transforming agro innovation toward sustainable development. Springer, Dordrecht, pp 97–129. doi:10.1007/978-90-481-9781-1

Regeer BJ (2010) Making the invisible visible, Vrije Universiteit, Amsterdam

Rip A, Kemp R (1998) Technical change. In: Rayner S, Majone EL (eds) Human choice and climate change. Batelle Press, Columbus, pp 327–399

Rittel HWH, Webber MM (1973) Dilemmas in a general theory of planning. Pol Sci 4:155–169

Roseboom J, Rutten H (1998) The transformation of the Dutch agricultural research system: an unfinished agenda. World Dev 26:1113–1126

Sachs J, Remans R, Smukler S, Winowiecki L, Andelman SJ, Cassman KG, Castle D, DeFries R, Denning G, Fanzo J, Jackson LE, Leemans R, Lehmann J, Milder JC, Naeem S, Nziguheba G, Palm CA, Pingali PL, Reganold JP, Richter DD, Scherr SJ, Sircely J, Sullivan C, Tomich TP, Sanchez PA (2010) Monitoring the world's agriculture. Nature 466:558–560

Schot J, Hoogma R, Elzen B (1994) Strategies for shifting technological systems; the case of the automobile system. Futures 26:1060–1076

Senge PM, Kleiner A, Roberts C, Ross R (1994) The fifth discipline fieldbook: strategies and tools for building a learning organization. Crown Business

Steyaert P, Barzman M, Billaud JP, Brives H, Hubert B, Ollivier G, Roche B (2007) The role of knowledge and research in facilitating social learning among stakeholders in natural resources management in the French Atlantic coastal wetlands. Environ Sci Pol 10:537–550

Tacoli C (2004) Rural–urban linkages and pro-poor agricultural growth: an overview. OECD DAC POVNET, Helsinki

Tiebout CM (1956) A pure theory of local expenditures. J Polit Econ 64:416. doi:10.1086/257839

UN (2008) Agriculture and sustainable development in the Netherlands. Retreived 12-11-2011 from: http://www.un.org/esa/agenda21/natlinfo/countr/nether/agriculture.pdf

Van Dam YK, van Trijp HCM (2011) Cognitive and motivational structure of sustainability. J Econ Psychol 32:726–741

Veldkamp A, Van Altvorst AC, Eweg R, Jacobsen E, Van Kleef A, Van Latesteijn H, Mager S, Mommaas H, Smeets PJAM, Spaans L, Van Trijp JCM (2009) Triggering transitions towards sustainable development of the Dutch agricultural sector: TransForum's approach. Agron Sustain Dev 29:87–96

Vervoort JM, Kok K, van Lammeren R, Veldkamp A, Beers PJ, Bregt A (2009) Bringing future scenarios to life. KSI 2009

Wiskerke JSC, Van der Ploeg JD (eds) (2004) Seeds of transition: essays on novelty production, niches and regimes in agriculture. Van Gorcum, Assen