Final Report TransForum WP-046

Images of sustainable development of Dutch agriculture and green space

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Introduction

"Who is the farmer?", such an innocuous question, but such a wide range of answers. That is probably why, in practice, we will give simple answers most of the time: The farmer is "the custodian of the rural landscape," or "the feeder of the world." Not a complete answer, but rather an *image* of what we really mean: metaphorical, simple, and easily communicated. And necessarily so, because the underlying complexities are often too vast to communicate. For instance, stating that the farmer is the custodian of the countryside also means that his/her cows must be in the pastures. It implies small-scale farming businesses, and ascribes important value to the landscape as a socio-cultural resource.

Images have strong, mobilising qualities, because they are often associated with very basic value orientations. For instance, public resistance against genetically modified organisms (GMOs), irrespective of whether it is justified, appears much stronger than warranted on the basis of scientific insights on its risks for biodiversity alone: food from GMOs is seen as "Frankenfood." Other typical examples of the strong mobilising power of images are biofuels, which were first seen positively, as a solution for climate change, and later on negatively, as a cause of world malnutrition problems.

We often encounter images where opposing value orientations meet in public debate. Opposite values like animal welfare versus animal production (Hurley 2008) or organic agriculture versus traditional agriculture (cf. Borch 2007; Hurley 2008) result in the use of simple images to frame associated innovations as either good or bad. For instance, animal welfare values lead to branding industrial farming with the image of the pig city and connotations of disease-outbreaks (e.g., bird flu, mad cow disease), such as images of cattle eradication. And the converse: animal production proponents use the image of treehuggers to frame organic farming as cute, but not very effective. One and the same innovation can be a clear-cut image of progress to entrepreneurs, and a nightmare for environmentalists.

Both the power and the abundance of images lend credence to the belief that images can make or break an innovation. Images continuously influence the innovative potential of promising inventions. Just like sustainability, images are a dynamic system property, always changing; there is no 'true' image. Their mobilising potential may be at the heart of non-linear developments in system innovation, and the multi-stakeholder requirements for such innovation imply that images not only act as a societal influence "out there", but also as a given within innovation projects. For a series or programme of innovation experiments, it then would be important to know both how images affect innovation, and how images can be managed to improve the innovative potential of the programme.

In the project "Images of sustainable development of Dutch agriculture and green space" three PhD-candidates studied the topic of images in sustainable development. Frans Hermans focused on the topic of societal images and their role and influence in innovation projects. The title of his sub-project was "Social learning for sustainability in dynamic agricultural innovation networks." Joost Vervoort explored the topic of "visualisation", that is, using and producing images for specific purposes, in the context of innovation projects and programmes, in a subproject called "Step into the system: interactive media strategies for the exchange of insights on social-ecological change." Finally, Dirk van Apeldoorn took a complex adaptive systems approach to images. He modelled various agro-ecosystems to compare images of those systems with the behaviour of those systems. His subproject was called "Modeling resilience of agro-ecosystems." We report the content, products, outcomes and insights from each sub-project in a separate Chapter below.

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Social learning for sustainability in dynamic agricultural innovation networks

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General introduction and societal relevance

The increasing complexity of modern day society has also led to increasing attention on a specific type of sustainability problems known as complex, messy or wicked problems (Ackoff 1974; Ritter and Webber 1973; Vennix, 1999). This type of problems can be characterized by their cognitive complexity and inherent insecurity, their normative complexity that allows for completely different interpretations rooted in different worldviews and finally the occurrence of a conflict of interests between different actors (Roelofs 2000). The last twenty years has seen a surge in new approaches to address this special category of problems. These methodologies seek to improve the scope of vision of the investigators as well as their ability to communicate both science and policy . New knowledge is created through a combination of scientific knowledge with new ways to involve the general public in multi-actor processes referred to as knowledge co-creation, or ‘mode 2’ science .

Sustainable agriculture is the case in point. The Dutch countryside is standing on the threshold of a major transition. Rural development in The Netherlands nowadays involves far more than just restructuring agricultural production. We are witnessing a shift from mass production with increasing price efficiency towards a more diverse sector with various specialities and niche markets. Integration of different styles of agricultural production is taking place, while at the same time natural functions are created or strengthened, new economic activities are started and growing attention is paid for the social quality of life in rural communities. This leads to conflicting claims with regard to the available space in the countryside, with the emergence of new demands with respect to housing and working, nature development, water retention, mobility and recreation (Knippenberg, 2005; Frouws 1998).

Several strains of research have come to the fore that try to deal with these complex sustainability problems by taking the complex, dynamic, multi-scale and adaptive properties of the systems they try to influence in a more sustainable direction:
Adaptive (co)-management , transition management (, strategic niche management all share a commitment to stakeholder participation as a more holistic, relational approach towards sustainable development. Not surprisingly these approaches also emphasize the importance of experimentation and social learning.

Problem definition and research framework

This research project has focussed on several of the most central relationships that characterise these various approaches using stakeholder participations and social learning in innovative projects.

Its aim was to shed new light on the relationship between stakeholder participation and social learning on the one hand and knowledge diffusion through networks in agro-ecological innovation systems on the other hand. The research consists of two main parts. The first part of this research project focussed on the differences between discourses of sustainable agriculture on the societal level and the project level, while the second part a dynamic network perspective was used to investigate the interaction between the project level and institutional level.

The main research questions were:

1. What are the current Dutch perspectives on sustainable agriculture?
2. What are the current perspectives on sustainable development of Dutch rurality and agriculture within TransForum?
3. What are the consequences of these perspectives for sustainable agricultural development?
4. How does information generated at the project level reach the organisational level and what role do different actors and organisations play in this process?
5. How does the network of an innovation project develop over time?
6. How can network growth and decline be explained? What role do learning effects at the project level and resource availability play in this process?

A mixed set of social sciences methods has been used to answer these research questions. Interviews were done with a broad set of interviewees to identify current Dutch perspectives on sustainable development of Dutch rurality and agriculture (research question 1). Next, an online questionnaire was produced using q-methodology and distributed to TransForum innovation experiments in order to identify existing perspectives on sustainable development of Dutch rurality and agriculture at the project level (question 2). The third research question was addressed through discussing the findings.

Social Network Analysis has been used in the second part of the research that investigated the relationship between the project level and the organisation level. Social network analysis has used to study the communication structures in networks spanning different actors and organisations and given the intrinsically relational nature of social learning in a complex environment, it can also be framed as an attempt to combine existing networks in a policy 'arena': places where a broad range of participants generate new knowledge and subsequently distribute this over the participating partners and further beyond . The case of the Nothern Frisian Woodlands was used to follow the development of the network over the 18 years projects have been running in this region.

Summary of main findings

Perspectives on rurality and agriculture

Following Frouws (1998) three perspectives on rurality and agriculture have been identified that have each incorporated the idea of sustainable agriculture differently.

1. *Agri-ruralist discourse*: This discourse focuses on farmers and their family. It regards the farmer as the custodian of landscape and nature. In this perspective the family farm plays an important role. The continuity of the family farm is an important sustainability issue.
2. *Utilitarianist discourse* This discourse focuses on market relations, with nature and landscape being important production values. It involves the consumers and producers of food and agricultural products. How to mitigate the adverse effects of intensive farming is an important sustainability issue.
3. *Hedonist discourse:* the hedonist discourse starts from the intrinsic values of nature and diversity. It involves tourists, city dwellers and animals. Animal welfare and landscape conservation are important sustainability issues.

Our findings point at a diminishing role for the agri-ruralist perspective; our results suggest that this

perspective is steadily being subsumed by the utilitarianist and hedonist perspectives. The results show that the original typology identified by Frouws still applies to the Netherlands, although the discourses and the coalitions related to them, have shifted somewhat in time. The discourses on sustainable agriculture are a natural extension of existing rurality discourses. Developments in multifunctional farming, industrial ecology and landscape preservation can be seen as a sustainability perspective in an already existing development strategy. The utilitarian, the agri-ruralist and the hedonist discourse have thus incorporated their own sustainability perspective, which excludes each other to a large extent. The results show that under the umbrella of sustainable development there is an intensified struggle over the future of the Dutch countryside. The concept of sustainable agriculture has not lead to a unified overarching vision for the future. On the contrary, the hedonist discourse and the utilitarian discourse seem to be polar opposites, that contest each other most intensively on the role of technology and the role of the countryside.

This relationship was further investigated at the project level. Using q methodology, we distinguished four distinct perspectives on sustainable agricultural and rural development within the innovation project portfolio of TransForum: progressive farmers, rural development professionals, conservative farmers and entrepreneurs. These perspectives are depicted in Figure 1.

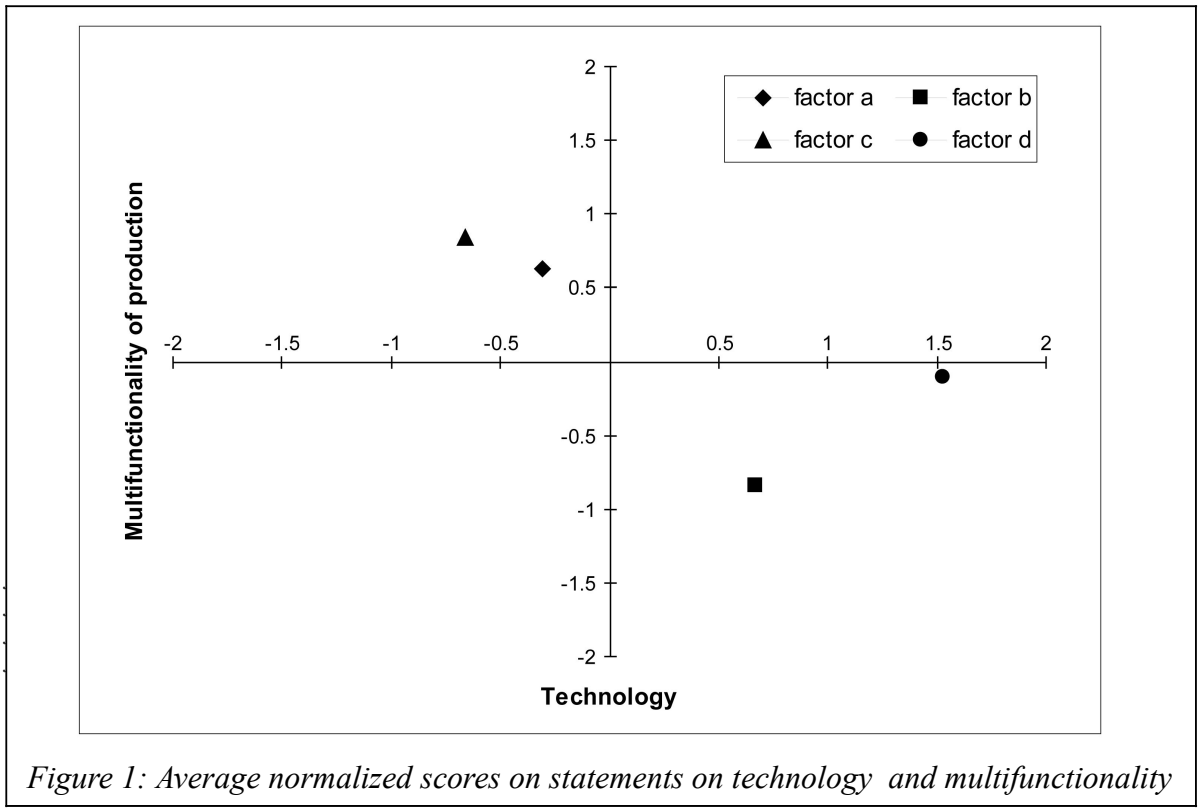

Figure 1: Average normalized scores on statements on technology and multifunctionality

Progressive farmers and rural development professionals reject technological fixes on the one hand, while on the other hand they embrace multi-functional agriculture. These two elements are strongly correlated, and in a sense rural development professionals are more radical than progressive farmers. On the other hand conservative farmers and entrepreneurs are far more prosaic in their sustainability outlook: rural landscape belongs to farmers and agricultural production on the one hand, while on the other hand, the belief in technology as a solution is firmly present here. However, the important distinction between conservative farmers and entrepreneurs lies especially in this last argument. Both regard technology rather positively, but entrepreneurs do not make a claim to the countryside for production as this indicator has a score near zero. In this regard, it is also interesting to note that the people in the innovation projects that derive their inspiration from industrial symbiosis and work on integration of product chains in animal husbandry (in order to minimize environmental impacts for example) are part of the group of conservative farmers and not

of the entrepreneurs as one might expect, (based on the large-scale preferences and general positive attitude towards technology of the entrepreneur). Both groups use the language of economies of scale and productivity increases, however the integrated intensive husbandry projects of TransForum have received a lot of societal opposition from locals . The rural area for agrarian production area reflects a core value of this group and it provides an important explanation for the 'dialogue of the deaf' (Van Eeten, 2001) that has surrounded this project.

A comparison between existing rurality discourses supports claims that the agri-ruralist discourse is slowly dissolving. At the project level we can identify the contours of what we believe to be the two dominant rurality discourses of the future: a prosaic rurality discourse that contains elements from the utilitarian and agri-ruralist discourses discourse on the one hand, and a more radical rurality discourse that is comprised of hedonistic and agri-ruralist elements on the other hand. However how these developments will play out and how these two resulting discourses will finally emerge is a question on how these perspectives will be communicated from the project level to the organisational level.

In order to study this process the second part of the research has focussed on the historical developments of one specific innovative project: the knowledge generated in the various projects that were set up by the members of two neighbouring environmental farmer cooperatives in the Netherlands: Vereniging Eastermars Lansdouwe (VEL) and Vereniging Agrarisch Natuur en Landschapsbeheer Achtkarspelen (Vanla). These two environmental farmer cooperatives where among the first in the Netherlands to have been engaged in sustainable agriculture, landscape management and the reduction of environmental pollution. Since the start of these two cooperatives in 1992, the number of this type of agricultural environmental cooperatives in the Netherlands rapidly grew to over 100 in 2001 . VEL and Vanla negotiated a contract with the authorities in 1996 when the Minister of agriculture granted the farmers the necessary space to develop and explore their own means (or novelties) to combat the mineral losses on their farms on the understanding that farmers would meet the general environmental aims earlier than elsewhere. In 1998, these two environmental cooperatives joined forces with three other regional co-operatives in the regional cooperative Northern Frisian Woodlands (NFW). In 2004 a regional contract was signed between local, provincial authorities and the NFW cooperative, giving the cooperative even more responsibility for the sustainable development of the region. The Northern Frisian Woodlands was taken up among the first TransForum innovative projects.

For our analysis of communication structures across organisations and projects we have chosen to construct two bipartite affiliation networks . Social Network Analysis provides an interesting option to further explore the micro-macro link of the multi-level perspective on emerging innovation networks , or as Stokman formulated it ,p. 10509): "Social network analysis in general studies the behaviour of the individual at the micro level, the pattern of relationships (network structure) at the macro level, and the interactions between the two. The analysis of the interaction structures that is involved in social network analysis is an important element in the analysis of the micro-macro link, the way in which individual behaviour and social phenomena are connected with one another".

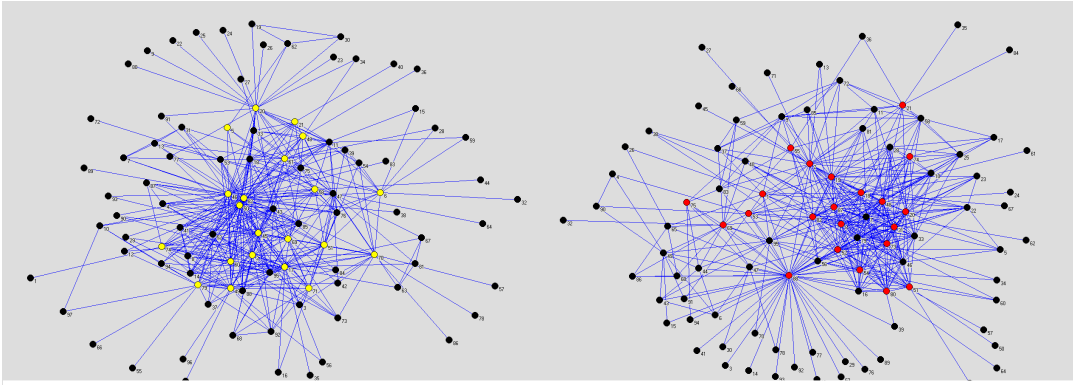

Figure 2: network of projects (left side) and events (right side)

Figure 2 depicts the organisational network in a simple one-mode form. The black nodes in the figures represent organisations, yellow nodes represent the different projects that were organised and that we considered to be the most relevant places where social learning occurred. Finally the red nodes represent short events that were used to disseminate results to a wider audience. Nodes are connected by a dark blue ties in case there is an actors who is member of both an organisation and a specific project or attended a specific event.

A more simplified form of the network has been depicted in figure 3. In this figure categories of different organisations have been aggregated, simplifying the resulting figures. In this figure the thickness of the lines indicate the amount of actors two types of organisations share.

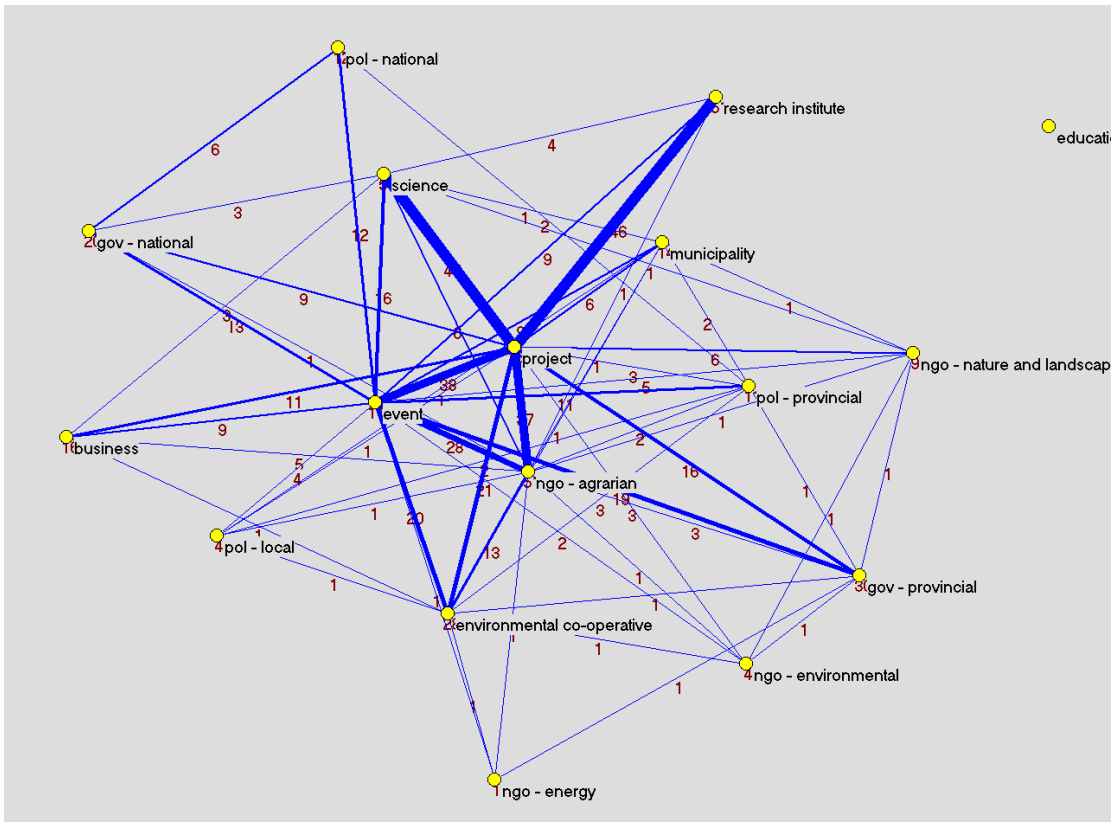

Figure 3: The organisational network in one-mode form.

The figure shows the different types of organisations dominating the network of the Northern Frisian Woodlands and the central position of collaborative projects and events in linking these different organisation together. It is somewhat surprising to see that the regional farmers union (ngo – agrarian) also took up a central position in the network. Even more central than the other main

organisations in the network: the environmental cooperatives, universities (science) and research institutes. The close connection between the ngo-agrarian and the environmental farmer cooperatives shows that the farmers cooperatives have more in common with the traditional agrarian NGOs than with environmental NGOs. Surprisingly enough there is no direct line between the landscape NGO and the environmental cooperatives even though landscape management played a pivotal role in the developed discourse of the role of farmers as landscape managers. The analysis further illustrated the important role the different events have played in reaching the national governmental and political level. During these events scientists and farmers form a united front to communicate the positive results to the higher level of politics and government. However the role of scientists in this network has been limited mainly to this one role. Systemic shifts in agricultural innovation systems requires the communication between different types of organisations and discourses. Bridging actors that master different organisational discourses are instrumental in these types of transitions. Our analysis shows that the amount of bridging actors in the NFW is fairly limited and that scientists are almost absent in this list. We conclude that scientist are sometimes involved in lobbying, but they stay mainly in their role as researcher.

Finally we have investigated the development of the project network over time. The formal project network at any point in time was constructed through aggregation of all projects that run on that time. The network thus consists of the projects, their members and the organisations that these members represented in the project. Once a projects stops the people involved also leave the formal network. Each time a projects therefore starts or stops the network changes its composition. In total we have identified 31 separate networks that represent a unique configuration of different projects, actors and organisations.

The results show that the network of the Northern Frisian Woodlands knows some distinct phases, both in terms of the amount of actors and organisations present, the composition of the network and their activities.

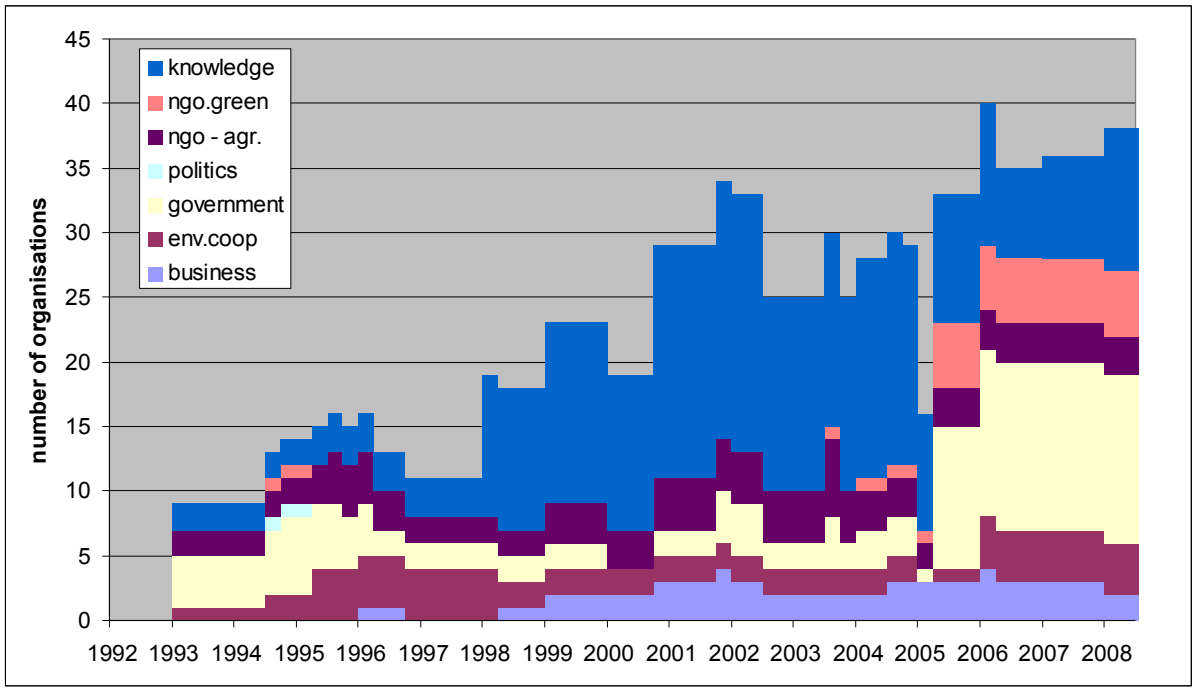

Figure 4: network size and composition over time

The different phases in the network correlate rather well with earlier description of niche developments. The first phase of self organisation was followed by two subsequent phases in which the networks activities could be characterised as vision formulation and lobbying and experimenting

and testing of the vision. The results of the experiments were contested however and this led a new phase in which the network was broadened again and the vision formulation started again: this time around the concept of regional development. Table 1 summarises the activities off the network actors over the different phases in time

Table 1: overview of network activities and network formation activities

Year	Niche activity	Local Network	Global Network
1990 – 1992	Self-organisation	Local farmers Local branch of Rabobank Provincial Government	Threat of top down national environmental legislation
1993 – 1997	Vision formulation and lobbying	Environmental cooperatives Farmer unions Provincial Government	Grant provided by Ministry of Housing, Spatial Planning and Environment
1998 – 2005	Experimenting and testing	Environmental cooperatives Farmer unions Provincial Government Researchers and scientists, mostly from Wageningen University	Deferment of national environmental legislation by Minister of Agriculture and Nature conservation and fisheries Scientific grant by Dutch N.W.O.
2006 – 2009	Broadening of network to regional development	More green NGOs involved	Subsidy by TransForum

An important conclusion regarding the network development was the role that was played by a few powerful actors. These actors are not, or only marginally, present in the local and regional network itself, but after the initial self-organisation of the farmers in environmental cooperatives they gave the network the legislative and financial space for the network to grow and develop further. Results show how the network expands and decreases in time, along with the external resources that sustain it. This result shows that the process of network evolution in agricultural innovation networks aiming for sustainable development, the evolution process depends less on the changing characteristics of network members, as often assumed, but more on the external resources made available for collaborative projects.

Societal relevance of findings

TransForum's working method has been inspired by the various approaches that deal with complex sustainability problems by taking the complex, dynamic, multi-scale and adaptive properties of the systems they study into account using the process of social learning. TransForums framework based on five working hypothesis that define sustainable agriculture as a dynamic system property in need of large scale system innovation also show this. According to TransForum susstainable agriculture is not an end state, but a process; one that is not linked to any particular technological practice or vision. This process should take into account non linear dynamics and requires the active participation of relevant key players from knowledge institutes, governmental bodies, civil society organisations and the business community in transdisciplinary social learning collaborative projects . As such our findings are of great practical relevance for TransForum as an innovative program but also on a more practical level.

For instance, the identified discourses have already proven their use in the analysis of the barriers

two other innovative projects of TransForum have experienced. The application of the three discourses on TransForums innovative project "De Sjalon" quickly showed that there were no external barriers towards the project and its members as was initially supposed. In fact the environment of the project and the project itself were very much part of the same rurality discourse. Using this analysis showed that the lack of progress was not so much the fault of a concerted opposition, but far more the result of internal disagreements .

The discourse analysis also sheds light on the 'dialogue of the deaf'that surrounded another TransForum innovative project: that of the New Mixed Farm. This project, that is characterized as an intensive animal husbandry project deriving its inspiration from industrial ecology, has met with a lot of local opposition. The discourse analysis showed that the underlying value of the people in the project strongly prefer the countryside as their specific location of agricultural production. This leads us to conclude that, in this case, the adherence to a mono-functional landscape is an another limiting factor that influences the potential for transitions. This is an insight that can help in taking away this barrier, since it can be dealt with more easily than that other limiting factor: the negative public perception.

With regard to TransForum as a program, the discourse analysis shows that the hedonist and utilitarian discourse have almost nothing in common in terms of their frame of reference. In order to relief the tensions in the Dutch countryside a new discourse is necessary: an overarching perspective that combines the two opposing future discourses. That new discourse on sustainable agriculture should combine the elements of the two most opposing elements: a discourse that favours high-tech production on the one hand within a multifunctional landscape has the most potential to overcome the current impasse.

The social network analysis shows that the dynamics of sustainability networks can be explained on an internal network level, but an even important variable in explaining network dynamics are the availability of resources in the initial envisioning phases, while the creation of legislative manoeuvring room is necessary in the experimenting and testing phase. This is an important finding that shows the necessity of differentb types of government support for these networks. TransForums working method in the final phase of the NFW has resulted in a more even composition of the network, the network is now more diverse with a larger contribution of environmental and landscape NGOs.

Regarding the role of scientist in the network: we have concluded that a large majority of the scientists involved do not function as bridging actors in the network. It is an open question whether this is something to be desired, but we think it is. However the current academic climate is not very conduce to scientist who can also play a role as bridging actor. In future innovation programmes, the role of scientist may also require more attention therefore.

Deliverables

A review of existing rurality discourses was made based on the scientific literature and interviews with TransForum participants, describing the three current different rurality discourses on sustainable agriculture. This review was published as a peer reviewed article in Sociologia Ruralis (Hermans et al. 2010, see below).

The review was used as an input for a q-methodology study. The results of the q-methodology study clearly illustrated where the concept of sustainable agriculture has conflicting issues between the visions. The role of technology and multi-functionality of the landscape are among the most contested issues when it comes to the visions of sustainable agrarian future (see figure 1). These differences in vision are a source of potential conflicts, not only at the national level, but also on the project level and especially between the project level and their social environment.

No separate tool was developed for this study to interact with stakeholders. However the insights gained in the project were used to analyse some of the practical difficulties surrounding some TransForum projects. On request, the identified discourses were used to analyse the practical difficulties two innovative projects from TransForum were experiencing: de Sjalon and New Mixed Farm. Two workshops were organised to discuss the findings of a regional discourse analysis on the perception of De Sjalon. The developed discourses proved to be a quick way to learn about the perceptions of this innovative project from relative outsiders. A second interactive workshop was organised for these farmers to refine their shared vision and to negotiate with each other their tasks and assignments within their project.

The second innovative TransForum project that the discourse analysis helped to analyse was the New Mixed Farm. This initiative also experienced heavy resistance from the local population, especially a local action group called 'behoud de parel'. The most important stakeholders were interviewed and the interviews analysed for the visions on sustainability discourses. Analysis showed that the visions in this case were almost polar opposites. In this case no workshops were organised because the gap between the different actors was considered too large to bridge.

Project results were discussed at meetings at Transforum, Telos and multiple conferences, seminars and workshops (see publication list below).

Publications

Peer reviewed

Hermans, Frans, Dirk van Apeldoorn, Kasper Kok and Marian Stuiver, 'Stages in niche formation and development; applying a longitudinal social network analysis to the institutionalisation process of a rural innovation project', (in preparation)

Hermans, Frans, Kasper Kok, PJ Beers and Marian Stuiver, 'Social learning in innovation networks' , (in preparation)

Hermans, Frans, Kasper Kok, PJ Beers and Tom Veldkamp: 'Assessing sustainability perspectives in rural innovation projects using q methodology', (under review with Sociologia Ruralis).

Hermans, Frans, Ina Horlings, PJ Beers, and Mommaas, H. 'The contested redefinition of a sustainable countryside; revisiting Frouws' rurality discourses' , Sociologia Ruralis, 52, January 2010.

Technical reports and book chapters

Horlings, Ina, Jules Hinssen and Frans Hermans, 'Botsende beelden; over innoveren bij maatschappelijke tegenwind, vertooganalyse van het Nieuw Gemengd Bedrijf' (conflicting images; innovations against social headwind), Telos, Tilburg, 2010.

Hinssen, Jules and Frans Hermans, 'De Sjalon, beelden van een grootlandbouwbedrijf', Telos, Tilburg, 2009.

Conference proceedings

Hermans, Frans, Kasper Kok, Tom Veldkamp and Hans Mommaas, 'Comparing rural discourses and niche perspectives in Dutch agriculture: assessing the potential for radical transitions using Q-methodology', First European Conference on Sustainability Transitions 'Dynamics and governance of transitions to sustainability' , June 4-6, 2009, Amsterdam, The Netherlands.

Hermans, Frans and Ruben Smeets, 'Participation in monitoring sustainable development: striking a balance between process and content', EPOS Conference, Sustainable Development in Policy Assessment – Methods, Challenges and Policy Impacts, June 15-16, 2009, Brussels,

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Step into the system: *interactive media strategies for the exchange of insights on social-ecological change*

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In our current times characterized by globalization, rapid environmental change and the unforeseen ramifications of accelerating technological development, the need for recognition and anticipation of environmental and societal change as it moves towards us is now more urgent as well as more problematic than ever (Martens and Rotmans 2005). In recent decades, sustainability research has moved away from single scale, single domain perspectives and the assumption that systems have a single equilibrium that allows for optimization. More subtle, inclusive and humble perspectives have gained a foothold across various scientific disciplines, partly based on the view that human and natural systems are fundamentally connected as *Social-Ecological Systems* (Holling and Gunderson 2002). Their analysis through *Complex Adaptive Systems* (CAS) theory (Levin 1999) has spawned many new insights. However, the messages resulting from these insights are far from straightforward. The Complex Adaptive Systems' perspective encourages policy makers to consider non-linear effects and sudden shifts; to take into account multiple scales of organization; to use complementary knowledge from different types of expertise (Gilchrist); and to be "at once bold and careful" (Lempert 2007). However, these messages from Complex Adaptive Systems theory arise from a world of conceptual metaphors based on scientific systems thinking, presupposing a background that is unfamiliar for a wide range of societal actors (Anderies and Norberg 2008). There is a risk that the theoretical arguments for more adaptive natural resources management are lost in translation (Beers, Boshuizen et al. 2006). At the same time, many managers and policy makers in sustainable development – such as those collaborating in TransForum practical projects - often have a wellspring of experience and insights on social-ecological system dynamics based on their practice, but do not have the tools available to translate this experience to a theoretical system analysis. In order to deal with these divides, societies have to explore forms of communication on sustainable development that are at once able to help exchange insights on system dynamics in an enlightening and informative fashion, and also engaging enough to inspire more adaptive, conscious interactions with the global environment. To take on this communication challenge, this research project employed several interactive visualization strategies.

Interactive visualization

Visualization is the main focus for most research on multi-media communication. We define visualization as 'any communication that uses visual structures to represent objects, concepts and relationships' (Pylyshyn 2003). In this broad definition, everything from a data table to a virtual reality environment is visualization. Sheppard (Sheppard 2001) describes visual communication as having three types of potential effects: *cognitive*, *affective*, and *behavioural*. Concerning visualization as an aid for cognition, Thomas and Cook (2007) and Tufte (1990) give us some clear benefits. Firstly, visual representations can *increase the information available* to a user at any one time, in terms of presentation, and following this, in terms of *memory retention*. The perceptual system can take over a part of the *workload* from what would otherwise have to be handled by cognitive inference, and therefore more information can be taken in. This benefit is amplified by the human capacity to handle *parallel information* when it is presented visually. Also, the strategic presentation of visual information can *clarify patterns* of value, relationships and trends, further reducing cognitive workload and *search time* for users. And unlike speech or written text, information presented visually allows for different personal *viewing styles* and patterns of examination and re-examination. Visual imagery can also trigger *emotional responses* instantly, because humans are set up for the visual recognition of, and subsequent response to attractive, puzzling or threatening elements in their environment. There is additional potential for the combination of multiple modalities of perception (e.g. auditory, tactile) to increase the bandwidth of human-computer interactions. Humans are able to handle a combination of inputs from these different modalities (Oviatt 1999). Levels of engagement with visual imagery can be further enhanced when an interactive format is used. Direct interactivity demands a higher level of engagement from users. Interactive features also give users more control to follow through on ideas about what is visualized, allowing them to change perspectives and revisit observations. Also, users can both receive and give feedbacks on their interpretations and choices (Csikszentmihalyi 1990). Finally, there is much potential in the use of on-line media to expand the reach of participatory processes in scenario development beyond the small group of stakeholders and the limited time of a workshop. The web has become a more and more participatory affair: a wide range of techniques for user-generated interactions and content-mix-ups, known collectively as "web 2.0" (Gooding 2008), have come to dominate on-line space. Through pervasive gaming methods (Jegers 2007), web 2.0 strategies can also be used to achieve a different kind of immersion.

Research problem and objectives

Responding to the communication challenge posed by the complexities of social and environmental change, this project explored the following research question:

How can interactive media help meet societies' need for clearer and more engaging communication on the dynamics of social-ecological systems?

The research in this project explored several multi-media strategies that were used to facilitate the collaborative generation of insights on social-ecological system dynamics between a broad range of societal actors on different levels. These strategies consisted of different combinations of two modes of communication, reflecting two ways in which humans process information:

-An analytical communication mode that allows societal actors to focus explicitly on their perspectives on system dimensions and dynamics. In this communication mode, schemas, abstract visual concepts and metaphors directly represent system characteristics.

-An experiential communication mode that focuses on societal actors' engagement with storylines about the past and future of real systems, organizations and regions. In this mode of

communication, complex dynamics are captured, as well as brought to life, by the richness of concrete examples and storylines.

Based on this framework, we explored the above research question through a number of subsequent studies that each focused on one of the following sub-questions:

1. What are the requirements for interactive media to produce clear and engaging communication on social-ecological system dynamics, and can a guiding framework be developed by combining the benefits of different media-based science communication strategies?

2. Can an interactive visualization method be developed that focuses on the effective exchange of insights of explicit, analytical perspectives on social-ecological system dimensions and dynamics?

3. Does a combination of such an analytical interaction method with a strategy for experiential, story-based communication produce complementary benefits in terms of the exchange of insights on, and engagement with, the dynamics of social-ecological systems?

4. Can the analytical and experiential communication modes be fully integrated into one interactive method that captures truly subjective perspectives on the past and future dynamics of social-ecological systems, including subjective dimensions of analysis? Do the dimensions generated by those using this method provide new perspectives on social-ecological system dynamics in general?

Finally, through a collaborative project, we sought to go beyond the spectrum of existing scientific communication strategies:

5. What new communication concepts and interaction modes are yielded by a collaboration with communicators and artists that operate outside the fields associated with scientific communication?

Results and conclusions

Each of the above questions was explored in a separate study.

1. Review and guiding framework

To explore question 1, we developed a strategy for the development of interactive media scenarios to help communicate uncertainties and complexities in coupled human and natural systems. For the collaborative exploration of future complexities and uncertainties, participatory scenario development has proven to be a powerful approach. A range of communication strategies with benefits for conveying complexity, however, has not yet been adopted by scenario developers. We presented a framework of criteria with which we structurally analyzed the benefits of interactive media communication. First, we considered requirements of feasibility, flexibility and stakeholder contributions. Then, we synthesized criteria for the communication of Complex Adaptive Systems. Finally, we set criteria for communicatory clarity and engagement. Using this framework, we reviewed several science communication fields, including landscape visualization, serious gaming and visual analytics. We then developed a strategy for interactive media communication in participatory scenario development, including two work-in-progress examples. This strategy employs mixed media, micro-games and accessible stakeholder contributions in a geo-web context, and is suitable for participatory work in live settings as well as online, from a local to a global scale.

Figure 5 shows our evaluation of the benefits and drawbacks of different science communication

fields in terms of their potential for the communication of social-ecological systems dynamics from a complex adaptive systems perspective. Figure 6 shows the communication strategy we proposed. This strategy combines the benefits of the different science communication fields.

	Feasibility, flexibility, participation	Capturing CAS characteristics	Communicative clarity and engagement	Strategy
Landscape visualization	(2) Some tools easy to implement, contributions in geo-web tools	(1) Links to process dynamics still in development	(3) Strong focus on representational power, users are visitors	(6) Total
Serious gaming	(1) Much resources needed to reach standard of commercial games	(3) Strong links between game models and scientific models	(3) Experience in engagement, no conscious focus on accuracy, validity	(7) Total
Visual analytics	(1) Difficult to transfer to new purposes	(2) Conscious focus but temporal dimension needs development	(2) Focus on accuracy and clarity, interactivity, analytical flow but abstract and no emotional engagement	(5) Total

Figure 5. Summary of the review. The scorings provide a rough summary of how suited each communication domain is to deal with each challenge, with totals for each evaluated research domain. (1) Unsuited, (2) moderately suited, and (3) well suited. The texts give a quick sketch of benefits or drawbacks considering each step.

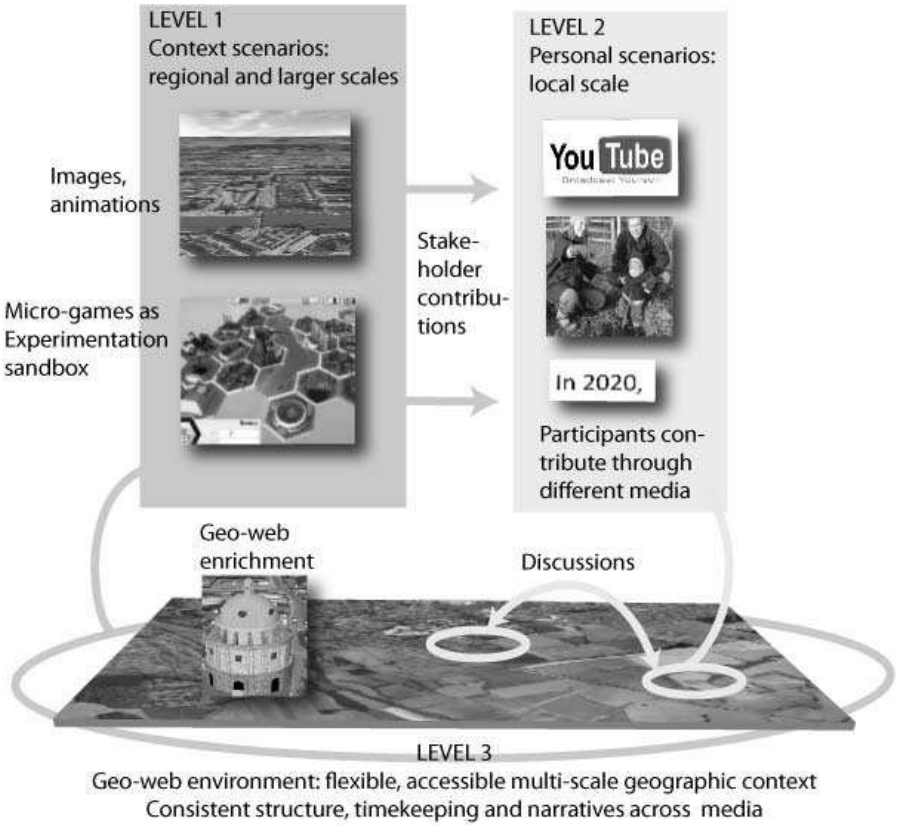

Figure 6. The structure of the three-level strategy for interactive scenario communication - ScenarioCommunities. Again, level 1 provides context scenarios as a starting point. Level 2 builds on web 2.0 techniques to let participants build personal storylines. Level 3 forms the geographical and temporal context. Rules, dynamics and narratives are consistent across platforms.

2. The Future Perspectives Test

To address question 2, we developed the Future Perspectives Test, an interactive, visual tool designed to elicit stakeholder perspectives on the dimensions and dynamics of land –and resource use issues. The application of this tool in two European cases showed that participants had highly different, multi-level perspectives on the key temporal and spatial scales for land use management. These differences were significantly related to views on social-ecological system dynamics and concepts of time. The results of this study showed the need for multi-scale participatory processes where the focus levels and system perspectives are co-defined by stakeholders. The case studies also showed that the Future Perspectives Test can be applied to meet
the information requirements of such an approach. The test consists of a new tool combined with two adaptations from pre-existing methods: The Scale Perspectives Test makes stakeholder perspectives explicit on the key spatial and temporal levels for their land use issues. The Myths of Nature Test elicits participants' views on the dynamics of social-ecological systems. The Circles Test captures participants' engagement with the future. The two test cases demonstrate that the Future Perspectives Test allows participatory process designers to relate to the dimensions of stakeholder perspectives as well as providing the means to challenge them.

Figure 7 shows the top five issues among the entries in the Scale Perspectives Test from a case study in Oxfordshire, UK. The image shows the multiplicity of perspectives between participants considering a single issue. Figure 8 shows an example of a link between participant's perspectives on the dimensions of sustainable development issues, and their overall assumptions about the responses of natural systems to human-induced disturbance, "myths of nature". Different myths of nature were strongly associated with a different focus on spatial levels and timeframes.

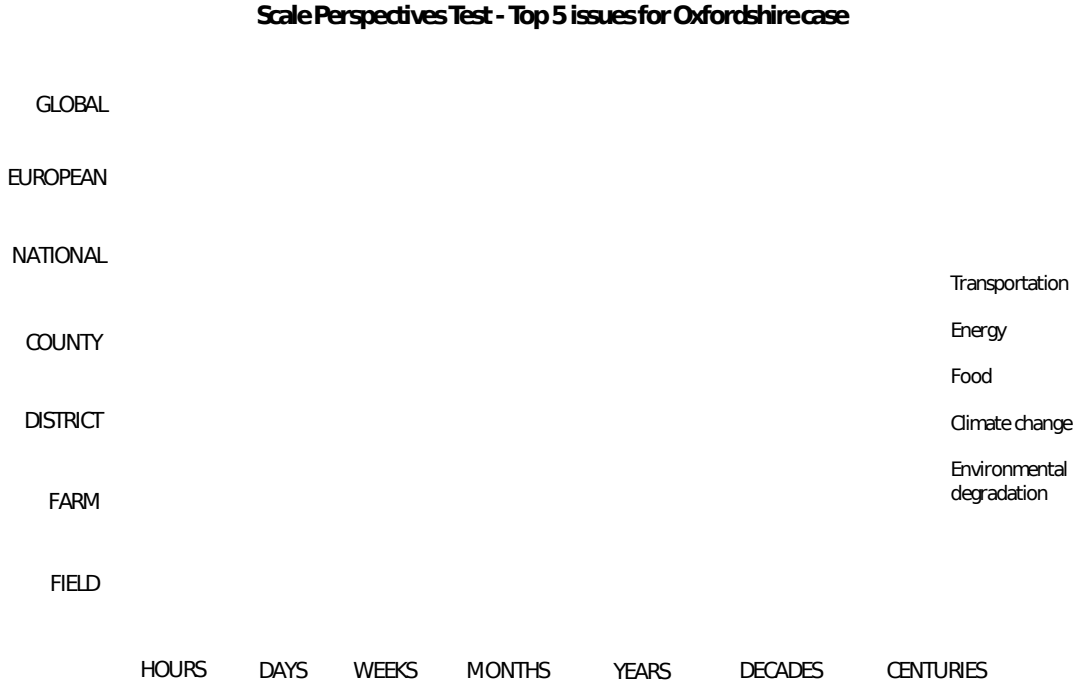

Figure 7. The top five most mentioned issues in the Scale Perspectives Test results for the Oxfordshire case: 1.Transportation 2. Energy 3. Food 4. Climate change 5. Environmental degradation.

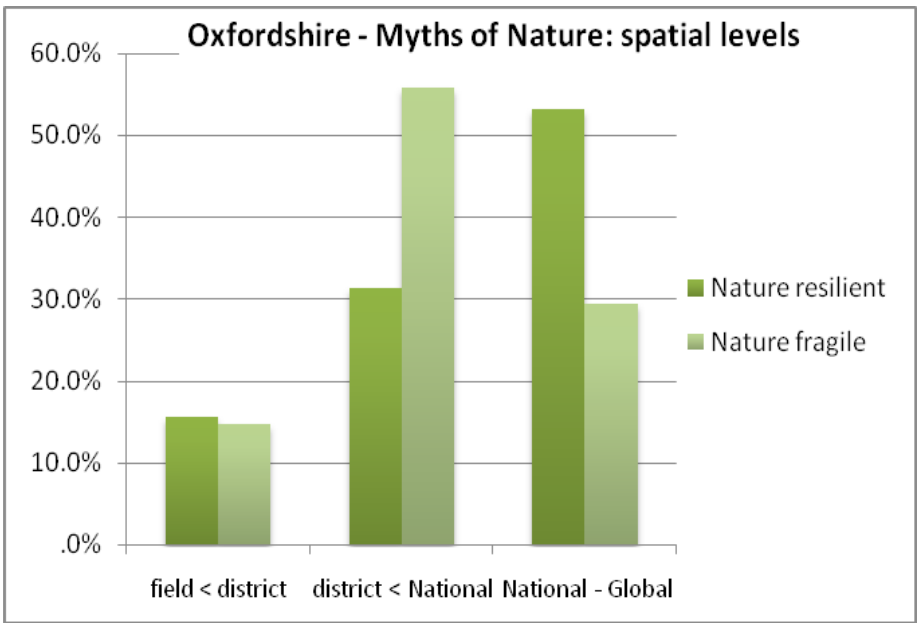

Figure 8. Oxfordshire Scale Perspectives Test entries (participants' perspectives) ordered by spatial levels, and divided by the two most prevalent myths of nature associated with these entries, in percentages of the total entries per myth of nature.

3. Analytical and experiential communication

We explored question 3 by evaluating the complementary of analytical and experiential communication methods in an interactive live setting. In an Oxfordshire, UK case study, we conducted workshops with local sustainable development groups where we combined the Future Perspectives test with a new experiential communication method, based on the guiding framework of the first study. Based on these workshops, we evaluated the analytic communication method in terms of its capacity to elicit analytic perspectives and facilitate the understanding of system dynamics through simple visual formalisms. We evaluated the experiential, scenario-based communication method on its ability to stimulate the creation of content that reflected social-ecological system dynamics in an experiential mode. Moreover, we assessed the complementary value of these two methods. The experiential, scenario-based method proved able to stimulate the participants in creating scenario content in an experiential mode. The analytical method elicited the dimensions, dynamics and systemic assumptions underlying perspectives on the future, and proved conducive to the formation of strategy on a group level. These benefits are complementary and were perceived as such by the participants. The highly participatory nature of both methods was an asset both to the participants' experience of the process and the methods' ability to generate results.

Figure 9 shows the design setup of the combination of methods. Table 2 shows the percentages of participants' contributions that contained descriptions of complex adaptive systems dynamics.

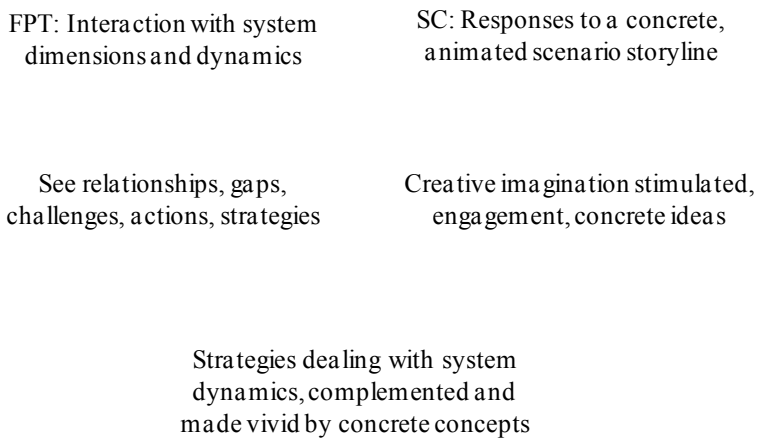

Figure 9. The complementary benefits of the Future perspectives Test and ScenarioCommunities methods as examples of experiential and analytical communication.

Table 2. Percentages of personal contributions per workshop that contain story elements reflecting insights on social-ecological systems.

	FPT-SC	SC-FPT
Non-local spatial level	80%	90%
Multiple spatial levels	30%	80%
Cross-level dynamics	60%	70%
Temporal dynamics	100%	100%
CAS dynamics	80%	70%
Average	72%	82%

4. The Scenario Scale Repertoire

We explored the possibilities a full integration of the analytical and experiential communication modes (question 4) with our study based on the Scenario Scale Repertoire. This method, which is used in the context of in-depth interviews, integrates the development of a scenario storyline with an exploration of system dimensions and dynamics. It also broadens the perspective on stakeholder perspectives on system dimensions. Inspired by Repertory Grid technique, it allows the interviewee to make the dimensions that he or she used to frame his/her personal perspective on a sustainable development project's past and future explicit. The SSR also allows the interviewee to reframe his/her personal storyline on the basis of each of these subjective dimensions.

We applied the SSR with 20 participants in the TransForum innovative practical projects that fall under the theme of regional development. A second group of 20 participants, all operating within the Dutch sustainability education system, was also selected to participate in SSR interviews. This study is still a work in progress at the time of writing; however, results so far show the SSR to be an effective visioning tool that integrates strategic planning with the elicitation of the dimensions within which sustainable development and knowledge projects are structured subjectively by individuals.

Preliminary results of this study show a spectrum of scales that go beyond the spatio-temporal frame of biophysical systems, and instead structure the relevant dynamics of human systems. In this way, this chapter expands on earlier theoretical assessments of scales specific to human systems, such as institutional scales, knowledge scales, network scales and project scales, and provides these theories with a new empirical basis.

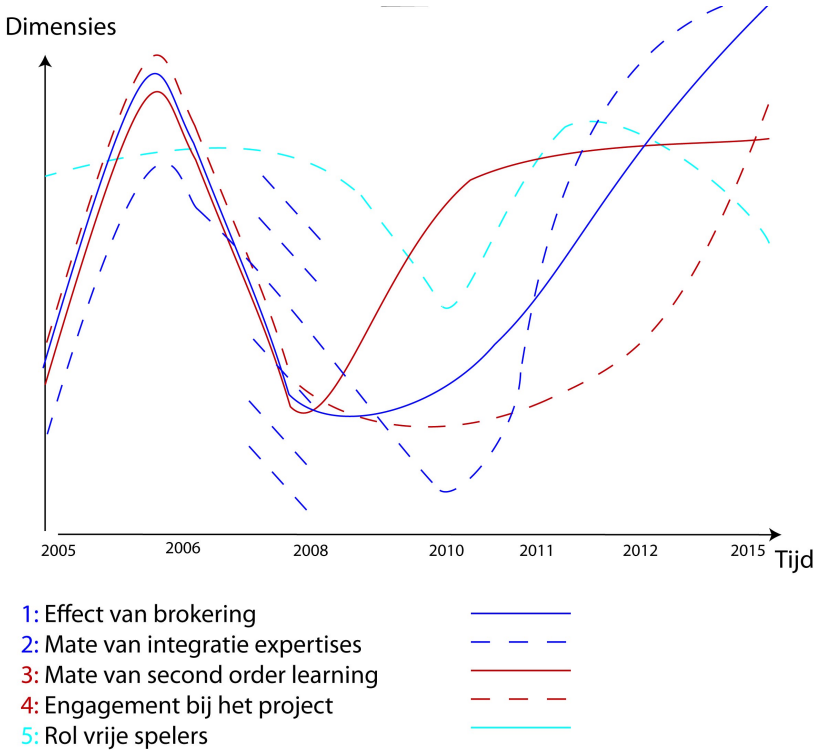

Figure 10. Part of a completed SSR method sheet. This part of the method lets the participant capture the project's dynamics in terms of each dimension elicited in the interview.

5. Collaborative concept design

Finally, we sought to explore the possible potential of communication strategies that lie beyond the various traditions of science communication that provided the inspiration for the tools used in the previous studies.

This study focused on the results of a co-operation with groups of visual/multi-media communicators and artists. The challenge that we set these groups was to develop communication concepts that would be able to capture the meaning of the manifestations of biophysical and social complexity in our world, and to make this meaning clear on an intuitive, sense level. The results of this challenge took the form of a large number of communication concepts, either in the shape of first designs or fully-fledged installations and visualizations. We evaluated as well as adapted these concepts so that they could be used as strong communication and interaction tools in workshops, trainings and educational settings, as well as in a mass media information context for some concepts. The communicators' concepts were evaluated first by their peers, and currently, at the time of writing, by three panels: a group of complex adaptive systems scientists, a group of communication experts, and a group of laypeople that would make up a potential audience. The concepts were so far judged to have high potential for the communication on and interaction with several characteristics of complex adaptive systems, including non-linear dynamics, cross-scale dynamics and path-dependency. In addition, some concepts provided insights in the attitudes needed to deal with social-ecological complexity: adaptive approaches, the value of multiple perspectives, and the promotion of a consciousness on the limits of knowledge.

Table 3. Overview of the communication concepts developed in the collaborative design study. Each concept has the capacity to reflect multiple aspects of complex adaptive systems theory and management.

	Nonlinearity	Feedbacks	Path dependence	Cross-scale dynamics	Adaptive Management	Uncertainty and he limits of knowledge	The value of multiple perspectives
Game concepts							
ChaosGolf	x	(x)	x	x	x	x	
Adaptive Tetris	x		x		x	x	
The Scale Game	x	x		x	x		x
Warped World		x			x		x
Group exercises							
Ouija Drawing		x	(x)	x	x		x
Feedback Breath	x	x					x
MetaMission					x	x	
Interactive visualizations							
Zoom		(x)		x		x	x
Path Orb			x	x	x		
Constellation Panarchy	x	x		x			
Metaphors							
The Average of Agony						x	x
Language conservation					x	x	x
Alternate reality concept							
Time Capsules							x

Societal relevance

To face the challenges of global environmental and social change in the 21st century, the exchange of insights and perspectives on the interactions in social-ecological systems is key. Communication strategies are needed that are engaging and stimulate both ideas and action, but all the while do not lose the complexity of social and ecological system dynamics in the process.

As a part of the TransForum "images of sustainable agriculture" theme, the studies conducted in this project all contribute to ways to fulfil this societal need for better communication.

They do this on two levels: one, by the tools resulting from this project, and two, by the general insights into the communication of complex systems change that the studies have garnered.

The products of this study: tools and concepts

The science communication overview and guiding framework created in the first study provides clear strategies for the communication of complex adaptive systems dynamics for those that are looking to take up the challenge through accessible, widely applicable participatory tools. The Future Perspectives Test provides an example of a tool that offers simple interaction structures that elicit knowledge about complex systems, based on participants' perspectives. This tool is useful in a broad range of contexts – it could easily be applied in a political or organizational change setting as well. Its counterpart, the ScenarioCommunities method, proved to be engaging and conducive to the creation of personal scenario content that reflected social-ecological system dynamics. An on-line version of this method can present a range of future scenario storylines to large audiences, and invite them to make their own personal contributions and discuss each others' perspectives on a large scale. The Scenario Scale Repertoire itself is a tool that allows for a thorough, in-depth view of a person's subjective perspective on the past, present and future of a project, a region, etc. Moreover, the scales and dimensions that result from the use of this tool can provide new perspectives on environmental and societal change, by highlighting dynamics and characteristics that do not register on other scales. Finally, the communication concepts developed in the

collaborative research with artists and communication designers provide a wellspring of new strategies for powerful communication that go beyond the tools that have been available thus far.

Recommendations and general insights

The work in this project in its entirety has also produced a number of insights that can be crucial to the development of effective communication on social and environmental change. Here, we summarize these insights in the form of recommendations for communicators, and give our tools as reference examples for these recommendations:

-Build on the implicit understanding of complex system dynamics and adaptive management that people involved in the practice of sustainable development, or any context of systems change, already possess. Find accessible, intuitive ways to elicit this knowledge and make it available in knowledge exchanges (ScenarioCommunities, Scenario Scale Repertoire, Future Perspectives Test)

-Be conscious about combinations of analytical and experiential communication modes. Both have drawbacks and benefits that are complementary. Create an analytical follow-up to a story-based, immersive communication strategy; create a strong real-world context for an analytical tool or abstract game (ScenarioCommunities/Future Perspectives Test combination, Scenario Scale Repertoire).

-Create communication strategies that bank on people's immediate experience of the complex: their own bodies, group dynamics, real-world events they have to respond to, interactive tools and games that require a skilful interaction with system dynamics (collaborative design concepts).

-Design communication concepts that, while simple in themselves, are semantically flexible enough to represent much more implicit information (Future Perspectives Test, collaborative design concepts).

-Use multi-media design and ergonomics principles to expressly broaden the communicatory bandwidth between societal actors participating through a communication tool (all tools and concepts in this study).

-Accessibility is essential, no matter what format the communication is in (all tools and concepts in this study).

Research history and process evaluation

Since the exploration of interactive media strategies in the service of communication through a complex adaptive systems paradigm was largely without precedent, this project has had a very adaptive and exploratory character. This has led to a number of strategy changes compared to the start of the project.

-Or original focus was on geo-information based communication strategies, but an exploration of the possibilities in this domain made it clear that other approaches (games, animations, abstract system depictions)b were needed that were better at capturing non-spatial, non-biophysical change.

-Our design and research philosophy was one of co-design from the first, for instance by incorporating stakeholder opinions in Oxfordshire in the development of the ScenarioCommunities method. However, our approach became more focused on collaborative learning and design over time, as it shifted from working with fully developed on-line interaction tools to working with prototypes in a live workshop or interview setting. This way, we were able to gather much more information on participants' experiences, and experiment with alterations to the method much more flexibly.

-In the context of TransForum, as the organization fine-tuned and adapted its perspectives and vision, the requirements on the "images of sustainable agriculture" theme and our individual research changed somewhat to reflect these adaptations. However, these requirements were never prohibiting or overly specific. It was reassuring to know that there was room within the TransForum project model for the explorative, adaptive work done in this project.

Deliverables

-We reviewed a number of science communication fields in the PE&RC project proposal for this research. This review was later used in Vervoort et al. 2010 (see below).

-Project results were discussed at meetings at Transforum, Telos and multiple conferences, seminars and workshops (see publication list below).

-We conducted two interactive scenario development workshops in Oxfordshire: one at Sustainable Woodstock and one at the Oxfordshire Rural Community Council. These workshops formed the practical basis for the paper submitted to Landscape and Urban Planning.

-We conducted two workshops on the creation of new visual concepts for complex adaptive systems science: for a group of students from the Royal Arts Adacemy and the MediaTechnology master of Leiden University, one at the Utrecht Arts Academy.

-We developed texts and tools for a website (http://www.scenariocommunities.com) where a number of tools were presented to participants in different case studies:

> -The Future Perspectives Test: results from this test were used in two papers.
> -The ScenarioCommunities method: essential for the workshops that produced results for the paper submitted to Landscape and Urban Planning.
> - Animations on the future of Oxfordshire: there were also essential for the scenario workshops.

-We developed a reader for the participants in the visual communication concept workshops. This reader was sponsored by the arts academies and vital for the participants' understanding of the topic.

-We presented all participants in the Scenario Scale Repertoire with a document that summarized their personal perspectives from the interviews. This was necessary feedback for the TransForum practical projects.

-We wrote two documents summarizing the results from the Oxfordshire scenario development workshops. These documents contained vital feedback for the participants.

-We wrote a summary document containing the most promising visual communication concepts from the arts academies workshops, for evaluation by expert panels. This document was instrumental for writing the paper.

List of project publications

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Vervoort, J.M., Kok, K., Beers, P.J., Lammeren, R.J.A. van. Analysis and experience: combining mental modes of communication on environmental change in participatory future visioning. *Submitted to Landscape and Urban Planning.*

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Modeling Resilience of Agro-Ecosystems

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General introduction and societal relevance

The world is now moving through a period of extraordinary turbulence; the speed and magnitude of global change, the increasing connectedness of social and natural systems at the planetary level, and the growing complexity of societies and their impacts upon the biosphere result in a high level of uncertainty and unpredictability (Gallopin, 2002). The trend of an increasingly complex world is not gradual, but pulses of revolution are alternated with periods of stability. These long lasting periods of stability with only gradual changes support a static worldview. Within this static worldview, the science of resource extraction developed concepts of carrying capacity and maximum sustained yield. It was in this context the UN Commission on Environment and Development (the Brundtland commission) introduced sustainable development. The Brundtland commission coupled socio-political and distributional issues to the limits of our natural resources. It was conjectured that our limits to growth could be objectively measured (Robinson, 2004). Meanwhile practical experience has challenged this view of the world. It now appears that some of the earlier confidence in being able to measure these limits to growth was misplaced. Our understanding of key elements on humans affecting natural systems appeared wrong (Lebel et al., 2006). Instead of an orderly and stable world where sustainability could be reached, the world is viewed as irreducible, uncertain and complex, where conflicting paths of sustainable development coexist (Kinzig et al., 2006). Sustainable development is now increasingly recognized as an ongoing process with multiple pathways towards a moving target (Robinson, 2004).

A new paradigm

In the contemporary world where conditions are changing rapidly, surprises are likely and uncertainty is high, managing for resilience enhances the likelihood for sustaining desirable pathways (Walker et al., 2004; Millennium Ecosystems Assessment, 2005; Folke, 2006). Formally defined, resilience is the capacity of a system to experience shocks while retaining essentially the same function, structure, feedbacks, and therefore identity (Walker et al., 2006). Instead of assuming systems to be stable, the resilience perspective shifts from a management of command and control, to a perspective of change. Sustainable development is then the ability to cope with, adapt to, and shape change within the coupled human-environmental systems (Folke, 2006). We propose to use the dynamic concept of resilience to study sustainable development.

Agro-ecosystems

Currently 38 % of the world land area is used for agricultural1 use, and is the principal cause of environmental degradation (Tainter et al., 2006). Agro-ecosystems can be considered as the

archetype of social-ecological systems. The change from hunting and gathering to agriculture represents a long history of humans modifying their environment. Agriculture changed the natural scale of variation in ecosystems mostly through command-and-control management approaches (Holling and Meffe, 1996). Modern agricultural with a few dominant species are the prime example of the reduction of variation. The price paid, however, is when unanticipated environmental or social problems arise; the expectation of certainty is not met and results in surprise and crisis in the social part of the system. The Avian flu is a telling example; the monocultures of poultry created a situation where ninety percent of a bird flock was killed and where the flu could only be stopped from spreading by killing all other poultry in the region. Classical swine fever and foot-and-mouth disease are other examples of these kinds of surprises and crises current agriculture faces. The surprises and crises in current agricultural can to a large extent be attributed to mismatches between scales of management and natural variation (Cumming et al., 2006).
Although agro-ecosystems are abundant and have major impact on a global scale, the research on agricultural systems and resilience is limited. From current work on resilience of agro-ecosystems it appears that agro-ecosystem management is characterized by a strong path-dependency (Anderies, 2005). Positive feedbacks between management and natural resources create a set of mutually reinforcing processes. The manager of agro-ecosystems is confronted with a legacy, with little more options than to re-enforce the current trajectory. The path-dependency implies heterogeneous management of natural resources at a local scale (Tittonell et al., 2007). The numerous different interacting components and agents of agro-ecosystems are operating on different scales while pursuing different (and possibly contrasting) objectives (Gomiero et al., 2006) creating a complexity larger than that of the majority of ecosystems.
In order to incorporate the resilience perspective in agro-ecosystem analysis, new tools need to be developed. A framework that is able to combine agro-ecosystem characteristics with the concept of resilience would thus present a valuable context for the analysis and design of agro-ecosystems and the exploration of future pathways of sustainable development.

Problem definition

The concept of resilience provides a way of thinking that presents a perspective for exploring pathways of sustainable development of agro-ecosystems. Resilience theory, however, has mainly been a theoretical concept applied to ecosystem management and increasingly to social-ecological systems. An integrative framework to analyse the complex behaviour of agro-ecosystems and resilience is lacking. In brief we argue that:

1. Resilience provides a new way of systems thinking, thus on agro-ecosystems functioning, and thus on sustainable development.
2. The new perspective calls for new tools.
3. This research can contribute to this goal by developing a social-ecological resilience frame-work for agro-ecosystems.

Results and discussion

Subject case

Soil organic matter (SOM) has been identified as an essential natural resource in many land-based agro-ecosystems. It is often said to be the most important indicator of soil quality and agronomic sustainability, because of its impact on other physical, chemical and biological soil properties (Reeves, 1997). Moreover management of soil organic matter is seen as essential for agro-ecosystems that have limited access to, or want to decrease external inputs. Furthermore complex interaction between organic matter and management have become apparent from earlier research on agro-ecosystems (Sonneveld et al., 2002; Tittonell et al., 2007).
Reijs et al. (2004) reported that farmers in the Northern Frisian Woodlands had found a new equilibrium by re-balancing nitrogen flows resulting in a well-balanced system (Groot et al., 2006).

This suggests that, from a resilience perspective, possibly an alternative stable state was discovered.

Farmers and scientists had together identified a set of measures that would mutually reinforce each other and would self-balance the farm (Reijs et al., 2004). Specifically, they experimented with the following measures:
-Reduction of chemical fertilizers and concentrates,
-A lower crude protein and higher fiber content in the silage,
-A higher fraction of organic matter and organic nitrogen in the manure,
-Limited grassland renewal and maize production.
The measures were considered to reinforce each other. A reduction of chemical fertilizers would lead to lower crude protein content in feed in complement by cutting the grass later in the season. This diet would, in turn increase the C:N ratio, and decrease the inorganic N content of the manure, leading to higher quality of the manure, in turn leading to higher soil organic matter content, finally leading to reduced need of fertilizers. Grassland renewal and maize production need plowing of the field, resulting in lower soil organic matter contents (Hanegraaf et al., 2009). When plowed and converted to arable land, 50% of the organic matter is lost within 6 years (Whitmore et al., 1992). Therefore, soil organic matter content can be conserved by limiting these practices.
For identifying complex behavior, of for example the dynamics in the Northern Frisian Woodlands, system models are particularly useful. They organize the key elements of a case into a structure that can be used to identify the slowly-changing variables, stabilizing and destabilizing forces, and important thresholds that determine the resilience of a system (Bennett et al., 2005).
Modeling the soil organic matter dynamics and management with an existing mechanistic model (Groot et al., 2003; Groot et al., 2007; Reijs et al., 2007) reveals that soil organic matter content and nutrient use efficiency probably represent a time lag of long-term non-equilibrium system development. Rather than alternative stable states, observed differences in N-efficiency represent a time-lag effect. Stopping grassland renewal will allow ecological processes to mature and the slow build up of soil organic matter capital.

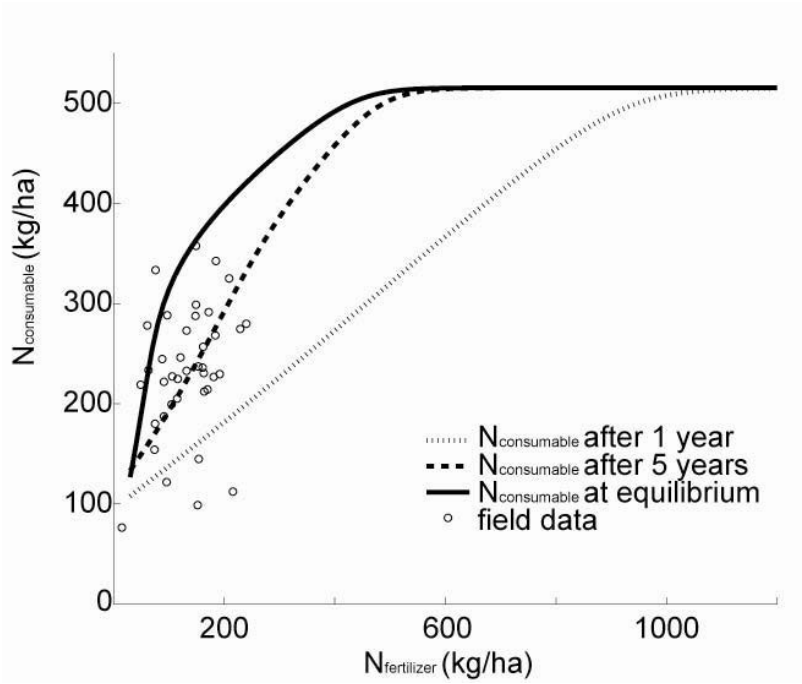

Figure 11. The change N-efficiency between the consumable part of the plant to external nitrogen input. For a field after years of maize cultivation, the dotted line is the response of the consumable part to fertilizer after 1 year. The dashed line after 5 year and the solid line when the system has reached equilibrium. The circles are the input-output relation of farms in 2006.

Spatial analysis reveals however that soil organic matter contents is not randomly distributed over the Northern Frisian Woodlands (See figure 11). Soil organic matter content shows a relationship with the soil depth limited by groundwater and texture.
Monte Carlo simulations (a form of sensitivity analysis) shows that this relationship is most likely caused by differences in decomposition rate of soil organic matter.

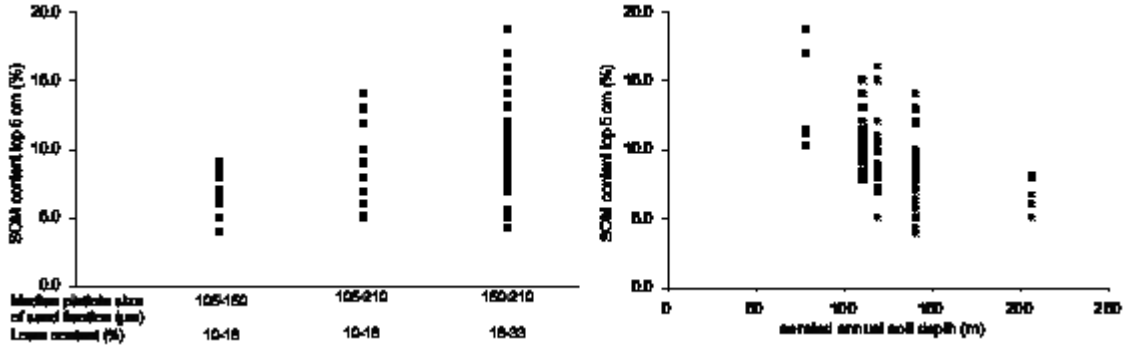

Figure 12. Effect of groundwater hydrology and texture on SOM contents. Data are derived from routine soil analyses at field level and detailed soil maps (Makken, 1991).

This non-random pattern of SOM in what we call the landscape asymmetry (See alsoCumming et al., 2008) provides windows of opportunity (Bouma, 2004) for farmers experimenting with alternative practices. Recognizing the landscape asymmetry allows for the further development of more sustainable farming practices.
The agro-ecosystem resilience of the Northern Frisian Woodlands is connected to this landscape asymmetry. In adopting a multi-scale framework we can identify a possible cascading cross-scale effect: Landscape asymmetry regulates SOM contents, SOM contents in its turn regulates the opportunity farmers have in reducing external inputs, The resulting preservation of the small-scale landscape allows for the development of a multi-functional landscape. Maintaining this particular agricultural landscape calls for environmental policies that recognize the importance of location as part of the landscape asymmetry. In contrast loss of landscape asymmetry might cause a collapse of current agro-ecosystem resilience.

This perspective where multi-scale dynamics interact, i.e. the panarchy proves to be especially insightful for studying long-term developments, which are generally overlooked by traditional agronomic studies. Modern conventional dairy farms for example, with a short term focus and their institutional setting leads to properties that can not be observed in natural ecosystems. Frequent grassland renewals in combinations with high inputs, results initially in high yields. This comes however, at the cost of long-term accumulated ecological capital of soil organic matter and its ability to transform fundamentally, thus reinforcing the incremental adaptation trap (Anderies et al., 2006).By incrementally adapting, short-term returns become a trade-off for other system configurations. Each small adaptation reinforces the dominant social and economic structures, further reinforcing the incremental adaptation process by economic forces and vested interests. The inertia thus generated by the land use history and biophysical processes might become so large that it precludes transformability of the system. The continuous disturbance by farm management prevents the system from developing structures of internal recycling. These systems locked up in the incremental adaptation trap hinder society's desire for agricultural transformations. Analysis of such a human dominated agro-ecosystem reveals that rather than alternative states, an alternative set of relationships within a multi-scale setting applies, indicating the importance for embedding panarchy in the analysis of sustainable development goals in agro-ecosystems.

We are currently testing the multi-scale landscape based perspective in a fundamentally different human dominated agro-ecosystem, namely mixed crop-livestock system with maize in Eastern Zimbabwe.

Societal relevance

The development of environmental cooperatives in the Northern Frisian Woodlands resulted in an increase of socio-economic capital. Self-governance and the interest in developing a multi-functional agro-ecosystem are illustrative of this capital. The increase of soil organic matter as a result of the reinforcing measures contributes to the development of ecological capital. So, from a sustainability perspective, the region has developed to a more sustainable landscape scale system, which is less resilient at the field level. The success of the environmental cooperatives to establish a new type of regional governance however, is dependent on the intrinsic slow dynamics at field level of soil organic matter accumulation. Institutional dynamics require fast and measurable results which do not match with the slow ecological dynamics at field level. This cross-scale dynamic system property is often difficult to address in our governance approaches (Cash et al., 2006). The concept of panarchy might prove insightful for tackling this kind of interactions at different time-scales.

Deliverables

An extensive review was made of the current state of the art of resilience thinking in relation to agro-ecosystems. This review was used in the research proposal for the graduate school PE&RC and will be included in the thesis.
Project results were discussed at meetings at Transforum, Telos and multiple conferences, seminars and workshops (see publication list below).

Publications

Peer reviewed

Van Apeldoorn, D.F. Kok, K., Sonneveld, M.P.W. and Veldkamp, T. (submitted). *Panarchy Rules: Rethinking Resilience of Agro-Ecosystems, evidence from Dutch dairy-farming,* Ecology&Society (special issues Scaling&Governance) .

Van Apeldoorn, D.F. Sonneveld, M.P.W., Kok, K., (submitted). *Landscape Asymmetry as a Source of Agro-Ecosystem Resilience*, Agriculture, Ecosystems & Environment.

Conference proceedings

Van Apeldoorn, D.F. (2008). *Modelling resilience of agro-ecosystems*. Paper presented at the Resilience Conference, 14-17 April 2008, Stockholm, Sweden.

Van Apeldoorn, D.F. Kok, K., Sonneveld, M.P.W. and Veldkamp, T. (2008). *Modelling resilience of agro-ecosystems: the co-evolution of regimes* (2008). Paper presented at the ALifeXI, August 5-8 2008, Winchester, UK.

Van Apeldoorn, D.F., Sonneveld, M.P.W. and Kok, K. (2010). *Landscape asymmetry as an element of agro-ecosystem resilience*. Paper presented at the Social-Ecological Resilience of Cultural Landscapes Workshop, June 15-16 2010, Berlin, Germany.

Van Apeldoorn, D.F. Sonneveld, M.P.W., Kok, K., (2011). *Landscape Asymmetry of Agro-Ecosystems and Resilience*, To be presented at the Netherlands Annual Ecology Meeting 2011, February 8-9 2011, Lunteren, Netherlands.

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