A. W. van den BAN

Integral design: innovation in agriculture and resource management

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Preface and acknowledgements

This book originates from the 'Integral Design in Agriculture' seminar, held in April 1998 in Wageningen. This seminar was initiated by the Communication and Innovation Studies group at Wageningen University and Research Centre, and organised in close co-operation with groups outside the Department of Social Sciences. The prime purpose was to explore the notion of 'integral design' from both a natural and a social science perspective, and build bridges between groups of scientists that usually do not work together in their efforts to help solve societal problems. The initiative resulted in productive debates before, during and after the seminar. The interest in the seminar, and the fact that several debates continued beyond April 1998, is an expression of the increased awareness among social and natural scientists that we need to find ways to co-operate if we wish to make a serious contribution to the many challenges in agriculture and resource management. This book presents a range of ideas on how such co-operation may take shape, and is meant to offer inspiration for further debate and progress.

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Chapter 1

Science and integral design in agriculture and resource management. Identification of issues and organisation of the book

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1. The changing relation between science and society

Agricultural research has always been closely connected to agricultural policy and practice. This is true not only for research that is carried out within institutions of 'applied' research, but also for research that tends to be labelled as 'strategic', 'fundamental' or 'curiosity driven'. These latter types of research are also often inspired directly or indirectly by societal problem definitions in relation to agriculture, either originating from governmental bodies, particular categories of farmers or other interest groups. Thus, it is not surprising that there is hardly a Ph.D. dissertation within the agricultural sciences that does not include an explicit reference to 'practical implications'. And even purely 'theoretical' products of scientific endeavour can have far reaching consequences for agricultural policy and practice, as theory influences our way of looking at the world, and directs our perception of problems and solutions. Hence, it is relevant for agricultural scientists to reflect on their relationship with society, irrespective of whether they work in experimental farms, research stations, agricultural institutes or universities. This is especially so since -in agriculture as well as society at large- the relationship between science and society is subject to considerable change and debate in recent years.

Modern society is characterised by a high degree of diversity, complexity, risk and specialisation (see e.g. Beck, 1992), and is subject to rapid change and shifting boundaries of time and space. In relation to this, knowledge is regarded as an ever more important resource, which leads some to speak of a 'knowledge society' (Boehme & Stehr, 1986; Verduin-Muller, 1991). At the same time, scientific knowledge claims have become more and more contested in societal debates; science has become demystified and demonopolised (Beck, 1992). This phenomenon is associated with a number of inter-connected factors such as the enrolment of scientists in networks of different societal interest groups, increased recognition of uncertainty, new forms of governance, higher public education levels, greater diversity within science itself, and the emergence of social studies of science that have convincingly demonstrated the socially constructed nature of scientific knowledge (Knorr-Cetina, 1981; Latour, 1987; Callon et al., 1986).

2. Towards 'integral design'

Despite the contested nature of scientific knowledge, and notwithstanding the fact that many of today's agro-ecological problems stem in part from the science-driven 'modernisation' of agriculture in the past (Van der Ploeg, 1987; Röling, 1996), scientists are expected to contribute towards solving these problems. Thus, many agro-ecological scientists are motivated to generate innovative solutions to societal problems. Among natural scientists such solutions are often thought of as being a *'design'* or an *'innovation'*, and the outcome of a *'design process'*. The 'designs' to which agro-ecological scientists contribute can take on many forms, such as land-use plans, technologies, seeds, animal breeds, rotation systems, food products, future scenarios, decision support systems, etc.

There is increasing recognition, however, that -in view of the societal developments described earlier- scientists' design processes must be organised in a different manner than before. It is felt that different societal interests must be taken into account in the design process, and moreover that prospective users need to play a significant role in shaping the design (Röling, 1996; Vereijken & Kropff, 1995; Van Veldhuizen et al. 1997; Jiggins & De Zeeuw, 1992). Furthermore, it is realised that many agro-ecological problems emerge from patterns of human action and interaction vis-à-vis the natural environment -amongst others through the use of technology- and that solving them presupposes changes in human (inter)action. Thus, the physical functioning of agro-ecosystems -the 'hard system'- is closely intertwined with the social, political and economic organisation of society, i.e. with processes in the 'soft system'. This implies that innovations in the 'soft system' may also contribute significantly to solving agro-ecological problems, and that a careful consideration of the relations between 'hard' and 'soft' solutions is necessary. Hence, the call for co-operation between social and natural scientists within design processes. In short, there is a call for design processes to be more multi-functional, more inter-disciplinary[1] and more interactive. We use the term *'integral design'* to refer to design processes that aim at incorporating these three dimensions (see also chapter 2).

[1] With the term 'inter-disciplinary', I refer to forms of co-operation whereby scientists from different disciplines work together in a team that aims at solving certain problems. In the team, the researchers stick to their own disciplinary perspective. However, they deliberately co-ordinate the research questions that each discipline adresses at various points in time, and carefully analyse the implications of particular insights and research findings for questions posed in other disciplines. This type of co-operation goes further than 'multi-disciplinary' co-operation, whereby disciplines remain more autonomous; the results from different disciplines are merely 'added-up'. In 'trans-disciplinary' co-operation researchers with different backgrounds develop a common conceptual framework and language (e.g. systems theory), thus 'trancending' their original disciplines.

3. Unresolved questions and issues

'Integral design' is still in its infancy. Widely accepted approaches and methodologies have yet to emerge, as do proper institutional arrangements to support these. In addition to these 'practical' issues, a number of conceptual questions can be raised in relation to the notion of 'integral design'. Below we will briefly introduce some of the issues that seem pertinent in this respect.

How appropriate is the notion of 'design'?

The term 'design' suggests a relatively high degree of deliberate effort, control and intentionality in bringing about change in agro-ecosystems. However, when we look at the actual use and functioning of agro-ecosystems, and ask ourselves to what extent this is the product of deliberate design efforts in the past, a certain amount of modesty seems appropriate. Many of the phenomena that occur within the natural and the social world are unexpected, or can be looked at as unintended consequences of human action (Giddens, 1984). Furthermore, many physical structures (e.g. irrigation schemes) and technologies that are clearly 'designed' are used in ways that deviate from the way they were conceived originally (Van der Zaag, 1992; Manzungu et al. 1996; Leeuwis, 1989); that is they are adapted or 'redesigned' (Rip & Kemp, 1998). In part, the above phenomena relate to the fact that multiple 'designs' -resulting from different periods, sources and actors, and in different societal realms, locations and networks- interact with each other in ways that are difficult to anticipate (Prigogine & Stengers, 1990). So if society is not so much the product of deliberate design, and if -as Richards (1989) argues- it is misleading to look at farms as if they were somehow 'designed', do we need to keep worrying about it at all? In our view, an answer to such questions cannot be sensibly formulated without taking into consideration what we understand by 'design processes' in the first place.

What is the nature of an integral design process?

There are several ways in which design processes can be conceived of and organised. For many, design is a systematic and planned approach towards solving particular problems, which is why the notion of design is often associated with control and rationalism. Others within the scientific community prefer to look at it as a creative process of research and discovery. This is especially so when no readily available knowledge exists for solving an agro-ecological problem, or when artistic aspirations are involved (such as in landscape design). More recently, it has been proposed that design processes must be looked at as processes of collective learning (Ostrom, 1990; Holling, 1985; Berkes & Folke, 1998; Röling & Wagemakers, 1998) or negotiation within a network of stakeholders (Koppen, 1994; Leeuwis, 1995; Callon et al., 1986). Röling (1996) proposes to label such learning and negotiation efforts as a process of 'social construction', thus giving a pro-active meaning to the originally descriptive concept that sociologists of science employed in their detailed ex-post accounts of how scientific knowledge and/or technologies are 'socially constructed' (Knorr-Cetina, 1981; Latour, 1987; Callon et al., 1986). Clearly, the way one looks at design has considerable implications with respect to the tasks, functions and/or phases one distinguishes in such a process, and hence with respect to the mode of organisation that is employed in actual practice. Hence, it is relevant to address the question what the most appropriate 'metaphors' (i.e. planning, problem solving, learning, negotiation and/or social construction) are for integral design in different conditions.

What is it that needs to be designed?
This book starts from the assumption that the concept of 'design' can be re-defined in such a way that it is worthwhile to maintain it. For such a re-conceptualization it is not only necessary to clarify the nature of the process, but also to assess *what* it is that must be 'designed' or 'constructed' in a process of integral design. Conventionally the idea seems to be that design processes result in a technology or plan that basically consists of a package of a-biotic and/or biotic artefacts, including a number of operational guidelines for use (Mok, 1982). For example a seed and a chemical product in combination with certain instructions for use in a specific context. We can also think of an irrigation system or land reclamation plan that presumes certain modes of operation, e.g. mechanised cultivation. It happens frequently that the biotic or a-biotic products of design process are much more explicit and visible than the guidelines with regards to human practices and the forms of social organisation (e.g. division of labour, support institutions, etc.) that need to be in place to support these. In other words, the 'social code' of particular designs (Mollinga & Mooij, 1989) tends to be less explicit than the 'physical code'. As many technologies fail, or are contested on the basis of their social implications (Van der Ploeg, 1987, 1990; Richards, 1985; Leeuwis, 1989; Röling, 1988), integral design processes probably need to pay much more explicit attention to the social and organisational arrangements surrounding a-biotic and biotic packages. In other words: these also need to become an explicit element within a design.

In addition, there are at least two dimensions that have to be carefully considered within integral design. First, before one can start to think about designing new (a-)biotic products and social arrangements one must have an idea about the problems that need to be tackled. Clearly, such problem definitions are related to the goals that are pursued. In the multi-stakeholder situations that integral design processes deal with, goals, interests and problem perceptions are likely to diverge considerably, so that the construction of a problem definition becomes a design-issue in itself. Finally, there is of course a process issue that needs to be addressed in every integral design effort. That is, one needs to address the question of how the design process can best be organised (or 'designed') and extended for it to result in a viable innovation, e.g. in the form of an effective and widely supported and/or used technology or land-use plan. Taking all together, there are several layers of design (problem definition, biotic and a-biotic artefacts, social arrangements, design and change process) that each require specific forms of knowledge and insight. The way in which these layers can be dealt with and interwoven in a design process, is an important area of concern.

What roles should different stakeholders play?
It is easy to argue that somehow different scientists and societal stakeholders must work

together in an integral design process, but it is far from self-evident how this can be realised in practice. Questions like: Who initiates the process? Who 'owns' it? Who contributes where? How do we deal with different points of departure and unequal power relations? Which actors are to be involved and which not? Is there a role to play for external facilitators? are only a few out of many that can be asked. It is probably not a good idea to look for standard recipes in relation to such questions, but it may be possible to identify some important principles at a more abstract level.

What is the use of detailed methodologies?

In operationalising integral (i.e. multi-functional, inter-disciplinary and interactive) design we can draw upon a variety of methodologies and approaches that tend to emphasise the interactive or participatory dimension. A range of participatory methodologies has been proposed, each of which is deemed suitable for a specific type of problem situation. Participatory Rural Appraisal (PRA, see Chambers, 1994a, 1994b), probably the most widely known example, typically provides a mode for making a community-based situational analysis, as a basis for further local action, problem solving and/or project identification. Clearly, a methodology like Rapid Appraisal of Agricultural Knowledge Systems (RAAKS, see Engel, 1995) is geared to something more specific, namely to diagnose the functioning of inter-institutional (knowledge) networks, with the aim of identifying opportunities and mobilising capacity for improving the innovative capacity of the network. Similarly, Röling's (1994) platforms for the management of collective natural resources are typically directed towards overcoming yet another type of problem situation, namely the unsustainable use of resources like fisheries, grazing lands or water, in connection with the existence of social dilemmas (Koelen & Röling, 1994). Finally, approaches like Participatory Technology Development (PTD, see Jiggins & De Zeeuw, 1992) and Interactive Bottum-Up (IBU, see Broerse & Bunders, chapter 15) are typically designed for solving technological problems in the development of low-external-input and sustainable agriculture (LEISA) systems.

Typically, such approaches and methodologies include a number of activities, phases, steps, methods, tools and techniques which are documented in handbooks and training guides (see e.g. Pretty et al., 1995; Van Veldhuizen et al., 1997; Salomon & Engel, 1997; PID, 1989). It has been documented that such methodologies run the risk of being applied in a rather mechanistic, ritualistic and/or routine-like fashion (Zuñiga, 1998; Khamis, 1998; Leeuwis et al., 1998), either because implementers fail to grasp the philosophy behind them, or are not genuinely interested in a participatory process (for example when the primary reason for using methodologies is to satisfy superiors and/or attract donor funds). Most authors on participation would agree that each specific local situation requires its own context-specific approach, which moreover needs to be adapted continuously as the process proceeds. This raises the question of how useful it is to translate interactive aspirations -and for that matter aspirations towards integral design- into clear packages that suggest that one can take them of the shelf, and apply them in a straightforward manner.

Is there a need and possibility for scientists to play a role?
Even if scientists show an interest in integral design processes (as is reflected in this book) one can wonder how important their role is in processes of societal change. After all, many innovations emerge without direct involvement of scientists (Kline & Rosenberg, 1986; Vijverberg, 1997). Clearly, practical limitations exist in this respect, as universities and research institutes are often far away -physically and culturally- from the local problem situations that somehow require design. Perhaps more importantly one can wonder to what extent societal problem solving and scientific endeavour are compatible; how can one do 'real science' in connection with integral design processes? This question touches not only on the issue of how one conceptualises 'real science', but also on how science is organised. Even if we come to the conclusion that different scientists need to play a role in integral design processes, do existing scientific reward structures, modes of financing science and scientific agenda setting procedures actually *allow* scientists to play this role? This raises all sorts of questions with regard to how universities and research institutes are organised, managed and linked to society and other forms of research (e.g. applied research).

Can inter-cultural communication problems be overcome?
Bringing together different societal stakeholders, natural scientists from several disciplines, social scientists and economists may well lead to a Babel-like confusion of speech. Each party is likely to have a different perspective on 'a' problem situation, which can be coloured amongst others by perceived interests, past experiences, existing frames of reference, scientific paradigms, and/or cultural meanings such as identity, normative considerations and different attitudes towards nature (Aarts, 1998; Douglas & Wildavsky, 1982). Moreover, groups of stakeholders or scientists may constitute different '*epistemic communities*' in that they adhere to dissimilar grounds of belief, modes of rationalisation and procedures for validating knowledge-claims (adapted from Arce & Long, 1987 and Knorr-Cetina, 1981). Such cultural and epistemic gaps certainly exist between natural scientists and social scientists, between social scientists and economists, and even among social scientists. In part this is an expression of fundamental differences between 'hard' and 'soft' sciences (Röling, 1996). It is clear that in integral design processes such gaps need to be overcome to a certain degree. Different actors must be willing and able to gain in-depth insight into the views of other stakeholders, and be ready to reflect critically on their own. Even if we assume for a moment that there is a willingness to so, the diversity among stakeholders may cause numerous communication problems and frustrations. This raises the question how such problems can be alleviated or managed.

4. Organisation of the book

This book does not attempt to give 'final' answers to the issues raised above. Rather, it presents a number of predominantly 'Wageningen' experiences and reflections in relation to integral design. These experiences are grouped together according to the type of innovation that is involved (land-use policy or technology), and/or a specific aspect in the design process (the role of modelling, communication or research organisation). Each part thus covers a particular area of interest. The 'unresolved issues' discussed in the previous section are not used as an organising principle, but function as general background questions to which we will come back in the final chapter. The comparison and integration of the experiences and reflections presented in the different parts may help us to take a few steps forward in the theory and practice of integral design.

Part 1: Introduction

The introductory part consists of two chapters. This current chapter briefly introduces the notion of 'integral design', identifies a number of general issues for debate, and explains the organisation of the book. In chapter 2, Cees van Woerkum further elaborates the concept of integral design and its underlying philosophy, and gives an impression of both the initial responses within the scientific community, and of the challenges ahead.

Part 2: Designing the use of rural space: balancing agriculture and other societal functions

With regard to the use of space, design efforts tend to focus on the allocation of different (combinations of) societal functions towards spatial units. As the role of agriculture in rural society declines, and new interest groups (e.g. landscape and nature conservationists, tourists, rural dwellers, environmentalists) emerge, the use of space has become much more contested than in the past (Lengkeek, 1997). In relation to this there is a need to rethink spatial policy processes, and the role of stakeholders and governments therein. This is especially so since conventional approaches towards policy-making tend to be less effective than before.

In chapter 3, Marjan Hidding identifies contrasting discourses on town and country that are put forward in processes of spatial planning, and that complicate aspirations towards integral design. Moreover, she suggests several strategies to overcome such difficulties, ranging from additional research to a redistribution of power and authority in spatial planning processes. Subsequently, Noelle Aarts & Cees van Woerkum analyse recent episodes in the design of nature policies, and the patterns of communication with the agricultural sector therein. In doing so, they employ several theoretical perspectives (amongst others negotiation theory) and empirically demonstrate the need to transcend an interactive approach, and move towards integral forms of policy design (chapter 4).

Part 3: The role of modelling in exploring land-use policies

Computer models have become popular devices within design processes, especially those that are geared towards the design of policies that regulate the use of land and other natural resources.

In chapter 5, Walter Rossing, Martin van Ittersum, Hein ten Berge & Cees Leeuwis discuss the pros and cons of modelling for integral policy design at various hierarchical levels, ranging from the global to the farm. Thereby, they emphasise the need to embed the use of exploratory land-use studies in well-facilitated debates among stakeholders. Rather than modelling biotic and a-biotic processes in connection with human objectives, Niels Röling proposes in chapter 6 to model human behaviour and patterns of interaction themselves. This in order to explore alternative institutional arrangements for the management of collective resources and ecological services.

Part 4: Designing technology for sustainable agriculture

The emergence of new technologies, farming practices and social arrangements is a prerequisite for achieving more sustainable agricultural production systems. In many cases the technologies need to be 'knowledge-intensive' in that they must enable a more precise use of external resources, and a more refined management and co-ordination of ecological cycles. Moreover, there is a greater need for such technologies and practices to be adapted to locally specific agro-ecological circumstances and socio-economic conditions.

In chapter 7, Pieter Vereijken elaborates on the prototyping approach towards the development of sustainable (arable) farming systems. This approach towards integral design is illustrated with a case study from the Netherlands. Subsequently, Cees Leeuwis suggests a number of adaptations of the prototyping approach from a social science perspective (chapter 8). These are mainly geared towards enhancing learning and negotiation processes within prototyping, in order to improve the capacity to deal with the 'soft' dimensions of technology design.

Part 5: Linking integral design with extension and communication

Clearly, it is neither practically feasible nor efficient to directly involve all farmers in integral technology development processes. Hence there is a need to explore how such processes may be connected with extension approaches.

To this end, Frank van Schoubroeck & Cees Leeuwis explore in chapter 9 how the conventional extension methodology in Bhutan was adapted in order to facilitate Integrated Pest Management, and how this inspired new integral design processes involving new technologies and social arrangements in different communities. Moreover, they point to various difficulties regarding the scaling-up of such socio-technical innovations. Following this, André de Jager, Eric Smaling, Davies Ondura, Mateete Bekunda & Niels Röling report on efforts to translate the principles and experiences of Integrated Pest Management towards the management of nutrients. Thereby, they draw on their experiences in Kenya where systems for Integrated Nutrient Management were developed in a participatory fashion, and incorporated in the curriculum for Farmer Field Schools (chapter 10). Subsequently, Edo Biewinga elaborates in chapter 11 how the Dutch Centre for Agriculture and Environment has embedded its prototyping activities within a wider communication and policy plan. Finally, on the basis of a literature review, Puk van Meegeren and Cees Leeuwis present a number of general guidelines for communication during integral design processes (chapter 12).

Part 6: Integral design and the organisation of research

Most scientists are of the opinion that in one way or another they have something to offer to integral design processes. Almost by definition, the notion of integral design requires that scientists from different disciplines, and across institutional boundaries (e.g. universities, research institutes, experimental stations, private companies) somehow work together, within the context of an interactive process.

In chapter 13, Johan Bouma introduces the idea of research chains as a way of organising the input of research within integral design processes. He gives a number of examples that illustrate how such chains can work effectively. Subsequently, Cees Leeuwis establishes that agricultural knowledge is increasingly regarded as a commodity, of which the exchange can be effectively co-ordinated through 'knowledge markets'. In his view, this poses a number of threats to integral design processes, and the formation of effective research chains therein (chapter 14). Finally, Jacqueline Broerse and Joske Bunders evaluate a research programme aimed at the interactive development of appropriate biotechnology for farmers in chapter 15, and point to a number of organisational obstacles that hampered this process.

Part 7: Epilogue

In the final chapter of this book, the Cees Leeuwis & Gaston Remmers reflect upon the extent to which the experiences and thoughts presented in this book allow us to answer some of the issues raised at the outset.

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Chapter 2

Towards integral design: background, responses and consequences

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1. Introduction

Many scientists believe that plans have to be made in isolation from the world outside, with a maximum of scientific input and a minimum of societal or political intervention. A good plan is a plan made by scientists and only by them. Practitioners have to implement such a plan as scrupulously as possible. The keyword is fidelity; what is prescribed has to be adopted exactly as it is formulated.

We did research on the way curriculum developers interacted or did not interact with practitioners. Some of these scientifically trained developers were very clear about their intentions: "A good teacher is the one who understands what I mean!" And: "I think that the teacher first of all is a person who has to implement the plan. With this I do not intend to degrade him. Good implementers are worth their weight in gold. One cannot expect them to raise all kinds of questions and problems, or to reflect on them. They are not taught to do so. That is not their job!" (Adolfse and Van Woerkum, 1997: 32, 35).

This attitude of scientific planners is widespread, also in the field of agriculture. Understandable as it is, I think that it is no longer the right attitude. In this chapter, I discuss a few developments that make it less desirable. Subsequently, I propose an alternative, which constitutes the subject of this book: integral design. After this, I examine the reactions of scientists to their problematic relationship with society. And finally, I discuss some of the most important consequences. It will be clear that these consequences are far reaching and will influence deeply the way scientists work.

2. The basic idea

'Integral design' refers to a design approach that accounts for the multi-functionality in agriculture, and is inter-disciplinary as well as interactive vis-à-vis involved societal groups. These aspects are interconnected.

Multi-functionality means that agricultural production serves different needs, including economic food supply, health, recreational or ecological needs. Consequently, the study of these processes has to be undertaken by distinctive disciplines. In order to achieve a coherent approach (*one* design) these disciplines have to be integrated. It is not enough that a certain discipline has to look at the results of another: the process itself of achieving an optimal plan has to be a joint affair. Inter-disciplinarity implies that models for working need to be constructed which enable us to incorporate a number of disciplines. Individual scientists thus become part of inter-disciplinary working groups.

In addition the working out of a plan has to incorporate the rationality and expectations of the people who have to implement this plan or are affected by it. Not in the sense that their views are to be taken as given. On the contrary, all actors have to be brought into the planning process on the basis of joint learning. Societal groups have to learn, as well as scientists and governmental officials.

Learning processes are often linked to negotiations. Consensual seeking of the common truth is a possible variant, that may be found in a specific context, but because of the multi-functionality, people will usually have different perspectives in most situations. For instance, if we look at animal production systems, we have to confront very different or even conflicting interests on the basis of strict economic, human health, animal welfare or environmental criteria. We can imagine negotiations without learning, and in the past such so-called 'distributive' negotiations were often encountered. The essence of integral design is negotiations combined with learning. Each of the actors involved in the planning process needs to learn about the motives and backgrounds of the other actor. Only on the basis of such joint learning negotiations can become creative ('integrative' instead 'distributive'), which is an important prerequisite for integral design to have positive results (see Aarts & Van Woerkum, chapter 4).

3. Why?

The shifting relationship between scientific planning and societal decision-making can be explained by a variety of factors. I briefly discuss some of them.

One of the first things is the way we look at knowledge (Röling and Jiggins, 1998). Knowledge, we know from the philosophy of science, is not discovered but constructed. Behind scientific results, also in the field of 'hard science', we can trace assumptions or presuppositions that account for what is important and what is not, and consequently needs to be dealt with (or not). There is a lot of implicit knowledge that influences the interaction between scientists; not only the interaction via scientific articles, but - more importantly - the interaction in laboratories or in the informal setting of congresses and workshops (Gilbert and Mulkay, 1984).

Of course, implicit knowledge is also an important domain in the field of other actors. Opinions about how to behave in breeding pigs or chickens, from the viewpoint of animal welfare, are loaded by mostly implicit assumptions about 'good' or 'bad' conditions.

Knowledge can be created by scientific research or by reality testing in practice. The experiences of farmers offer a rich source of information, as every extension officer will be quite willing to admit. However, this knowledge, as well as the implicit knowledge mentioned earlier, has been underrated in planning processes in the past. We have to look at opportunities to correct for this under-usage.

A second factor is the growing concern about the effects of new technology. Technology is linked to risks. On the one hand we think that by creating a society based on technology we are much more or even too much dependent on it. Technological problems can affect us deeply (the 'millennium-problem' is the best example). On the other hand new technology creates possibilities with unknown and 'risky' consequences, as is the case in biotechnology. Some of these consequences could be very harmful (or not), socially undesirable or unethical (or not). These consequences could be physical as well as social. If society does not accept new technology, this technology is unusable. Of course, this 'societal risk' is also an economic risk. Only those risky technologies that are made acceptable to societal expectations can be developed to their final form. The way this is done (constructive technology assessment) clearly resembles ideas on integral design.

The change in policy style, from instrumental steering to facilitation and interactive planning, would be unthinkable if the old style had been very successful. In fact, the 'crisis of governance' has a lot to do with the ineffectiveness of setting goals and assessing means in an instrumental way. We are not able to manage the big problems in society, unless we change our decision-making processes.

This point can be made clearer by looking at the knowledge component. To solve societal problems we need three types of knowledge:

a. knowledge about the problem and its causes;
b. knowledge about technical solutions;
c. knowledge about the change process that is needed to lead the involved actors from a to b.

In an instrumental policy approach we can bring in data on a and b. But data on c are not readily available. Society is not 'knowable'. As Van Gunsteren said (already in 1976!): " ... central plans, informed only by technical or scientific rationality, cannot work! (...) Rule-making can only effectively guide behaviour if it is tied to ongoing forms of life; that is, if the rule makes sense in terms of the practical rationality of the ongoing interactions, that they are supposed to regulate" (Van Gunsteren, 1976: 136). The only way to gather the knowledge we need is to interact with people to develop suitable solutions.

Interestingly, knowledge about the needed change processes in society influences the way technical solutions are perceived. Often, researchers in the field of technological innovations invent clear-cut solutions, neglecting the societal context. Only by experiencing that in this way nothing can be achieved, will they think along new lines and arrive at other research strategies. For instance, in the field of soil management, they learned to think about new methods of making a dirty soil cleaner when they got to know that the old solutions ('complete cleaning') were not appropriate. Only a few heavily contaminated soils could be cured in that way, because of the gigantic costs. Now they move to technologies that support natural processes in the soil to clean itself. The objective is not any longer to clean the soil, but to improve the cleaning processes. Of course this will take much more time. But it allows work on many more spots at the same time, because of the modest (financial) inputs that are necessary. From a purely technological viewpoint the effect is questionable (the soils are not 'cleaned'). From a societal viewpoint a lot has been gained (in many cases situations can be improved).

4. Responses

What is the reaction of scientists to this emerging debate? We can distinguish three groups.

The first group of scientists sticks to the old practice of bringing in data and offering models, hoping that responsible persons and institutions will use them in a proper way. If government or society does not adopt their ideas, then they are disappointed. However, being irrational, this non-adoption can not be taken seriously. So, they can only wait for better times.

The second group is aware of an acceptation problem and takes initiatives to close the gap. They try to increase the cost-benefit ratio of their research by paying attention to their communicative behaviour. They try to present themselves, at non-scientific congresses or via booklets, in an understandable or even attractive way. They publish in all kinds of professional and trade journals outside their scientific circle, they write in newspapers, they are eager to be interviewed and they prepare themselves for this. For instance, under the label of PUS (Public Understanding of Science) much has been done to inform the public about the characteristics (and benefits) of biotechnology.

The third group sees itself as a part of a much broader process of solving societal problems, and thinks that communication is a very important element in this process. But, unlike the second group, this communication is not defined in terms of better presentation but in terms of a better interaction. In discussion with scientists of other disciplines and with governmental and societal groups, they try to construct common problem definitions and accepted solutions that meet the rationalities of others. Instead of disseminating 'the right word' they engage in two-way communication.

It is of course the last group that fits in with the integral design approach. For these scientists it is clear what constitutes their specific expertise. However, they have consistently related their knowledge to the larger framework and societal context (see also: Bouma, 1997). They feel the interdependencies, not only within the technological realm, but also vis-à-vis economic, social, psychological or cultural realities. They know that the effectiveness of any solution depends on the way technological solutions are integrated in a societal process, in which people can move from a to b.

5. The consequences

The idea of integral design is simple enough. The reasons for this new approach are also obvious. Yet, the consequences cannot be neglected. Integral design requires quite a different scientific practice, from which we are far removed. Let us look at a few of these consequences.

One of the consequences is the willingness and the ability to dig into the world of others, being scientists or societal actors. This is related to the perception of one's own identity. You are a biologist or you are an expert in realising natural values, you are a hydrologist or you are able to control water quality problems, you are a toxicologist or you can create better soils. It is this applied perspective that brings one nearer the other actors. With this approach another professional role set appears: in interaction one either refers mentally to colleagues of one's own breed or one is open to others. If we look at planning processes as a form of thinking, and at thinking as an internal dialogue with others -as a result of interactions or anticipating them- the question arises: which people appear vividly in the heads of these planners? Only if the role set is broad and if the interactions with various other people are intense, will this referential thinking, which is unavoidable, reach further than the peer group of co-scientists.

This empathic quality of scientists can not be isolated from their willingness to reflect upon their own premises. I mentioned already the often implicit assumption of scientists of what is important to them or not, or what is methodologically correct or not. For instance, in policy processes aimed at creating new nature, a biologist or ecologist has to think about such a basic concept as that of biodiversity. Is it a statistically measured variety of nature, is it the presence of a rare species, or is it a process towards one of these things? Above all: what does it mean? Is it a fate of history or are we directly responsible? What are the consequences of the extinction of the dinosaur or the panda? These biologists meet experts on cultural history, who look at landscapes as a natural heritage, that has to be preserved on the basis of the same arguments as the inner city of Amsterdam. What is the value of this? Both groups are asking these types of questions and the others have to respond. Only if they both are able to reflect critically on their own presuppositions can they move further together. They cannot change the other party, unless they change themselves.

Another consequence is that scientists need to have the ability to work in situations that are quite different than those presented in handbooks and university courses. There, scientific knowledge often is depicted as stock knowledge. With this I mean knowledge that a) has a quality of its own, b) is transferable to others (as a packet) and c) is independent from the subject that 'bears' the knowledge. My vision of knowledge leads to the concept of flow-knowledge, in which knowledge can be identified as a) something which derives its quality only from the interaction between involved actors, b) in principle not transferable (knowledge is always taught, associations are unavoidable and meaningful, we 'fill in' and we visualise mentally) and therefore c) being the unique property of everybody. Knowledge is the particular vision of everybody of the reality around him/her.

Students have to learn to participate in discussions and negotiations, where knowledge is not automatically the final answer to specific questions, but a part of the common problem. They have to respect other sources of knowledge, from different disciplines, from practical experience. They have to understand the meaning of implicit knowledge, which may be a hindrance to overcoming one's preoccupations. As they have to be able -socially- to participate in processes of integral design, which calls for abilities like good listening, knowing one's part in the turn-taking machinery of a discussion or expressing oneself in an understandable way.

This new situation also has consequences for the methodology of research. In academic circles worldwide we see a tendency towards uniformity, towards standard protocols. Indeed, this makes sense. The possibility of comparing outcomes is an important step in the formation of a 'body of knowledge' upon which decision-makers can build. On the other hand, integral design requires flexibility. Sometimes results have to be produced in a very short time, perhaps half the time prescribed in a standard method. Of course, one looses reliability and validity. But one gains in relevance.

Integral design has stimulated meta-research on adaptive methodology, a way of working in which practical restrictions (time, money) are taken as given, and from which an adapted research model is developed. Adaptive methodology is not 'bad research': it is the best you can do in certain situations. Students have to be trained to decide carefully how to act in a variety of situations in order to solve a certain problem.

6. Conclusion

Integral design is not a panacea. It implies hard work in uncertain conditions, with no guarantees of results. Discussions with others can be very stimulating and offer creative incentives. But often they are troublesome or even frustrating.

To illustrate this let us look at the discussion about the way chickens should be housed. Free-range chickens have to be able to go outside according to the tenets of organic agriculture. The market specialists are also in favour of this, as it pleases the consumers who like to live 'as close to nature as possible'. However, for environmental experts, open-air housing is undesirable because of the emission-effects. According to them chickens should be raised in closed accommodation, with as little access to the open air as possible. Health experts are also not in favour of open-air housing. Free-range chickens, they argue, are more often ill, partly due to the contaminated faeces of other birds with which they come into contact. So the chickens are put inside. But the discussion does not end there. Environmentalists like to see chickens on grids with wide holes, so that manure can be removed quickly and easily. Health experts, however, are against this solution, because the larger holes can cause injuries to the chickens' legs. Yet others, including the consumer expert, want the chickens on the ground. They have to be able to walk about freely. Question: What solution would integral design come up with as the ideal chicken housing?

This book is meant to offer scientists, struggling with this kind of questions, a source for reflection. Final answers are not given. The core idea of integral design is still fresh and needs a lot of elaboration. But we will move in this direction, a challenging perspective.

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Chapter 3

Integral design as a task and challenge for spatial planning

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Abstract

The idea of integrality has always been highly appreciated by spatial planners. However, the interpretation of 'integrality' has shown remarkable changes over time. In the fifties the question of integration mainly concerned the spatial organisation of different forms of land-use; now much more attention is given to the interaction between different planning actors. Looking at today's planning practice the three different dimensions of the concept of integral design -i.e. 'multi-functional', 'inter-disciplinary' and 'interactive'- are easily recognisable. This does not mean that integral design is an easy task in the field of spatial planning. In this paper the complexity of integral design in spatial planning is elaborated in terms of the existence of different 'discourses on town and country'. Such a discourse is understood as a more or less consistent complex of ideas about (aspects of) the spatial organisation of, and/or spatial policy for, town and country. These ideas are constructed and reconstructed in interaction between researchers, planners, designers, policy-makers, politicians and interest groups, and are embedded institutionally in government institutions and societal forms of organisation. The existence of different discourses and discourse communities asks for integration strategies. Three of such strategies are roughly indicated towards the end of this chapter.

1. Introduction

The concept of integration is not alien to spatial planners. Indeed, many regard the task of an integrated approach to spatial questions as being at the centre of their discipline. This task is often referred to as having two sides. On the one hand it is important to arrive at a plan that is well founded in terms of content; the effort to achieve integration is expressed here in the first place as conceptions of the spatial organisation of land-use. On the other hand, the objective is to arrive at a plan supported by the involved sections of society, in this case the effort to achieve integration is mostly expressed by the manner in which interaction between participating public and individual actors is given form (Hidding, 1997). The attention given to these two sides of the planning task has not always been this great. Up until the Sixties, blueprint planning prevailed; integration of content was deemed most important. Since then, quite a lot has changed in the theory and practice of spatial planning; aspects of procedure have been given much greater prominence. In all cases, integration has been shown to be an ideal that is difficult to realise. The history of spatial planning comes across, therefore, as a continuous struggle to realise this ideal.

In the following I will develop in greater depth some aspects of 'integral design' within the framework of spatial planning. Firstly, I will typify spatial planning according to the three dimensions of 'integral design' as they are set out by Leeuwis in chapter 1 of this book, namely: multi-functional, inter-disciplinary, interactive. Dutch planning practices serve as references. Next, I will focus on the difficulty of the task of integral design. With reference to five actual discourses on town and country, I will demonstrate that there are widely conflicting opinions as to future spatial organisation and structuring and its associated policies; it is therefore obvious that the achievement of integrality is no simple matter. Finally, I will outline a number of strategies that could bring 'integral design' closer.

2. Spatial planning and the three dimensions of 'integral design'

In spatial planning, everything hinges on just one simple question at the end of the day: "What do we want to achieve and where?" In other words, the issue is that of locations for different functions, such as agriculture, nature, potable water supplies, housing, shopping amenities, industrial activity, outdoor recreation and traffic and transport within a certain geographically defined region. In addition to this, there are questions of spatial structuring and management within spatial planning. The spatial plan gives the answer to these questions; it throws light on the position of different functions in relation to each other, gives and idea of the desired spatial structuring and, if necessary, talks of future management. One of the dimensions of 'integral design', namely, handling questions of multi-functionality (Leeuwis, 1999) is consequently an inherent part of the phenomenon of spatial planning. The history of Dutch spatial planning shows that the design task in question became more inclusive as time went by. This has to do, in the first place, with the increasing intertwining of town and country, giving rise to increasingly conflicting functional demands on these areas. Besides this, the development of a comprehensive environmental policy also has a role to play; spatial planning is increasingly taking shape in conjunction with environmental and water policies, and this also means that the connection of land-use and soil and water quality becomes a part of the design task (Van der Vlist, 1998). In order to keep the design task manageable, there is a discernible tendency towards selectivity in planning practice; at regional level attention is mostly focussed on a specific problem area. The effort to achieve integrality has its limitations!

Current spatial planning also shows characteristics of 'integral design' in another way, namely, in the case of interactivity. Up until the Sixties, Dutch spatial planning was still strongly influenced by destination-centred planning; in the eyes of the planners everything that needed to be addressed was in fact addressed by the spatial plan. The relationship between the plan and its execution was scarcely seen as a possible difficulty. In the Seventies, greater attention was starting to be paid to this question. It was no longer the plan but the co-ordination of the actions of those involved that was elevated to the position of central planning issue. In the first instance, attention was focussed especially on the authorities; horizontal, vertical and later even diagonal co-ordination of the actions of the government became a central point for attention during planning. In the Eighties this one-sided focus on the actions of the authorities came in for increasing criticism. This government-centred thinking was regarded as an important cause in the failure of government policies; the concept of a viable and self-constructed society was put into greater perspective (Den Hoed et al., 1983). Not the co-ordination within the actions of the authorities but the interaction between public and private actors came to the fore. Interactive formation of plans was no longer regarded as simply a means of creating the necessary platform for plans but also as a strategy to strengthen the content quality of plan formation; i.e. planning as a learning process (Friedmann, 1987).

Finally, the fact that the field of spatial planning is worked from divergent disciplines is not surprising against the background of the above. Even in that period in spatial planning when all attention was focussed on the production of a spatial plan there was talk of input from different disciplines. Besides town planners and architects and civil and cultural engineers, social scientists have also had an input from the start. This input was mainly in the area of the formulation of the spatial programme through various different forms of research, from population predictions to experiential research. The emergence of new problem areas, among which were nature and the environment, and the increasing attention for the aspects of planning procedure, led to a further growth in the number of disciplines involved with spatial planning.

3. Integral design - a capricious task.

From the above, it emerges that the three dimensions of 'integral design' as defined by Leeuwis are easily identifiable within spatial planning. In planning practice an integral approach proves to be a difficult task, not least because different categories of actors have greatly diverging ideas about questions of content and procedure. In this section I will define this concept in greater depth using a summary of five actual 'discourses on town and country'. This section is based on research that I carried out with two colleagues from the University of Nijmegen (Hidding, Needham & Wisserhof, 1998).

A discourse on town and country is understood as a more or less consistent complex of ideas about (aspects of) the spatial organisation of and spatial policy for town and country, that is being constructed and reconstructed in interaction between researchers, planners, designers, policy makers, politicians and interest groups, and is institutionally embedded in government institutions, social organisations and their organs. Such a discourse perspective includes both the substantive and the process dimension of spatial planning. Within a discourse, three distinct but interacting layers are identified:

- (a) theoretical perspective(s);
- (a) plan concept(s); and
- (a) management strategy(ies).

The first layer involves scientific concepts for analysing the relationships between town and country. The second one includes concepts about the desired spatial organisation of town and country, probably grounded in the theoretical perspective(s). The third layer comprises approaches for influencing or managing spatial processes. The multi-layered nature of a discourse is inherent in its institutional embedding in different organisations: government agencies, research institutes, planning departments, architect bureau's, NGOs, for example. This means that a discourse perspective on spatial planning allows for interaction between theory and practice. Within the current debate about spatial policy for town and country five discourses of town and country can be identified:

- town and country as 'separate entities';
- town and country as 'networks';
- town and country as 'ecosystems';
- town and country as 'locales'; and
- town and country as 'real estate'.

Because discourses are constructed and reconstructed in social interaction, they can be seen as historical phenomena. The discourse of town and country as 'separate entities' has by far the longest history (Derks, 1986). It covers many aspects of town and country, and from an institutional point of view it is in many countries firmly embedded in governmental policies in the field of spatial planning. The other discourses are more recent and focus on specific aspects of town and country. Therefore, it might be better to speak of 'proto-discourses'. At the moment, they represent a hard core of ideas, with a potential to organise around themselves a broader set of views and a wider institutional setting.

Town and country as separate entities

The idea of town and country as 'separate entities' has dominated spatial planning for many years. This discourse represents the classical view in which town and countryside are seen as spatially separated phenomena, as 'points' and 'plains', respectively (Witsen & Zonneveld, 1996). Theoretical contributions reach back at least as far as the eighteenth and nineteenth century, when the industrial revolution gave rise to strongly economically oriented views on the relationship of town and countryside and led to the rise of big towns and cities (cf. Derks, 1986). In the twentieth century, the 'separate-entities' view grew into the heart of a spatial policy for concentrating urban development and preserving the countryside as open space. Some plan concepts are the compact city or conurbation, and restrictive areas where dispersed building and ribbon development is constrained (Table 1). These concepts focus on a *spatial pattern*, particularly the relatively sharp distinction between densely populated built-up areas, and scarcely populated open areas. This morphological structure is most manifest at the regional level. The discourse of town and country as separate entities primarily pertains to this level of spatial organisation.

Because of the many social, spatial and environmental aspects of the contrasting relationship between town and countryside, the classical discourse has broadened over the years, not only analytically but also in terms of plan concepts and management strategies. In general, a management strategy requiring strong public-sector steering has been most prominent, since the realisation and preservation of a sharp distinction between town and countryside requires considerable intervention in processes otherwise unregulated. The experience of socio-spatial developments in many countries, after all, is of diffuse urban systems in which the boundaries between town and countryside are fading away. The classical discourse therefore requires the availability of strong and effective planning instruments for policy implementation, as well as a willingness by governments to apply such instruments.

Town and country as networks

The rise of the 'network' discourse is closely connected to the transition of an industrial society towards a post-industrial society. Theoretical contributions about the latter, for example, refer to the importance of inter-organisational networks. Interactions among organisations are seen as a crucial factor for innovations (Castells & Hall, 1994). As there is a constant flow of persons, goods and information through these socio-economic networks, infrastructural networks are a crucial part of the spatial organisation of post-industrial society. This is reflected in the way spatial organisation is looked at. It is primarily seen in terms of a spatial network, i.e. in terms of 'lines' and 'nodes' which form the bedding for different kinds of traffic flows (Teunissen, 1997). New technologies for transport of persons, goods and information are important in this discourse. As a result of these technologies, companies and households have become relatively 'footloose'. As long as they have access to the infrastructural network they can settle anywhere, in principle. Where they settle can be influenced by spatial policies. Plan concepts in this discourse take flows of persons, goods, information etc. as a guiding principle. The concepts focus on *socio-spatial processes*. Along the traffic lines, large 'corridors' (Table 1) of economic activity could emerge. Creation of these corridors has to be a task for public-private partnerships. Management strategies in the network discourse, therefore, do not give a central role to the public sector. Government agencies are but one group of actors in the social networks that are formed to create corridors.

In the network discourse, 'town' and 'country' are no longer separate entities but rather a kind of derivative. Areas with a high density of 'flows' could be characterised as urban, the meshes within the infrastructural networks as rural (Dietvorst & Hetsen, 1996). Because socio-economic and infrastructural networks manifest themselves from a local to an international scale, this town and country discourse is not confined to the regional level.

Town and country as ecosystems

The discourse in which town and country are conceived of as ecosystems is rooted in the relatively recent striving for 'sustainable development' and, thus, for the integration of ecological principles in spatial organisation. Apart from theoretical contributions which elaborate the idea of sustainability itself (WRR, 1994) scientific efforts are directed to the analysis of risks and the development of technologies that can contribute to one of the many aspects of this meta-objective. Spatial organisation is primarily analysed in terms of 'streams' and 'cycles'. Much attention is paid to streams in the context of hydrological systems (Tjallingii, 1991) and to bio-flows resulting from the migration of animals and the dispersion of seeds and plants (Teunissen, 1997). It is these processes that are considered key factors in (among other things) today's nature conservation policies. The metaphor of 'networks' is often used too, to denote the beddings for streams and bio-flows at different geographical levels. Natural processes are the starting point for spatial planning and design, rather than human needs for housing, working, recreation etc. Accordingly, plan concepts in this discourse such as the water system, the 'casco', and the 'EHS', the (Dutch) National Ecological Network (Table 1) focus on *physical-spatial processes.* The purport of these concepts is to reduce the negative effects of social activities on streams and bio-flows and on the physical networks which function as their beddings, mainly at the local and regional level. Different management strategies can be applied to achieve this, ranging from public-dominated strategies to market-oriented strategies (e.g., transferable rights of production or pollution). Due to the normative element in this discourse, the self-organisation of the actors involved will generally be set within a regulatory framework: 'meta-steering' by a central government.

In this discourse too, town and country are derived concepts. The location of human activity depends on the possibilities for minimising negative effects on streams and bio-flows. One possibility is to situate polluting functions downstream and to situate non-polluting functions upstream (RPD, 1996).

Town and country as locales

The discourse of town and country as 'locales' regards the spatial organisation of society as a set of places with specific identities and meanings. Since different meanings can be given to one place, spatial organisation is a multiple-reality (Mormont, 1990). The theoretical basis of this discourse originates in post-modernism with its focus on multiple realities and a critical attitude to the 'grand narratives' of modernity. Plan concepts in this discourse focus on *space as places:* a rich differentiation of ambiences which enable different groups of people each to find an appropriate place to identify with (Hajer, 1996). Examples of such concepts at the regional level are the urban landscape and the green metropolis (Table 1). Both concepts are meant to combine the spatial qualities of town and country. The concept of the urban landscape takes the town as a point of departure, with a focus on the spatial and environmental qualities of residential areas, whereas the green metropolis concept starts from the countryside, with its focus on greenery in urban areas. In terms of management strategies such concepts require a close co-operation between institutions in the field of urban and of rural research planning and design. A management strategy that is particularly suited to facilitating such a co-operation of diverse actors is network steering. Governments have an initiating and facilitating role in this strategy; they do not dominate decision-making.

In this discourse, 'town' and 'country' are relevant in so far as places correspond with current images of urbanism or ruralism. 'Urban' and 'rural' in this case are not physical-spatial categories but rather socio-spatial constructions: representations of ideal-typical images that people see as their desired residential or recreational environment.

Town and country as real estate

The discourse of town and country as real estate sees the spatial organisation of society as coming about mainly through the market in property rights. These are traded, as a result of which buildings are constructed or torn down, buildings and spaces are put to various uses. It is recognised that this takes place within rules and constraints imposed by government bodies (Kruijt et al., 1990). However, the emphasis is on market processes, the self-organising capabilities of the market, and the possibility of the market process to maximise welfare. Moreover, too much government intervention, it is argued, can produce sub-optimal situations: government intervention should be limited to creating the conditions for, and removing the hindrance to, an optimal functioning of the market. This discourse has no place for plan concepts as such. It does, however, work with ideas of spatial organisation which the market, if it could work perfectly, would bring about. In particular, the 'landscape' of land prices should show smooth transitions from low to high prices, and plots in the same geographical situation (with respect to the location of other activities and to transport) should have the same prices. If similar plots have widely different prices, then the cheaper land is being used sub-optimally; it is not realising its 'development potential'. The management strategy propagated within this discourse is one that will allow each plot of land to be used for what people talking in this discourse call its 'highest and best use'. This consists of reticent spatial planning and facilitating the working of the market.

This discourse does not include town and country as separate entities. In fact, no specific spatial organisation of the environment is prescribed. Historically, the market has tended to produce a sharp distinction between town and countryside, because of the economies of large-scale production and the costs of crossing space. But that can change, and is changing. Any form of spatial organisation can be accepted as an outcome." (Hidding, Needham & Wisserhof, 1999).

Table 1. Selection of planconcepts in The Netherlands

Concept	**Disciplinary basis**	**Planning principle**	**Target situation**	**Implications for planning**
Compact city	spatial planning	concentration of urban functions	strong urban field	strict implementation of spatial policies
Restrictive area	spatial planning	protection of rural areas	open rural areas	strict implementation of spatial policies
Corridor	spatial economics	connection to traffic routes	space for economic activity	reticent spatial planning
Water system	hydrology	demarcation of river basins	sustainable water management	restructuring of public administration
Casco	landscape ecology	concentration of spatial dynamics	organised landscape	co-ordination of the use of space
EHS	landscape ecology	connection of nature areas	ecological network	reorientation of spatial planning
Urban landscape	landscape ecology	coupling of town and country	spatial qualities	reorientation of spatial planning
Green metropolis	landscape architecture	conditioning of urbanisation	unity of town and country	reorientation of spatial planning
Price landscape	land economics	functioning of the market	pareto-optimal land prices	reticent spatial planning

The different discourses elaborated above elucidate some interesting aspects of 'integral design' in the context of spatial planning. First, they show that within a discourse questions about the process of planning (the strategic layer within a discourse) and the content of planning (the layer of the planconcepts and their underlying analytical categories) are intertwined in a specific way. This means that there is no general answer to strategic questions; these questions should be considered within the context of a specific discourse or a combination of such discourses. Second, as the more recent discourses focus on specific aspects of town and country, 'integral design' raises questions about the relationship between the different discourses and discourse communities. Is there a willingness within the different discourse communities to communicate and to search for 'integral' solutions for spatial problems? And how could this search be organised? In relation to this latter question, some suggestions will be made in the next section.

4. In search of integral design strategies in spatial planning

As in spatial planning 'integrality' always has been highly appreciated both planning theory and planning practice might be a valuable source when searching for strategies for 'integral design'. Three such strategies are identified below.

The first strategy builds predominantly upon the rich tradition of technical disciplines in the field of spatial planning. 'Integrated design' is primarily strived for through constructing integrated planconcepts, i.e. planconcepts that bridge the distance between two or more discourses of town and country. If this is done in an intelligent and attractive way, integrated planconcepts could possibly get support from different discourse communities. In fact, this strategy primarily focuses on aspects of content and not so much on the process; it is assumed that the quality of the integrated planconcept is central in creating the necessary public support. An example of such an intelligent strategy can be found in the so-called 'strategy of the two networks' (Tjallingii, 1995). This strategy is to look for possibilities for sustainable spatial development in the spatial organisation of traffic and water streams; traffic infrastructure serves as a central point for spatial organisation of dynamic forms of land-use; functions demanding stable physical-spatial conditions are linked to the water flows. The spatial working out of this strategy varies, depending on the characteristics of the region and the interaction between the actors involved.

In the second strategy, content and process are much more intertwined. A fundamental notion underlying this strategy is that answers to spatial problems can no longer be found in undisputed 'facts'. The mere existence of different discourses of town and country illustrates this. Under these conditions planning should be used as a 'search instrument'; in relation to this Kleefmann (1984) speaks of 'reconnaissance planning'. Planning should be aimed primarily at the creation of alternative visions of the future and action strategies. These alternatives are not meant to be a finalised concept, but serve as input for a discussion on the possibility and desirability of the visions of the future as set out. In order for this discussion to be fruitful and lead to responsible decisions, insight is necessary into the social and spatial consequences of the various alternatives. The different discourses or combinations of them offer good possibilities of arriving at various alternatives; such alternatives can then be worked out in close co-operation with the discourse communities involved. The possibility of reaching an agreement between different discourse communities, be it in the shape of the achievement of a consensus or in the form of barter (i.e. win-win situations), could be explored in the discussion. The planning approach of the national 'Netherlands 2030' project (RPD, 1997) is inspired by this idea of planning.

In the third strategy the answer to the question of how to come to an integral design is sought in adapting systems of power distribution to specific spatial issues and discourses. An interesting elaboration of such an approach can be found in the WRR-rapport Ruimtelijke Ontwikkelingspolitiek (WRR-report Spatial Development Policy). In this study, the government takes on responsibility for a 'main national spatial structure', comprising the main infrastructure and the dominant landscape structure. Within the framework of this main structure, integral design can take shape at regional level. At this level, it is a question of "accommodating as well as possible the different interests, wishes and claims based on concrete development designs" (WRR, 1998, p.151). This, then, requires an interactive process between the various groups involved at regional level.

Further exploration of these strategies is worthwhile in order to find more definite answers to that fascinating question: "How to set further steps towards integral design".

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Chapter 4

Communication and nature policies: the need for an integral approach to policy design

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Abstract

This chapter analyses patterns of communication between the government, agricultural sector and nature conservationists surrounding the development and implementation of the Nature Policy Plan in the Netherlands. It shows how the original policy plan was developed with little involvement of the agricultural sector, leading to various forms of non-acceptance by farmers and a conflictive atmosphere. It continues to report on subsequent initiatives to interactively develop policies concerning nature and agriculture in De Peel region. In doing so, negotiation theory proves to be useful perspective. On the basis of the analysis it is concluded that an interactive approach to policy design alone is not sufficient. In addition to an interactive style of management, 'integral' design processes require a multi-functional mode of tackling problems, an inter-disciplinary style of inquiry, and more attention for implicit social knowledge and identity issues. In order to accommodate this, it is suggested that -within policy (negotiation) processes- more attention is needed for the facilitation of learning, joint fact finding, and the analysis of power relations. Finally, integral design requires a re-valuation of oral forms of oral communication, and a reduced focus on written policy documents.

1. Introduction

In 1990 the Dutch parliament accepted the Nature Policy Plan (NPP) (1990), designed to conserve and develop 'nature' over the next 30 years. Implementing the NPP, however, has not been easy. There have been clear indications of resistance by farmers and others. Conflicts arising from the implementation of the NPP have emerged all over the country.

In this chapter, we will analyse communication and negotiation about nature and nature related policies. On the basis of several case studies, we will demonstrate the need for an integral approach towards land-use policy design. First, we will clarify the background of two empirical studies, which form the basis of our statements on integral policy design. The main theoretical starting points will be explained. Subsequently, we will analyse communication about nature and nature policies between stakeholders (like the government, farmers and nature-conservationists) in different contexts. The first empirical study will demonstrate clearly the need for an *interactive* approach towards land-use policy design, while the second amplifies the need for a *multi-functional* (or cross-sectoral) and *interdisciplinary* approach. In relation to land-use policy design, we will present two important additional dimensions that need careful attention, i.e. *implicit and social knowledge* and *regional cultural identity*. Taking these five dimensions together we will speak of an *integral* approach towards land-use policy design, using the metaphor of a wheel with five spokes that needs to be set in motion. Before concluding the chapter, we will emphasise some concrete shifts that are needed in current design practice in order to move towards integral land-use policy design.

2. Background, perspective and methods of research

The NPP has mainly been based on reports of biologists and ecologists who worried about the declining quality and quantity of nature in the Netherlands. The central element of the NPP is the maintenance and development of a network of areas of outstanding natural values (the so-called 'ecological superstructure'). Farmers in such areas are encouraged to refrain from certain farm practices such as early mowing and intensive fertilisation, and are compensated for the loss of productivity. They may also sell land, if such land is wanted for nature conservation or nature development. All decisions are of a voluntary kind, as clearly indicated in the NPP (Wagemans & Boerma, 1998). Nobody will be forced to sell land or to sign a contract with certain restrictions.

However, as already mentioned, the implementation of the NPP has caused many problems and conflicts. Therefore a government grant was made available to study conditions conducive to (non-)acceptance of the NPP. We will refer to two studies we conducted in this field (Aarts & Van Woerkum, 1994, 1996; see also Aarts, 1998).

In our research we used an *anthropological* perspective. In short, anthropologists are interested in actors' motives for communicating and acting in a certain way. This leads to improved insight in interactions between different actors (Geertz, 1988). With regard to communication sciences, the surplus value of an anthropological perspective is the bringing in of a *cultural* perspective: people communicate and interact with each other in connection with both a certain worldview and (inter)actions that (have) take(n) place in other domains, periods and locations. Consequently, the central points of attention are the interactions themselves and the context in which they take place. The main questions, then, are: why do people say what they say and act as they act? What happens when people talk to each other? Which message is intended and why do people react as they do?

First we studied the reactions of farmers to the NPP and tried to explain why they reacted as they did (Aarts & Van Woerkum, 1994). We started with a conceptual model, which centred on several dimensions of the concept 'acceptance':

1. acceptance of the policy problem
2. acceptance of activities of the government with respect to the problem
3. acceptance of the measures to solve the problem. The question is whether these are considered as:
   a. realistic
   b. effective
   c. fair (compared to what is asked from other people)

After an initial orientation of what was going on in practice - including a two months stay on a farm - we held sixty in-depth interviews with farmers in three regions of the Netherlands. The open-ended interviews were structured by a number of conversation themes which were the result of connecting the conceptual framework to concrete activities with respect to nature and nature policy. When compared to a quantitative survey, this qualitative method allows for a more detailed probing of the motives and arguments behind particular opinions. Furthermore we attended six meetings, organised by the government to inform people in a specific region about nature policies and mostly visited by farmers. The interactions that took place at these meetings were analysed by continuously passing through the cycle of reflection - observation - analysis - reflection (Wester, 1987).

The next object of study was the communication between the government, farmers and nature-conservationists in 'De Peel', a region in the South of the Netherlands where the consequences of modern high input - high output agriculture are clearly having a negative impact on the existing nature. In De Peel young farmers had decided to talk with other stakeholders involved instead of using protest and 'wait and see' tactics (Aarts & Van Woerkum, 1996). The study started from a conceptual framework with communication and negotiation as leading concepts. Thus, several concepts from negotiation theory were used during the analysis. These included the distinction between 'distributive' and 'integrative' negotiations (see section 4) and the recognition of three preconditions for starting a fruitful negotiation process:

1. conflicting interests
2. a feeling of mutual dependency between stakeholders
3. opportunity to communicate

Again we made use of a qualitative research method, conducting in-depth interviews with different stakeholders and observing and analysing interactions between them (see section 4).

3. Nature, nature policies and the agrarian community

Looking for farmers' opinions about nature and nature-related policies we found out that farmers did not accept the NPP at all. Notwithstanding this, farmers love nature. They hold a different view on what nature constitutes than, for example, nature conservationists do. For farmers, nature is everything that grows and lives around them, and this includes the plants and animals that are the products of their own practices. For many organisations that promote nature and try to protect sites with special natural values, nature is nature as far as it resembles 'original nature', growing and flourishing without the help of mankind. Above all, the quality of nature is connected to the rate of biodiversity. From the farmers' point of view, nature is doing rather well. Hence, the problem that lies at the root of the NPP was neither recognised nor accepted by the majority of farmers. Moreover, they did not see interventions with respect to nature as isolated from, or in any way different from, the many other government interventions in the area of nature and environment. Farmers expressed, in general, being 'fed up' with regulations. The NPP is seen as a part of a seemingly never-ending chain of restrictions and regulations. Consequently, farmers tend to perceive the government as an enemy.

Most farmers did not consider the specific measures included in NPP to be realistic. Farmers who run modern agricultural enterprises prefer lower ground water levels and other regimes for mowing than those recommended within the NPP, and are only willing to sign a contract to participate in the Plan if their land is unsuited to modern farming.

Finally, farmers did not consider it reasonable that they alone should bear the burden of creating a better natural environment. Other citizens, they believed, are not asked anything in comparison. In their view, they are the ones who for generations have been responsible for the beauty of the landscape and nature around them. Now they are made the victims of what they themselves created.

Perceptions, experiences, interests, cultures

Different perceptions of nature, we found out, are linked to different experiences, norms, practices, goals and interests, in other words: to different cultures. As one farmer clearly stated: "I love to see an old, lonely tree on my land, but if it turns out to be an obstacle, I suddenly do not like it anymore and I will cut it down". This statement shows how the perception and judgement of what is beautiful and what is not, is related to interests. Thus, the core problem is not the clash between different perceptions of nature, as often is claimed, but, more broadly, a clash between different cultures touching each other's borders and therefore experiencing each other as threatening. The fact that farmers (might) have deviant perceptions of nature is no problem, until they are asked to change their behaviour with respect to nature in a way that interferes with their interests.

Underlying the arguments that farmers put forward to defend their perception of nature and to denounce the governments' nature policy are a few more fundamental contradictions. The central concern for farmers is the survival of their farms under reasonable conditions. However, they increasingly feel confronted with developments that form a threat to their right to exist. As a result, they tend to withdraw under the motto: 'as long as we can avoid it, we will not do anything'. As part of the defence, farmers' attitude towards the government is characterised by negative stigmatisation (Elias, 1965): the worst examples and experiences are repeated over and over again in order to support the argument that nothing good can be expected from the government.

Looking at government communication activities after the NPP's assessment and ratification, the general impression is that of a chain of misunderstandings. At public meetings, farmers were expected to listen to the information about the NPP being provided by the government, but instead they had a strong urge to speak about their own problems. From both sides communication was one way, pushing forward conflicting concepts of nature, resulting in ever more frustration rather than understanding. It is totally unrealistic for the government to gain support with the help of these meetings. In all, the communication between farmers and the government about nature policies takes place in the context of a heavily troubled relationship. A crucial point is that farmers have not been involved in the development of the NPP. Their perceptions, experiences, fears and interests have not been taken into account. The NPP is about animals, plants and ecosystems. Nothing is said about the behaviour of farmers while this is the main topic during the implementation of the plan. Thus, the implementation of the NPP, which is explicitly based on voluntary co-operation from farmers, has been seriously hampered.

4. Nature policies as the result of an interactive negotiation process

Studying farmers' acceptance of the NPP led to a rethinking of the role of communication in (nature-related) policy processes in the Netherlands. Instead of using communication for the diffusion and promotion of a plan that had already been designed in detail (resulting in non-acceptance by main stakeholder groups), communication should play a central role in developing an acceptable plan. Hence, nature policy should be considered as the result of an ongoing negotiation-process between different stakeholders. We call this interactive policy design. In general, the attention paid to more interactive forms of governmental steering, especially in environmental policies, is growing (see, amongst others, Glasbergen, 1995; Engel, 1995; Röling & Wagemakers, 1998, Giddens, 1998).

During the research period, the feelings of mutual dependency tended to increase on the side of both farmers and the government. For the government, this feeling was induced by the lack of acceptance of nature policy. Farmers, in turn, increasingly realised that nature policies are inevitable, and felt a need to alleviate the adverse conditions that confront agriculture in general. As a result, both parties made attempts to (re)engage in communication about nature policy. Within a relatively short period a number of so-called *environmental co-operatives* were established in the agricultural community, aimed at organising initiatives in conjunction with other actors to deal with the problems and issues involved in the conservation of 'nature' at local or regional level. The activities of such co-operatives have been accepted as experiments, and some of them are even subsidised by the government.

One of these environmental co-operative organisations was formed in 1993 in De Peel, a region in the south of the Netherlands of outstanding natural beauty, threatened by the consequences of intensive farming, particularly pig farming. Studying the activities of this so-called De Peel Environmental Co-operative (PEC), our starting point was to see whether interactive policy design could contribute to a more acceptable plan for preserving nature, and to examine which factors furthered or hindered this process.

In the PEC, a selected group of farmers and horticulturists co-operates with a view to maintaining an economically viable agricultural sector in De Peel, recognising that this will only be possible if continuous attention is given to the preservation of nature and the environment. Right from the start, the PEC has involved itself in a network of relationships with other actors with whom it negotiates in order to further its goals. Subject of our study were its relations with:

- the government
- the regional organisation of nature conservationists: Working Group Save the Peel (WGSP)
- the agrarian community

The starting point for the process of negotiation in De Peel was a strong feeling of mutual interdependence between the PEC, the WGSP and the government: "we all had a problem that would never be solved unless we communicated with 'the others'". Discussion is the basic mechanism for learning and negotiations to start moving (Putnam & Roloff, 1992). People learn to recognise each other's problems and interests and they understand better their interdependencies. These are important preconditions for creating concrete plans, in which different interests are integrated. However, in practice it is not so easy. Our study of the PEC activities showed that their efforts to organise a network of all the actors involved and to keep this network alive put the farmers of the PEC in the complex role of 'network managers' - managing relationships and trying to keep all parties in tune.

In discussions with the government the PEC was confronted with bureaucracy and slow decision making. The change of the government from overall director to facilitator of negotiation processes is, even if necessary, not always visible. Traces of its old face as central regulator are still there, and nobody can predict what will be the outcome of frictions within the government bureaucracy over the preferred policy style. As a result of this, criteria for judging the approach or effectiveness of the PEC are unclear, and it is uncertain whether the experiment will be supported in the long run.

The contacts with the regional nature organisation, WGSP, relieved a lot of tension. After several meetings, the discussions between PEC and WGSP became more and more constructive and both parties were searching for a common goal to work on. This process of interaction indeed resulted in a common plan, supported by all actors involved, including the government. The plan, called *'Peelland, space for agriculture and nature'* (1995), aims to realise a nature-friendly and at the same time economically sustainable way of farming in the Peel. On the one hand, the plan consists of a number of experiments with respect to nature and environment, to be carried out on farms. On the other hand, the plan includes a number of concrete trade-offs. For example, farms that had been located in the heart of a vulnerable natural area were relocated outside the region. In return the WGSP was willing to accept some farming at the border of the nature areas.

However, the relationship between the PEC and the WGSP is fragile. The Peel experience taught us that old attitudes, old stereotypes ('nature conservationists prefer plants and animals to people' or 'farmers are only out for economic gain') are strongly embedded in social relations and interactions. Moreover, the perceptions of the farmers of the PEC evolve faster than those of their constituency. Since different parties (government, nature conservationists, local farmers) tend to confront the PEC with pressures and demands which are difficult to agree upon without seriously jeopardising the opportunity to reach compromise with the others, the PEC often ends up in a 'boundary role conflict' (Turner, 1992). This makes it unable to always act and react consistently. Here, the PEC has to balance its role as negotiator in a situation of conflict with its role as mediator. In other words, it can act to promote particular interests or it can act as a change agent, internally for 'their' farmers, but also externally for the other parties. In the first role there is a strong tendency to minimise contacts with the constituency during the negotiation process, until concrete results can be presented. Most labour union negotiators, for instance, act in this way. In the second role of mediator, a lot of contacts with both the constituency and the other parties are pursued in order to guarantee everyone stays involved in the learning and collaboration process.

Different types of negotiation

Behind these two role types lies a different conception of the negotiation process. We distinguish two types:

1. distributive negotiations, on the basis of one cake that has to be divided, and
2. integrative negotiations, on the basis of the baking process, in which the cake's consumers are directly involved in producing the cake they want (Pruitt & Carnevale, 1993).

Distributive negotiations start from fixed positions, which are held onto as firmly as possible. Often the case is overstated, too much is asked, knowing that something will have to be given up, but as little as possible. Integrative negotiations start from an interest in or an idea about the desired future. People do not overstate in such cases. In distributive negotiations the negotiators keep underlying motives and their background to themselves. They keep quiet about personal feelings. In integrative negotiations participants are open, trying to share their feelings, motives, beliefs and interests. In distributive negotiations threats are common. The constituency is kept alert, with an energetic spread of images of 'the enemy', to guarantee, if necessary, an activist response. In integrative negotiations such threats are minimised. Functional relationships are kept as amicable as possible. Joint fact-finding, which refers to the creation of a common knowledge base that offers facts that are accepted by all parties, is a common phenomenon, whereas such activities are often unthinkable in distributive negotiations. On the contrary, in the latter knowledge is translated into arguments that are used as 'weapons' in the struggle to get the maximum result. In integrative negotiations there is a concern for the consequences of possible solutions for the other, and, most importantly, parties are learning to see themselves from the perspective of others. They learn to be socially reflective. Such learning processes are absent in distributive negotiations (Van Woerkum & Aarts, 1998).

In some situations, distributive negotiation is sufficient to arrive at a solution. This is especially the case when interdependencies can be broken off, which is, for example, the case with market relationships. However, in situations of ongoing interdependencies, as is the case in De Peel, integrative negotiation seems the only way to find sustainable solutions that are satisfactory for all parties involved.

The PEC has made great efforts to establish an integrative negotiation position. However, the move towards this position is not yet complete. As indicated before, the inclination among stakeholders to stick to their positions, and fight only for their own interests, is strong. Moreover, the farmers of the PEC tend to behave differently in different situations. Sometimes they 'promoted' their beliefs instead of stimulating debate about them. Moreover, at times they engaged in 'scape-goating'. It is no longer the WGSP that is the enemy, but the government. In picturing the government as unwilling and non-co-operative they create new distances, now between regional and national levels of government. The main conclusion is that the outcome of the negotiations in De Peel is promising - at least the long-lasting impasse has been broken and it is a fact that (groups of) farmers and nature conservationists have grown towards each other -, but still fragile.

5. An integral approach towards land-use policy design

An important insight we gained from our studies in the field of communication and nature policy is that the development and implementation of nature policy can no longer be considered as the concern merely of biologists, ecologists and nature conservationists (see also Milton, 1996). Too many stakeholders with all kinds of interests, who all have possibilities to influence the process, are involved. Therefore it seems much more fruitful to integrate nature policy in the broader perspective of land-use policy. Seemingly separate problems need to be linked: agricultural problems, nature problems, environmental problems and water-management problems need to be dealt with and studied in a coherent manner. This implies that we need to move beyond just an *interactive* approach to policy design. In this section, we will sketch the contours of an *integral* approach to policy design. This concept includes a number of interrelated ideas and principles, which can be considered as the five spokes of a wheel; a firm framework is needed to consolidate the wheel and to get it moving. We suggest the following five principles for shaping an integral design trajectory:

1. a multi-functional tackling of regional problems
2. an interactive style of management
3. inter-disciplinary exchange and inquiry
4. use of implicit and social knowledge
5. reinforcement of the regional cultural identity

1. a multi-functional tackling of regional problems

From an integral design perspective, creating a land-use policy can be pictured as an effort to consider the countryside as a unit that needs multi-functional (or cross-sectoral) attention. Until now, this is -at least in the Netherlands- still not the case. Isolated policy-plans are made for different sectors like agriculture, nature, water-management, recreation and so on. Each policy-plan reflects its own starting points, with little attention for other domains. Of course there is always a need for co-ordination. This happens, however, at 'the edge of the file', where agricultural development clashes with nature, or nature with recreation. Then solutions are sought in order to restrict as much as possible the negative consequences of a development for other domains or sectors. These kinds of solutions often lead to half-hearted compromises, not satisfying any of the stakeholders. Besides, such compromises - resulting from distributive negotiations - are inherently unstable: nature conservation organisations realise 100 of the 150 hectares of nature, but continue dreaming and thinking of the lost 50. Every party involved perceives such a plan as a necessary intermediate station towards a better result. With every new problem, new negotiations are necessary, and the chances that existing agreements will be disputed again, are relatively high.

Instead of separate plans addressing nature conservation, agriculture, recreation, preservation of cultural-historical values, etc., one overall plan that connects the different sectors in one specific region need to be created. The consequences for the process leading to such a plan are, of course, enormous. Therefore we will take a closer look at the other spokes of the wheel.

2. an interactive management style

In order to realise one plan for a certain region, an interactive style of policy-making is needed. Interactive policy-making is directly related to decentralisation because it refers to the need to incorporate the perspectives and interests of local actors in the government's view, as well as to the need to bring local actors in line with each other. With interactive policy-making, responsibilities for the development and implementation of policies will partly shift from the government to the people who are directly involved in the policy problem and its solution. The idea is that better plans will be realised, in the sense of a plan that fits into the situation of the actors involved. In addition, these people will develop 'ownership' and, via participation, come to engagement. Support will arise instead of being 'created'.

Here we call to mind the Nature Policy Plan (NPP). Governmental communication about the NPP was about the solutions for the nature problem, and the matching arguments. These arguments are the product of a lot of thinking and talking within a small circle of policy experts, politicians and specific societal groups. However, these arguments mean very little to citizens who are outside of this small circle, and who have not gone through the learning process from which they resulted. In general, arguments are worthwhile within a certain perspective, reflecting certain experiences, fears, interests, goals etc. From other perspectives they are meaningless. This explains the problems of acceptance of the NPP within the agricultural sector. In addition, we saw problems arising at the relational level. In any situation where the government - because of the pressure of specific societal interest groups - develops a plan, which is subsequently applied to groups of citizens who were not involved beforehand, one can expect that the relationship between the government and the latter will be seriously disturbed.

Interactive policy design does not mean that stakeholders in discussions should forget about their own interests and should only think of the common interest. On the contrary, stakeholders should make their interests explicit. Therefore we do not refer to 'a good conversation' but to negotiations (see section 4).

3. inter-disciplinary exchange and inquiry

Dealing with different functions and sectoral interests at the same time reinforces the need for cross-disciplinary exchange and Cupertino in science. New questions will emerge, for example regarding the interrelations between different functions and possible trade-offs between interests. Thus, scientists of different disciplines, working on problems of land-use planning, should find new ways to communicate. Although it is clear that inter-disciplinarity should be a cornerstone of an integral policy-design approach, it does not easily materialise. Scientists are not used to working in inter-disciplinary teams and are often not eager to. Disciplines have their own theoretical scope of reference, research methods, institutional traditions, technical language, sources of funding, etc. As Elias (1972) pointed out, these serve not only to foster communication possibilities for the development of new scientific insights within a specific discipline, but also to reproduce distinctions between disciplines, and the building and maintenance of corporate identity.

As with other actors, scientists should take a critical look at their own concepts and starting points. They often start from relatively poorly reflected assumptions about what is important to focus on and what is not. Besides, many concepts (i.e. biodiversity, sustainability, nature) are multi-interpretable. Here we have an important reason why research on the same topic can lead to opposite results. This is, for instance, the case with evaluations of the effects of agrarian nature management, leading to conflicting policy recommendations (see De Volkskrant, 27-3-1999 and 31-3-1999 for a public discussion in this respect). Not only starting points, but also the scope of research differ, as well as the definitions of a 'positive' result. From a strictly biological or ecological point of view a positive effect of agrarian nature management refers to the number of plant species. From a broader perspective, farmers' concern with nature on their farm can be seen as a positive development in a step-by-step process, leading to more and better nature.

Of course, disciplinary research is always needed, not only to further develop the discipline, but also because disciplinary data and conclusions are needed to identify and to solve societal problems. However, in order to translate disciplinary conclusions effectively into policy recommendations that do not exclude each other, and/or to formulate relevant research questions for a coherent research program with respect to a certain problem field, inter-disciplinary communication and negotiation is needed.

4. use of implicit and social knowledge

In an instrumental mode of policy design, technological knowledge is the most important source of information. From an integral design perspective, serious attention must be paid to social knowledge. On the one hand, social knowledge refers to motives and backgrounds of different actors involved, on the other hand it refers to knowledge of the social process: what does it mean for an actor to go from a to b, which obstacles have to be overcome, or which perspectives need to arise?

Another kind of knowledge which should be taken into account is what we call 'implicit knowledge' which refers to knowledge based on 'lifeworld' experiences, as well as to knowledge embedded in assumptions, starting points and 'taken for granted' notions and perspectives. A study of implicit knowledge will help to explain why certain explicit arguments are not accepted (for instance a different perception of nature). It will also support the search for new ideas for policy development and policy implementation. Since interactive design is driven by the idea that rationalities of the actors involved should be taken into account seriously, the recognition of the legitimacy of implicit knowledge is of great importance. Only by making implicit assumptions and ideas explicit will space for creative integrative solutions arise.

5. reinforcement of the regional cultural identity

The fifth spoke, finally, refers to structural attention to cultural identities. We can assume that the need for identity is an important explanation for many phenomena in our present-day society. Examples of such phenomena are hallmark clothes, wanted by young people, and the choice for a certain style of music as a label for social recognition. In our culture, there is a growing inclination towards distinction and authenticity in response to developments such as globalisation. This tendency also affects land-use and land-use policy design (Van der Ploeg, 1997). Local people appropriate their own region, while immigrants choose very consciously for the character of a certain region. The number of publications about the history of a region, photo books and even videotapes is increasing.

Land-use policy design can also be pictured as an effort to define and reinforce the cultural identity of a region. This can lead to several activities, in the realm of housing, recreation or even regional economy. The enthusiasm for producing and promoting regional products is increasing (Van Broekhuizen et al., 1997).

Recognising the importance of cultural identity puts forward an interesting dilemma:

how can the cultural characteristics of a region been preserved in a situation that requires urgent change? This problem was met in several regions in the Netherlands, e.g. where forestry was planned in a historically open landscape. Local people resisted for this very reason (Van der Velde et al., 1998). A precarious balancing is needed here, which may be better achieved through an integral design approach.

Of course cultural identity is not shaped only via the landscape and other 'external' phenomena. The characteristics of a culture are also expressed in practices, language and in common values and norms. These could be a source of ideas for specific projects with respect to land-use policy as well.

6. Initial implications of integral policy design

On the basis of the five dimensions described in the above section, projects and programs aiming at the design of comprehensive land-use policies can be shaped, evaluated and stimulated. However, this implies a structural change of many 'old habits'. We will mention a few which in our view need priority attention.

In the first place, frequent meetings between different stakeholders at different moments of the policy process should be organised, instead of occasional hearings. Social learning, 'reframing' of opinions that are based on (formerly implicit) assumptions requires a continuous learning process (Daniels & Walker, 1996). Such a learning process implies frequent contact between the government and actors involved, as well as between the local actors themselves. Integrative negotiations require face-to-face contacts, whereby confidence is built up step-by-step (Lewicky, 1998).

Secondly, we have the problem of differences between actors, not only differences in the way they define their interests or perceive a problem, but also differences in power. Since a precondition for integrative negotiations is perceived interdependency between parties, a much more serious analysis of power sources is needed than is current in practice. Unequal power relationships have great influence on the readiness to participate in the negotiation process. Important stakeholders will retire from the negotiation table if they have the feeling that they have 'nothing to win'. On the other hand, if important stakeholders are not involved in the process of policy development, it can happen that they use their (sometimes unexpected) power to hinder the implementation of the policy, as farmers did with the nature policies.

Thirdly, informal oral presentations should be re-valued. Policymaking has more and more become dependent of written policy documents. These documents, however, are mostly the result of all kinds of implicit compromises between actors at various policy levels, and are therefore difficult to tune into the 'everyday' society where orality is of decisive importance. In informal talks, people frame a certain theme; they develop a shared perspective. By everyday conversations they also label information in a positive or negative way: is the information originating from the 'out group' or the 'in group'? In order to overcome such problems, 'joint fact-finding' is an important activity within integrative negotiations, as it enlarges the basis of commonly accepted knowledge. Joint fact-finding too requires frequent and intensive face-to-face interactions between stakeholders.

7. Conclusion

In this chapter we analysed farmers' resistance to the NPP from a communication-scientific point of view. One of the main conclusions is that in the NPP, the problem of nature has been pictured as a disciplinary, biological problem, leading to specific solutions. However, the implementation of the NPP appeared to depend on the behaviour of different groups of people in the society, especially farmers, who were not involved in the process of policy development, with serious problems of acceptance as a result. Therefore, we have suggested an interactive way of policy design, which means that important stakeholders are involved in an ongoing negotiation process, leading to qualitatively better and more acceptable policies. This requires at the same time a multi-functional approach towards land-use policy design: stakeholders try to formulate a common problem that includes all the separate problems with respect to land-use in their region. Thus, neither the nature problem, the water-management problem nor the agricultural problem is focused on in isolation. Together with this, the role of the government has to change from all-round regulator towards facilitator of local and regional initiatives. Citizens need to take on board these initiatives and feel responsible for them (Giddens, 1998). Finally, scientists studying technical and social problems in society, will have to co-operate in a way they are not used to. In order to prevent results of disciplinary studies in a common field from being translated into recommendations that exclude each other, they should intensively communicate their assumptions as well as their results.

If all actors involved recognise their interdependence in finding effective solutions for land-use problems, the acceptance of a common problem is the only fruitful starting point for a co-operation that will gradually take shape.

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Chapter 5

Designing land use options and policies. Fostering co-operation between Kasparov and Deep Blue?

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Abstract

To support processes aimed at changing land use at macro and micro levels, distinct types of land use studies are available. This paper focuses on exploratory land use studies and their role in multi-disciplinary, multifunctional and interactive design processes at different hierarchical levels. Special attention will be given to the strengths and weaknesses of using computer modelling in such learning and negotiation trajectories, which involve stakeholders, i.e. policy makers, environmentalists, consumers, farmers, and scientists. A methodology is presented in which science-driven technical information is confronted with value-driven objectives under given values of exogenous variables (e.g., regarding population growth and requirements for agricultural produce). Land use scenarios are generated showing consequences of different priorities for objectives by using natural resources and technical possibilities in different ways. Applications of such an approach are given for the regional, farm and field level, each addressing specific questions, and target groups. The paper focuses on the type of results these studies produce and their potential role in integral design processes. It is concluded that computer-based exploratory studies can play a significant role in integral land use design processes, provided that deliberate attention is paid to minimising certain inherent risks. Such risks might be controlled better in deliberately organised design trajectories. In the absence of deliberate design processes, the results of exploratory land-use studies can contribute to the emergence of such processes by influencing individual reflection, societal debate and design priorities.

1. Integral design, future studies and modelling

Problems with food security, the maintenance of a social infrastructure, unequal distribution of regional income and the depletion of natural resources are some of the reasons for (inter)national, regional and/or local administrations to initiate active land use policies. Similarly, at the farm level , farmers are active in developing strategies or 'micro-policies' in order to adapt their farming systems to an ever-changing environment. Within such design processes at different hierarchical levels, multi-disciplinary knowledge and information is required for the generation of problem definitions, the identification of design objectives and the means to realise design objectives. Different types of land use studies can be used to help explore possible future developments in connection with societal and/or farmer goals. Many of these make intensive use of computer modelling techniques. Since land use studies of this type are future studies, we can use classifications used in future studies to come to grips with their differences in design and output. One classification divides future studies into four categories, based on two criteria:

- the 'level of uncertainty' in assessing future values of system parameters, and exogenous factors (e.g. related to land use: population growth, trade and market developments) greatly affecting the system's options and limitations. Usually the longer the time horizon of a study, the greater the level of uncertainty.
- the 'level of causality' in the model of the system, used to characterise possible future system states. Models can have an empirical statistical basis enabling description, rather than explanation, of the system or models may have a more mechanistic basis with information on causal relationships within the system. The four categories of future research are presented in Table 1.

Table 1. Typology of future research. If uncertainty in the system is apparent, 'what-if' questions can be addressed. If uncertainties are small the probability of future events can be assessed. If causality of the model is prominent, more systematic future research is possible. If causality is lacking, only regressive or deductive methods are available leading to projections or speculations of future events (after Van Ittersum et al., 1998).

	Low Uncertainty	High Uncertainty	
Low Causality	**Projections**	**Speculations**	*'deductive research'*
High Causality	**Predictions**	**Explorations**	*'systematic research'*
	'A chance that'	*'What-if?'*	

Projections are based on a low level of causality. If more information on causality and relations underlying a projection is available it may evolve into a prediction. If the level of uncertainty increases, usually associated with the time horizon considered, a projection might evolve into a speculation and if more information is available about how different processes and developments are related, a speculation changes into an exploration of the future. Explorations show options for future developments given assumptions about uncertain developments. Projective and predictive land use studies are especially suited for purposes of identifying problems. These studies are based on extrapolated trends and facts from past and present and may shed light on plausible developments (e.g.. Brown and Kane, 1994; Alexandratos, 1995). Exploratory land use studies are particularly useful for gaining insight in future options, and thus for the formulation of design objectives. For a proper identification of design measures, predictive tools, capable of predicting effectiveness and responses to (micro-)policy instruments, are required.

This chapter focuses on exploratory land use studies and their role in multi-functional, multi-disciplinary and interactive (i.e. integral) (micro-)policy design processes (see Leeuwis, chapter 1) at various hierarchical levels, ranging from the supra-regional to the field level. We draw on a paper by Van Ittersum et al. (1998), and try to expand their analysis to include a critical assessment of opportunities and threats for model-based exploratory studies. In most land use policies the ultimate aim is the development of 'sustainable' land use systems that guarantee production, food supply and other aims. However, the notion of sustainable development is usually not discriminative. To overcome this problem we first present a means of operationalisation, as part of a methodology to explore future land use options. The methodology is illustrated in three examples for different hierarchical levels; focus is on the type of results generated rather than on discussion of the actual results. On the basis of these examples we will reflect on the potential of exploratory land use studies for integral design processes, and especially on ways in which they can be used in an interactive process. In doing so, we will pay specific attention to the question of how the results of computer modelling can be connected with human design processes. The debate on the usefulness of computer techniques in areas where the experienced human mind serves perfectly well, aided by keen observation, is not exclusive to the issue of land use design. Numerous parallels can be named to join the playful duel paraphrased in our title, ranging from medicine to architecture, from optics to flight control, and many more. Skilled master mind or dumb repetitive power? We feel the need to move beyond the 'mind or machine' contrast, and focus on how human design capacities can be integrated productively with computer capacities. After all, even top chess players have come to use computers as analytical aids and sparring partners.

2. Operationalising the inherent subjectivity of 'sustainability' in land use studies

Different stakeholders, be they policy makers with different political background, farmers, environmentalists or consumers, reveal different perceptions of 'sustainable land use'. These perceptions comprise ecological, agro-technical and socio-economic dimensions, which can be regarded as objectives and constraints that are given different priority by the various stakeholders. Thus, operationalising sustainable development is equivalent to finding compromises that are acceptable for the stakeholders involved. Design of sustainable agricultural production systems should consider value-driven (what is considered 'good' or 'desirable') and technical (what is 'feasible' or 'attainable') aspects and includes the weighing of ecological, agricultural and socio-economic objectives.

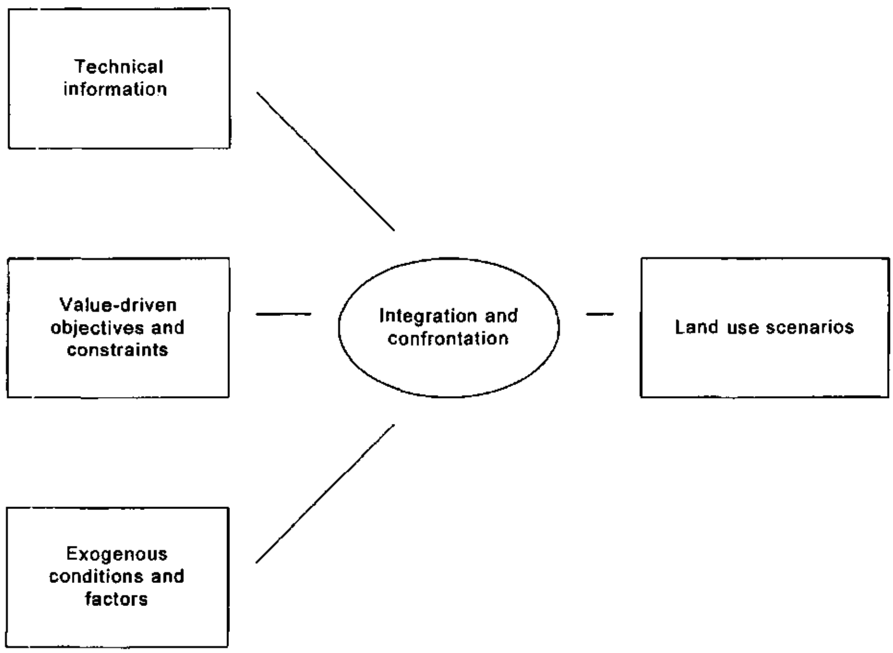
Priorities for various objectives are driven by perceived needs of and risks for the farm or (supra-) regional households. These perceived needs and risks have their roots in the set of preferences and aims of the stakeholder. As a consequence of the differences in preferences and aims, land use options that satisfy all stakeholders are illusory and developing sustainable land use can be seen as a negotiation process. Classifications have been proposed to structure thinking about preferences and aims of stakeholders at different hierarchical levels. At the field level, focus has been on the attitude towards perceived risk, particularly related to financial issues (Tait, 1985) but also related to health (Rola & Pingali, 1993). At the farm level, the notion of farming styles (Van der Ploeg, 1994) provides a useful concept for thinking about individual farmer's preferences and aims. At the regional level, a classification has been proposed based on uncertainty about (1) fragility or robustness of nature and (2) fragility or robustness of the socio-economic framework of society (WRR, 1995). At each level, differences in perceptions, resulting in different priorities given to objectives, are an important reason for disagreement on land use (micro-) policies among stakeholders. A consensus-oriented policy making process is possible only if different objectives are made explicit and the trade-offs between these objectives are clear for all parties. It is here that science may contribute by demonstrating the technical opportunities of meeting different sets of objectives and revealing trade-offs among objectives. Thus, science shows the consequences of different appraisal of needs and risks for individuals, society and environment, which can be input for discussion among stakeholders. This requires a method of analysis that discriminates between information on i) value-driven preferences and ii) science-driven information. Exploratory land use studies operationalise such a method.

3. Exploratory land use studies at field, farm and supra-regional levels

Methodology

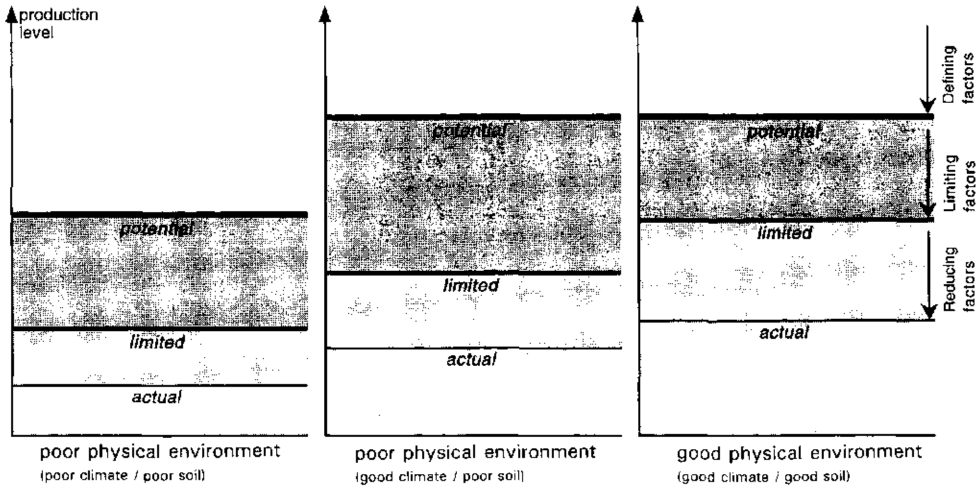
In exploratory land use studies, options for future land use are assessed using information on i) knowledge of biophysical processes underlying agricultural production possibilities, ii) objectives as driven by perceived needs and risks, and iii) values of exogenous variables that might greatly affect the system under study (Figure 1). Simulation models or, at the higher hierarchical levels, Multiple Goal Linear Programming (MGLP) models are often used as a tool to integrate these different types of information, and to generate land use scenarios (De Wit et al., 1988; Van Keulen, 1990; Rabbinge, 1993). A scenario approach is used to investigate combinations of exogenous conditions, preferences for objectives and technical possibilities.

Figure 1. Methodology for exploratory land use studies at different hierarchical levels.



Studies of agricultural land use capitalise on the unique quality of *agricultural* production being ultimately defined and limited by climate, soil properties and crop and animal characteristics. In contrast to studies using trend extrapolations where system performance is used as input, exploratory studies use system properties as input. Basic knowledge on soils, climate, crops and animals and their interactions is used for the identification of alternative land use options. Basically, crop and animal performance is determined by growth-defining, growth-limiting and growth-reducing factors. Associated yield and input levels are strongly affected by the physical environment in which production takes place (Figure 2) (Rabbinge, 1993; Van Ittersum & Rabbinge, 1997). Current technical and socio-economic constraints, for example related to infrastructure, farm structure or imperfect knowledge are purposefully ignored in the models. Instead, the concept 'best technical means' is adopted, which implies that the most efficient techniques available, according to current knowledge, are applied. If included, socio-economic constraints are evaluated in a scenario approach. The purpose of such abstraction from current socio-economic constraints is not driven by technocratic ideals. Rather, the approach enables thinking about future options without being limited by currently prevailing socio-economic constructs. The alternative, to consider the future a trend-extrapolation of today, is not only depressing but also incorrect as many unexpected events during the last decades have shown.

Figure 2. Production levels and associated growth factors in various physical environments. Source: Van Ittersum & Rabbinge, 1997.



Driving variables in exploratory land use studies vary with the hierarchical level. At the (supra-) regional level, demand for food drives agricultural production. Ultimate food requirements are rather conservative. In terms of caloric value the share of cereals, root crops and tubers in the human diet falls, while the share of vegetables, sugar, fruits and, definitely, animal products rises as a consequence of higher incomes, but elasticity of food consumption is ultimately rather low. In exploratory land use studies at (supra-) regional levels, requirements for agricultural production, both in volume and in composition, are deduced from food requirements, and are treated as an exogenous variable in the model. Demand for industrial products derived from agricultural products that add greatly to the total demand for agricultural produce, may be analysed with a scenario approach. At the farm level, agricultural production is driven by some measure of (variability in) financial return, in combination with the requirement to utilise an area of land. In principle, production of goods and services that are not primarily agricultural, such as nature conservation, game hunting or on-farm recreation could be introduced into the exploration as part of scenarios. At the field level, driving force in the models is growth and development of a crop or an animal, once sown or born. Again, alternatives may be evaluated in scenarios with different timing of start of growth and development and different rates, reflecting differences in e.g. crop sowing dates or cultivar characteristics.

A number of exploratory land use studies using the presented methodology has been carried out. At the global level a simulation study was conducted to investigate possibilities for world food production and food security (Penning de Vries et al., 1995), at regional level studies have been carried out for the European Union (WRR, 1992; Rabbinge et al., 1994), the Fifth Region of Mali (Veeneklaas et al., 1991), the Mariut Region in Egypt (Ayyad and Van Keulen, 1987) and the Atlantic Zone of Costa Rica (cf. Bessembinder, 1997; Bouman et al., 1998). At farm level exploratory studies have been conducted for various agricultural sectors in the Netherlands (Van de Ven, 1994, 1996; Rossing et al., 1997) and for smallholder farms in East Java (Van Rheenen, 1995). Various studies have been carried out at the field level. Overviews of contributions from the school of Production Ecology are given by Rabbinge (1993), Rossing & Heong (1997) & Goudriaan & Zadoks, (1995). In the following sections examples are given of studies carried out at field, farm and supra-regional levels with focus on the type of questions they address and the type of answers they present.

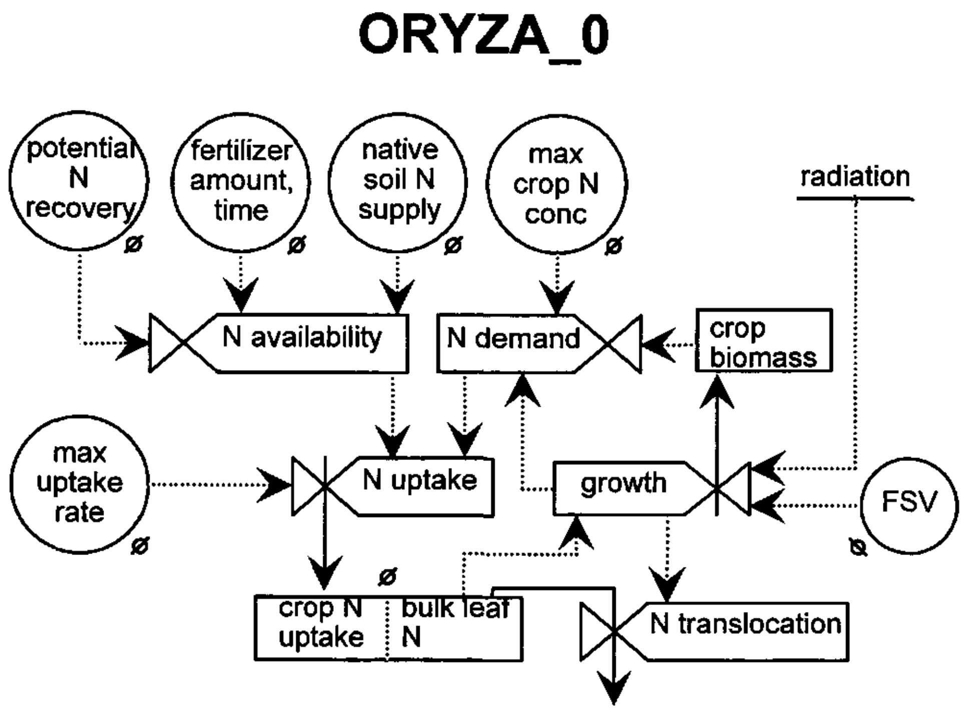
An exploratory land use study on nitrogen fertiliser application regimes in rice crops (Ten Berge & Riethoven, 1997)

To meet the demand resulting from population increase, global production of rice needs to be increased 70% by the year 2025 compared to the level of 1993. Although in principle, there is enough land area to meet such increase, the competition among agriculture and other land uses is increasingly a source of concern. It is highly likely that a major part of the increase in rice production will have to be brought about by an increase in the production per hectare: a formidable task for farmers, policy makers and scientists.

In the mid 80s, a project was established to train researchers in a number of research centres in South and South East Asia in the use of systems analysis tools for rice production research (Penning de Vries et al., 1988). Models were used as vehicles to synthesise information and represent the quantifiable state of the art in rice production ecological research. One of the themes addressed in the project concerned rice-nitrogen interactions. Aim of the theme was to increase efficiency of nitrogen use in irrigated rice systems. Irrigated rice was chosen because it supplies 75% of the annual global production. Target groups for output from the research were extensionists and research and extension managers.

The system considered comprised a field with a particular soil on which a known cultivar of rice is grown under irrigated conditions, i.e. water is not a limiting factor, and the crop is as much as possible free of pests, diseases and weeds. Time scale was one growing season, spatial scale usually less than 10 hectares. Labour and technology were assumed not to be limiting, economies of scale were ignored.

Figure 3. Relational diagram of the ORYZA-0 model. Valves represent rates, blocks represent state variables, and circles represent soil, crop and management characteristics. Solid arrows indicate material flows, dotted lines information flows. Source: Ten Berge & Riethoven, 1997.



Starting with a rather complex model in which major processes governing rice production under nitrogen limitation were combined, the researchers were able to simplify their model of the system considerably as a result of focused experimentation at several locations that were part of the research network in Asia. The resulting model, ORYZA-0, is a dynamic rice growth model that describes key processes related to the uptake and utilisation of N (Figure 3). Key processes are N-release from the soil itself, recovery of added fertiliser-N and its dependence on crop stage, allocation of N in the plant, and the role of total leaf-N in biomass production under given levels of solar radiation. All local minor stresses are accounted for by a single integrated correction factor. The model requires daily global radiation as input, and a number of parameters specifying soil and crop characteristics for a particular site. The model was tested extensively and found to reproduce crop behaviour in experiments satisfactorily (Ten Berge et al., 1997a,b).

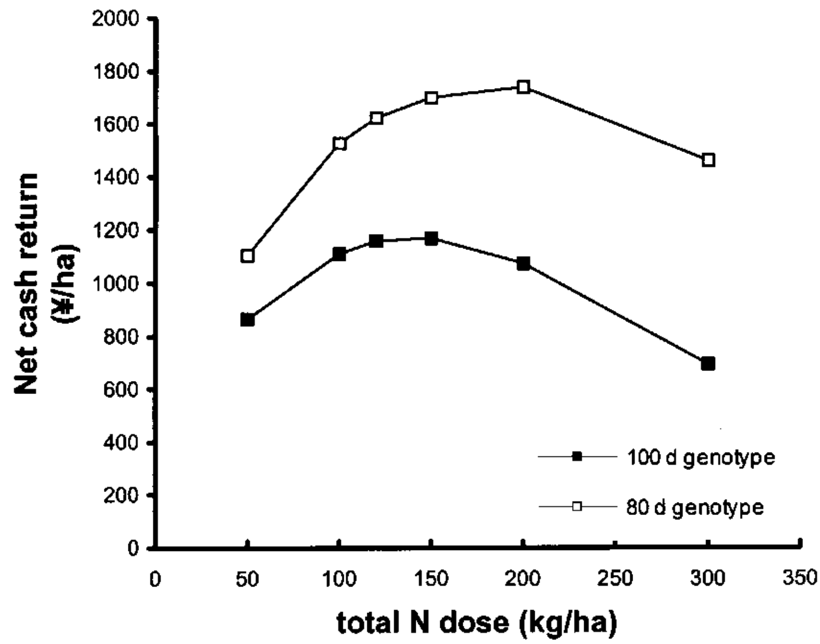
An optimisation approach was used to integrate agronomic information represented in the crop model and value-driven objectives. Two objectives were identified, both to be maximised: i) agronomic efficiency, calculated as kg rice per kg nitrogen applied, and ii) net cash return from fertiliser N input, defined as the yield increase (kg ha^{-1}) resulting from fertiliser application, multiplied by the local farm gate price of rice, minus the cost of fertiliser. Optimisation was based on a random search algorithm (Ten Berge et al., 1997b), rather than on linear programming. The algorithm generated a large number of time curves, each representing a possible continuous time path of application of an *a priori* fixed amount of nitrogen fertiliser. Grain yield or net cash return associated with each time curve was evaluated with the ORYZA-0 crop model, given the set of crop characteristics and environmental conditions.

Model-based explorations focusing on agronomic efficiency were conducted for locations in Bangladesh, India and China. Results revealed that adjustments in local fertiliser recommendations would bring about significant increases in rice yields without changes in the total amount of N applied. These results prompted evaluation in 10 experiments on experimental farms in the three countries. In all but one experiment, the model-based timing of the recommended dose increased rice grain yield by 15% and more, without a change in the total amount of N applied.

The results were taken to farmers' field in the Chinese provinces of Jiangxi and Zhejiang. In Jiangxi province demonstration plots covered some 100 farm units in Taihe county. At a nitrogen input level of 150 kg ha^{-1}, 12% yield increases were found with the model-recommended application pattern compared to the local recommendations. Thus, while at 6 ton per ha the reference yield levels in farmers' fields were lower than on-station (7.5 ton per ha), increases in agronomic efficiency could be reproduced. Major cause of yield increase was a larger number of filled spikelets per panicle. Exploration of economic optima for the conditions in Jiangxi province demonstrated the need to distinguish between growth duration of cultivars. Net cash income from fertilisers was higher in short duration (35 d seedling + 80 d field duration) cultivars than in medium duration (35 d + 100 d) cultivars (Figure 4) for all levels of fertiliser input. Simulations showed that also agronomic efficiency of short duration varieties exceeded that of medium duration varieties. One of the reasons was found to be the larger investment in vegetative biomass of medium duration varieties, resulting in a lower harvest index than for short duration varieties. This result was confirmed by local knowledge: the short duration varieties give higher net cash return from fertiliser and optimal rates of N application for short duration varieties are higher.

Improvements over local recommendations were also found at other locations. In Jinhua (Zhejiang province, China) and Cuttack (Orissa, India) model-based N fertiliser schemes were found to result in 4% and 10% yield increases, respectively, on average. Further increases in yield were found when, in addition to timing of application, also the total amount applied was optimised in on-station trials of model-based explorations.

Figure 4. Calculated net cash return from fertilizer N input (yuan per ha), for cultivar types of 80d and 100d field duration (seedling stage 35 d in both cases), at Nanchang, China, late season. Each point represents net income obtainable under best (optimized) N management. Source: Ten Berge & Riethoven, 1997.



The results stimulated further and more large-scale testing in Jiangxi and Zhejiang provinces and in 1997 local recommendations represented on Rice Production Maps, printed colour maps of farm management guidelines, were updated based on the new insights. In 1998, the new recommendations were fully adopted in Jiangxi province, and were spread on large scale through maps for 100,000 villages. In India, the approach was tested in the nation-wide Soil Test Crop Response Programme, as a precursor for extension.

An exploratory land use study on environmentally friendlier flower bulb production systems in the Netherlands (Rossing et al., 1997)

Current agricultural production systems in the Netherlands show a considerable use of pesticides and nutrients per unit area. Several causes can be identified for these input levels, e.g., high land prices, relatively low input prices and a defensive attitude of growers towards environmental issues. Government policy aims at reducing the side-effects of agricultural production systems, mainly focusing on emissions of nutrients and use of pesticides. The objective of the study on environmentally friendlier flower bulb production systems in the Netherlands was to support design of production systems that meet environmental objectives in addition to economic objectives. Target group of the study was an association of growers and environmentalists.

Fragmented agronomic information was synthesised and technical options for flower bulb production systems were investigated with a time horizon of 10 to 15 years (2005-2010), which implies that farm sizes (in terms of labour and area, both treated as exogenous variables) were based on what experts judged to be feasible. Level of knowledge, insight and expertise, available farm equipment and farm structure were assumed to present no limitation.

An MGLP model was used to integrate agronomic information and value-driven objectives. Three objectives were identified: i) farm gross margin, ii) pesticide input in terms of active ingredients averaged over the cropped area and iii) nitrogen surplus, calculated as the nitrogen not taken up by the crop or not transferred to a subsequent crop, averaged over the cropped area.

Agricultural production options were quantified for four bulb crops, i.e. tulip, narcissus, hyacinth and lily and one break crop, i.e., winter wheat with positive effects on soil structure and suppressing soil borne diseases. In addition inter-crop activities were defined, for instance to control wind erosion or to prevent leaching of nutrients in winter. For all specified production options of crops and inter-crop activities, inputs and outputs were quantified. Production options of crops were characterised by soil type and soil health, cropping frequency, crop protection regime (chemical, mechanical or biological control) and nitrogen regime (with and without nitrogen limitation). Inputs and outputs were quantified using empirical information, expert knowledge and production ecological theory (Van Ittersum & Rabbinge, 1997).

Table 2. Values of economic and environmental objectives for flower bulb farms at the optimization of each objective without restrictions on the others. On clay soils a single level of pesticide and nitrogen input is allowed in the model. After Rossing et al., 1997.

Objective optimised:	Values of objectives:				
	Farm gross margin (index[a])	Pesticide input (kg a.i. ha^{-1})		Nitrogen surplus (kg N ha^{-1})	
		sand	clay	sand	clay
Farm gross margin (max.)	104	73	12	195	134
Pesticide input (min.)	-4	0	12	169	134
Nitrogen surplus (min.)	2	8	12	55	134

[a] Index value 100 corresponds to a farm gross margin of 205,000 Dfl.

Table 3. Characteristics of the optimal farming systems on the developmental paths for pesticide input (A-B-C-D) and nitrogen surplus (A-E-F-G). After Rossing et al., 1997.

	Pesticide input reduction			**Starting point**	Nitrogen surplus reduction		
	D	C	B	A	E	F	G
Farm gross margin index[a]	-4	77	97	**100**	62	38	2
Pesticide input on sand (kg a.i. ha^{-1})	0	10	30	**50**	50	9	8
Nitrogen surplus on sand (kg N ha^{-1})	140	140	140	**140**	100	90	50
Soil fumigation (ha)	0	0	0	**1.2**	2.2	0	0

[a] Index value 100 corresponds to a farm gross margin of 205,000 Dfl.

The MGLP model combines crops, production techniques of crops and inter-crop activities in a crop rotation in such a way that the objective to be optimised reaches its optimum value while meeting the upper or lower bounds on the other objectives. Results of the procedure are the optimum values for the objective functions and the associated crop rotation. Table 2 presents results of a so-called zero round of the MGLP model for a specific farm type. In the zero round, the model is optimised in subsequent runs for each of the objective functions without any bounds on the other objectives. For instance, farm gross margin reaches a maximum of 104 (expressed as an index: 100 is the farm gross margin, in Dutch guilders, of a farming system satisfying the governmental environmental targets for the year 2000) when imposing no bounds on the use of pesticides and on nitrogen surplus (resulting in 73 kg a.i./ha and 195 kg N surplus/ha on sandy soil, and 12 kg a.i./ha and 134 kg N surplus/ha on clay soil). Table 3 illustrates trade-offs among the various objectives, derived from various runs of the MGLP model. Letters represent different crop rotations, characterised by crops, production techniques of crops and inter-crop activities. Starting point for the model calculations were the governmental targets for the year 2000 with respect to pesticide input and nutrient surplus, i.e., for pesticide input a maximum of 50 kg a.i. and for nitrogen a surplus of 140 kg N per hectare; farm gross margin for this system was 100, as indicated above. A higher reduction in pesticide input is achieved when going from production system A to B, C and D. A higher reduction in nitrogen surplus is achieved when going from production system A to E, F and G. Trade-offs make explicit the consequences of conflicting objectives: economic viability is for example more in conflict with reduction in nitrogen surplus than with reduction in pesticide use. The perspective on the trade-offs among objectives, and the associated optimum crop rotations focused discussion between farmers and environmentalists on preferred strategic pathways for the farm, rather than on tactical decision making.

An exploratory land use study on perspectives for the rural areas of the European Union (WRR, 1992; Rabbinge et al., 1994)

In the early nineties, immediate motives to carry out a study on perspectives for the rural areas in the European Union (EU) were i) tension between EU and the world market in the GATT negotiations; ii) increasing societal attention to aspects other than agricultural productivity, such as environmental protection, nature and landscape and iii) the widespread increase in agricultural productivity resulting in increasing surpluses of agricultural products and the associated budgetary consequences for the EU. Target groups of the study were policy makers in the Netherlands and the EU. In addition, the study aimed at stimulating the public debate on the future of rural areas.

Table 4. Objectives and scenarios included in the EU study (WRR, 1992; Rabbinge et al., 1994)

Class of objective	*Objective*
Agricultural	1. maximise soil productivity
Socio-economic	2. minimise costs of agricultural production
	3. maximise total employment in agriculture
	4. minimise regional decrease in agricultural employment
Environmental	5. minimise loss of nitrogen per unit of area
	6. minimise loss of nitrogen per unit of product
	7. minimise input of pesticides per unit of area
	8. minimise input of pesticides per unit of product
Scenarios	*Descriptors*
Free market and free trade	low costs, free market, minimum of restrictions in the interests of social provisions and environment; imports and exports of food
Regional development	regional employment in agriculture, regional income from agricultural sector; self-sufficiency for food
Nature and landscape	conserve natural habitats, creating zones separating them from agricultural areas; imports and exports of food
Environmental protection	minimisation of unwanted emission of contaminants from the agricultural sector to the environment, conserve soil, water and air, nature can be integrated with agricultural activities; self-sufficiency for food

The study explored the long term (25 years) consequences of policy objectives for the rural areas of the EU-12 (the study was completed in 1992), given estimated future requirements for agricultural produce and regional differences in production conditions. Technical possibilities that are present in the agricultural sector under different value-driven policy objectives were identified. Agro-technical, socio-economic and environmental objectives were considered of which eight were finally selected (Table 4). The objectives were confronted with technical information on land use representing various production possibilities in an MGLP model. Technical information was based on knowledge of biophysical processes underlying crop and animal productivity; application of best technical means at cropping systems level was assumed. Only constraints imposed by the agricultural system itself were considered, i.e. suitability of physical environments, water availability and crop and animal characteristics. Institutional, market or infrastructural constraints were not considered. Requirements for agricultural produce were derived from assumptions on population stabilisation, imports and exports and prevailing diets. Requirements were quantified for situations of self-sufficiency and free trade, and for two diet variants: one representing a current average diet in the EU and one affluent diet with more animal products.

Table 5. Four land use scenarios for the EU, in terms of objective values and in terms of type of agriculture

	Scenarios				*Today*
	Free market, free trade	Regional development	Nature and landscape	Environmental protection	
Objectives					
Agricultural area (10^6 ha)	42	77	26	61	127
Agricultural employment (10^6 MPU[a])	1.5	2.2	1.8	2.2	6.0
Nitrogen surplus (10^9 kg)	2.1	2.8	2.1	2.1	11
Use of pesticides (10^6 kg a.i.)	60	89	21	33	400
Type of agriculture (% of agric. area)[b]					
Yield-oriented agriculture	53	35	0	0	na
Environmental-oriented agriculture	0.0	1	100[c]	55	na
Land use-oriented agriculture	47	64	0	45	na

na, not available

[a]MPU, Man Power Units

[b]See text for explanation of different orientations

[c]Imposed

Technical coefficients for the land use activities were derived from the results of a mixed qualitative/quantitative land evaluation, using a Geographical Information System in combination with crop growth simulation models (Van Lanen et al., 1992). In the qualitative part of the land evaluation, crop requirements of three indicator crops (grassland, cereals and root/tuber crops) were confronted with soil and climate characteristics of approximately 4200 land evaluation units. For those units considered to be suitable for one or more indicator crops, potential crop yields were determined with crop growth simulation models, in which information on crop properties, soils and climate is integrated in a quantitative way (Bouman et al., 1996). Results of the land evaluation showed that in the north-western part of Europe yield levels were often relatively close to their potential. This implies that the scope for further yield increases is limited. In other regions of the EU, mainly southern, yield gaps are still enormous and natural resources allow substantial yield increases.

In a next step, cropping systems have been defined for different production aims (so-called production orientations - Van Ittersum & Rabbinge, 1997) and crop rotation schemes (De Koning et al., 1995). Three production orientations were considered: yield-oriented agriculture (aiming at high soil productivity), environment-oriented agriculture (aiming at low emissions of pesticides and nutrients per ha) and land use-oriented agriculture (very extensive forms of agriculture with no use of pesticides). Application of the concept best technical means for quantification of inputs and outputs of cropping systems required empirical information from actual and alternative production systems, and expert judgement on the best way production may take place when the target yield is known (Van Ittersum & Rabbinge, 1997).

The information at cropping systems level was confronted in the MGLP model with the eight objectives, and the requirements for agricultural produce (an exogenous variable), to generate scenarios on future land use for the EU. The model finds an optimal solution to the problem of fulfilling the requirements for agricultural produce, under the constraints imposed on the objectives. This can be achieved by choosing different types of cropping systems and production techniques and locate them in the most appropriate region. Different priorities can be given to these objectives to force an optimal solution in a certain direction.

The eight objectives enable construction of numerous scenarios, which have been summarised in four major policy views (Table 4), illustrating consequences of contrasting choices. In the Free trade and Free market view, for instance, costs for agricultural production are minimised and no other major restrictions are imposed on the model. The requirement for agriculture produce from within the EU is modified according to expectations regarding new market balances. The model will now select the most cost-efficient types of land use in the most productive regions. In the Environmental Protection view, strict bounds are imposed on the objectives that represent the loss of nutrients and pesticides per hectare. Requirement for agricultural produce is fitted to self-sufficiency. Also in this scenario the costs for agricultural production are minimised, but with the strict bounds as mentioned above. The model will now select types of land use that have relatively low emissions per hectare and are to some extent still cost efficient. Table 5 gives examples of one type of results. This table represents optimum values of the objectives and the selected types of agriculture. Another result of the study is the land use allocation within the EU associated with optimum objective values (WRR, 1992; Rabbinge & Van Latesteijn, 1992).

Results of the study show:

1. The relative 'performance' of different i) physical environments within the EU, ii) cropping systems and iii) production technologies, in reference to policy objectives at the EU level. Only a limited number of combinations of objectives and production systems are feasible.
2. Selecting a particular set of objectives implies a strong bias toward particular land use allocations and consequences for other objectives. Not choosing, or efforts to maintain the

present land use will lead to high costs, economically and environmentally sub-optimal situations and societal objectives will not be achieved.

3. Support for regional development through regional authorities will lead to sub-optimal solutions at European level. There is a clear conflict of interest between regionally defined policies and the policies for the EU.

Evidently, a societal and political discussion on objectives and, next, a corresponding set of policy instruments is necessary.

4. Exploratory land use studies and integral design

Experience with computer-based Decision Support Systems in agriculture suggests that -in order to contribute effectively to decision-making and learning- such systems must anticipate the decision-makers' problem perceptions, and be embedded in wider support activities and networks (Leeuwis, 1993). In other words, there must be a fertile ground to do something with the information provided by the DSS. Even though it has not been systematically explored, it seems plausible to expect similar conditions for effective use in the case of computer-based exploratory land-use studies. Thus, our hypothesis is that -in order to have impact- the use of computer explorations must be carefully embedded in and/or linked to an ongoing (micro-)policy design debate or process. Nowadays, it is increasingly recognised that strategic design trajectories related to land use must involve collaboration between different societal stakeholders, farmers, consumers, (micro-)policy makers and scientists. In the terminology of this book: there is a need for *integral* (i.e. multi-functional, multi-disciplinary and interactive) design (see Leeuwis, chapter 1). This would imply that exploratory studies need to be carried out with close involvement of stakeholders, be they policy makers, societal interest groups or farmers. From a perspective of integral design, then, the question emerges whether or not the use of computers and computer models in integral design processes is associated with certain inherent strengths and weaknesses. In this section we will hypothesise some of these, and also reflect -if relevant- on their possibly differential significance with regard to various hierarchical levels. In doing so, our starting point is that integral design processes must be regarded as collective learning and negotiation trajectories (see Van Meegeren & Leeuwis, chapter 12), and hence that use of computers and computer models must fit within such a learning and negotiation context. In a subsequent section we will reflect on the extent to which the hypothesised strengths and weaknesses have played a role in relation to the earlier presented cases.

The potential of computer-based explorations

Potentials of computer-based explorations are evident in the domains of interaction between scientists and stakeholders and between scientists and scientists. In the scientists - stakeholders domain, a first advantage of using computer modelling in integral design processes is the *acceleration of iterative learning*. Model results can be compared to believes and perceptions, and causes for particular results can be traced to assumptions on system behaviour described in the model. Models also represent useful vehicles in another key area of learning, i.e. switching between different scales and domains. At the farm level, attention may switch between economic performance at the whole farm level and that at the crop level, and between peak labour requirements and nitrogen utilisation by crops. Thus, the pace and scope of hypothesising, experimentation and observation is greatly increased. Especially at higher hierarchical levels, modelling allows for experiments of thought that could never be organised empirically (e.g. for reasons of scale and risk). Thus, additional feedback and new horizons for policy making can be provided. Also at the farm level, computer-based explorations add considerably to on-farm experimentation approaches such as empirical prototyping (see Vereijken, chapter 7). On-farm experimentation usually allows for only a small number of different experiments over a relatively short time scale, and is not very suitable for risky and radical experiments. Computer-based studies enable quick and iterative exploration of a large number of options -including new and hypothetical- ones, under a wide range of physical environments (including e.g. variable weather conditions).

Secondly, computers allow for presentation of the various forms of feedback provided by exploratory land use studies which further enhances joint learning. The results of explorations can be visualised graphically or in the form of animations. Also, computer modelling exercises can be incorporated in simulation games as a playful manner of involving stakeholders. Thus, through their iterative and communicative capacities, computers and computer modelling may contribute to the *interactive* dimension of integral design.

A third asset of computer modelling relates to the issue of *multi-functionality*. As we have seen, computer models are useful in quantifying the performance of land use systems in various dimensions. Such results may be used in integral design processes in two ways. Awareness of the gap between current and calculated performance stimulates awareness of opportunities and of obstructions in their realisation. Secondly, the degree of conflict between different societal goals and functions reveals win-win situations or the need to make choices. Thus, computers and computer modelling contribute to informed negotiation processes that are part and parcel of integral design.

The choice to use computer modelling also has important implications for the process of knowledge gathering by scientists involved in the process. Modelling provides a language and vehicle for co-operation between different disciplines (Rossing et al., 1999; Wossink & Rossing, 1998). Constructing a model requires many building blocks, and a lot of co-ordination and in-depth debate among scientists, which otherwise is difficult to organise. Thus, as our case-studies show, computer models can contribute significantly to the *multi-disciplinary integration of complex knowledge* that is needed for dealing with complex societal problems of an inter-disciplinary nature. Perhaps an equally important strength is that building a model leads usually to a very clear identification by scientists of relevant knowledge gaps (i.e. what is *not* known; see Van der Werf et al., 1999), underlying assumptions and uncertainties. This may help stakeholders in integral design processes to identify areas for joint fact-finding as part of societal learning and negotiation processes (see Van Meegeren & Leeuwis, chapter 12).

Risks associated with computer-based explorations

A key risk associated with the use of computer-based explorations in integral design processes is that they may contribute to an *in-balanced or biased debate* among stakeholders in various ways. Typically, such explorations generate only a limited number of articulate options or scenarios, and inevitably exclude a range of other thinkable options. In this context, there is a risk that the debate is drawn almost by default towards those options and scenarios that are articulate, while alternative options are much more difficult to discuss, propose and/or underpin. Thus, *the range of debate may be limited in an undesirable manner*, leading to an unwarranted favouring of certain options over others. Similarly, computer models are inherently selective internally (i.e. for reasons of simplicity, or lack of knowledge) with respect to the variables, goals and opportunities for manipulation that they include, and thus make tangible in a debate on (micro-)policies. For example, the case-studies show that the models purposefully abstract from all sorts of human constraints (e.g. related to organisational arrangements, infrastructure, labour availability, conflict, cultural meanings, etc.) to the realisation of certain scenarios and options. This can easily lead to *insufficient attention for social-organisational design issues in the debate* (see chapter 1); the models provide a better language for discussing 'technical feasibility' rather than 'social feasibility'. Another possible bias is that exploratory land use studies may help to foster a climate in which talking about arguments (pro's and con's) becomes the default option. This may be attractive to academics, but it is contrary to key recommendations for the facilitation of negotiations among different stakeholders. Fisher & Ury (1981), for example, stress the importance of talking about interests rather than positions and arguments, as arguments are always secondary to interests. That is: stakeholders tend to select and construct those arguments that fit their interest, so that talking about arguments becomes in fact quite unproductive and inefficient (see also Aarts, 1998). An *over-emphasis on arguments and argumentation* may well occur in debates where exploratory models are used as a resource, as stakeholders may assume –e.g. on the basis of their associations with computers as powerful and 'magic' devices- that complex problems can now be solved through rational argumentation and deliberation inside the computer model.

Such (in part inherent) biases may jeopardise easily the position of particular stakeholders and societal interests, as it is likely that some significant issues and options can be less easily articulated, discussed and/or made credible than others are. Also, during integrative negotiations (see Aarts & Van Woerkum, chapter 4) such an unintended narrowing of the area of discourse may be at the cost of finding creative win-win solutions and trade-offs which fall *outside* the scope covered by the computer model. In some cases, stakeholders can be expected to deliberately (ab)use the inherent selectivity of computer models, and use it as a way to manipulate and influence the policy debate. This is especially so when the skills and resources required to use computer-based explorations are not equally distributed among stakeholders. Even if stakeholders are not very likely to do the modelling themselves, well-resourced stakeholders can hire or employ the necessary expertise, and explore and articulate particular options, goals, etc. while other parties cannot, thus generating a certain bias in the debate.

A second risk relates to the *transparency* of complex models. It is almost unavoidable that complex models are experienced at least partially as 'black-boxes' by stakeholders, whereby the outcomes are taken for granted, without proper understanding of the mechanisms and processes at work. This can easily lead to either unnecessary distrust of the outcomes, or to their uncritical acceptance, without considering the underlying assumptions, limitations and conditions for application. Misunderstanding or misinterpretation of an exploratory study's aims and results may easily occur, as happened frequently with the study on perspectives for the rural areas in the EU. To be clear: exploratory land use studies present static options, showing technical possibilities (according to current level of knowledge and available techniques) to meet a set of value-driven objectives or preferences, but they do not give blueprints for future developments. For instance, in several scenarios of the EU study, no agricultural land use was allocated to the Netherlands, because from a biophysical point view there are more competitive regions in Europe with respect to satisfaction of particular land use objectives. This was misinterpreted by various people as: 'the Council predicts (or even worse 'wants') agriculture to disappear from the Netherlands.' Exploratory land use studies may also point at challenging gaps between current and alternative production techniques that perform better with respect to the objectives considered. However, they do not provide an indication about whether and/or how to implement these alternative land uses. In all, understanding the assumptions and limitations of models takes time and energy, and unless this investment is made, models may form an obstacle to learning for societal stakeholders.

Finally, the issue of the *quality and validity* of exploratory models forms a third and related risk. To assess quality of modelling approaches, validation is generally put forward. During validation model output is compared to experimental results, using relevant exogenous and endogenous variables as inputs to the model. This procedure is feasible at field level, where intensive measurement programmes can reveal the values of the input variables. An example was given for the ORYZA-0 simulation model for nitrogen management in rice. Similarly, the so-called input-output coefficients of land use activities used in linear programming models at farm and regional level can and must be validated. But unlike results of models at the field scale, results of exploratory land use studies at the farm and higher scale levels cannot be validated. Because models used in the explorations are not meant to reproduce the current situation, many factors determining current land use are not considered in these models. In addition, experimentation at farm and higher levels to validate explored options is impossible. Given this situation, there is a risk that validity and quality of the model becomes an issue of debate itself among stakeholders with diverging interests, who bring in all sorts of additional factors and arguments in order to 'correct' the model. Such a debate may be productive and insightful (even if it can never lead to a validated model), but may also lead to endless argumentation on whether an outcome is meaningful and significant or not.

5. Evaluation - strengths and weaknesses in practice

Computer-based exploratory studies can play a significant role in integral design processes, provided that deliberate attention is paid to minimising risks. Let us now review the case studies with risks and potentials in mind.

The study about future land use in the European Union was initiated by the Netherlands Scientific Council for Government Policy (WRR, 1992). This Council may, called or uncalled, advice the Dutch government on a range of policy issues. The study on the future of rural areas in the European Union was an uncalled advice to the Dutch government, but published timely. It appeared in the midst of discussions on a reform of the Common Agricultural Policy ('MacSharry reforms'). Execution of the study itself was not formally embedded in a policy process, but from well before until long after its publication, the study was presented in over 100 meetings at different national and international forums, as well as in a range of scientific and popular publications. Initially, transparency and validity of the model constituted an important issue of debate, related to agronomic and economic aspects of the model. The fact that socio-economic structures were largely and purposefully ignored constituted a paradigm shift that caused much discussion. Later, when the explorative approach became clearer, focus shifted to less model-oriented aspects, such as the opportunities and threats associated with the conclusion of the study that agricultural land use in Europe has entered an era of contraction. The original study included a Tentative Ecological Main Structure for Europe (Bisschoff & Jongman, 1993) that stimulated thinking about opportunities to use land for purposes different from agriculture.

In the study on flower bulb production systems stakeholders were involved throughout the exploration (Rossing et al., 1997). The stakeholders, an association of progressive flower bulb producers and environmentalists in the main bulb growing areas of the Netherlands, took the initiative to design production systems that meet both environmental and economic objectives. The study was carried out at their request to assist in this design process. In two workshops, the association defined criteria by which the bulb production systems in the model were to be evaluated. The association was also involved in discussions on the technical options represented in the model and the assumptions related to farm structure constraints. This approach created a level of appreciation of the validity of the assumptions in the model. Results of the explorations were discussed with the researchers, and, much more extensively, within the association. Soon, not so much the model or the model results were made an issue of discussion, but rather the challenge in the results that farm management could be improved considerably beyond the current level without inherent and major negative financial consequences. The model thus served as a vehicle to support a process of building trust and confidence among the members of the association of farmers and environmentalists. It resulted in the association starting a lobby in the flowerbulb industry for on-farm experimentation with more environmentally friendly production systems. A national project to that end was started in 1998.

The study on nitrogen management optimisation was initiated through national agricultural research institutes represented in a project based at the International Rice Research Institute. The model was an eco-physiological model that, albeit simple, would be hard to understand for non-scientists. However, at the field level, the role of the model was to guide field experimentation, and to provide a certain degree of explanation of the observed phenomena. Model transparency was not a crucial issue because the model's relevance could be ascertained in real life. The model does limit the real-world options, because of its focus on fertiliser nitrogen, rather than organic N sources. Reality in many Asian countries is that animal manure is used for other purposes than to fertilise the soil. However, with animal production systems increasing, extension to organic N sources will become relevant.

The potential of model-based explorations to accelerate iterative learning was demonstrated by the extensive debate in science and politics, but particularly among societal groups following the case study at the European level, the initiation of a national project by the association of growers and environmentalists to test sustainable flower bulb systems on commercial farms, and the wide-spread uptake of the more efficient N application regimes in China and India. In all cases multi-functionality of land use was approached in a quantitative way, explicitly distinguishing between value-driven objectives and means of achieving them. And finally, all three case studies provided a platform for collaboration among scientific disciplines.

From the case studies we conclude that for exploratory studies to be effective, communication about aims and results is critical. While relevance and quality of model explorations can be ascertained experimentally for studies at the field level, reflection and discussion are the main methods at higher integration levels. Such reflection and discussion is part of stakeholders' learning and negotiation and effective communication about exploratory studies should be tailored to this aim. During integral design processes a facilitator who is well versed with the available models, and has an understanding of the dynamics of collective learning and negotiation, can play a role in timing the use of model-based studies, influencing the agenda for debate so as to correct in-balances, use other media for communication in order to improve transparency, stimulate debate on interests rather than the validity of arguments, etc. (see Van Meegeren & Leeuwis, chapter 12, for a more general discussion on facilitation).

It will be clear that the presence of a skilled and credible facilitator can be much more easily ensured in cases where there is indeed a deliberately organised (micro-)policy design process. This may be an important limitation, as many (micro-)policy processes do not meet this criterion, and are far from tangible and transparent. In the absence of an identifiable (micro-)policy development process, it remains useful to use exploratory land use studies in order to influence public debates and design agendas. Exploratory land use studies have indeed proved effective in stimulating such debates, as is exemplified by the presented case studies. Thus, exploratory land use studies can be used both for inducing (micro-)policy design processes, and as a resource within already organised design trajectories. Given the need to deal with inherent interpretative difficulties and risks the latter may be the preferred -but difficult to materialise- option for use.

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Chapter 6

Modelling the soft side of land: the potential of multi agent systems[1]

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Abstract

Land use modelling has, until recently, been dominated by crop growth models which focus on a-biotic factors to predict crop production under various assumptions. These models do not allow modelling the behaviour of cognitive systems. Hence computer modelling was of no use to agricultural scientists concerned with the soft side of land use, i.e., scientists who look at land use as the outcome of interaction, negotiation, conflict, learning and agreement. Given the increasing predominance of people as a force of nature, looking at the soft side of land is becoming increasingly relevant for developing sustainable land use.

The very recent development of new forms of modelling, based on object-oriented computer languages and new interface software, has changed all that. These forms of modelling derive from work on distributed artificial intelligence (DAI) and Cellular Automata (CA). The chapter focuses on modelling Multi Agent Systems (MAS) which seems to hold promise for a form of simulation of complex land use issues that emphasises the interaction and learning of autonomous cognitive agents. A special feature of MAS is that it allows examination of the emergence of complex macro phenomena from relatively simple micro activities.

The chapter describes the soft characteristics of the phenomena that need to be modelled and examines the ability of MAS modelling to deal with these characteristics. This examination is based on a review of literature, a Wageningen MSc thesis and experience with a course on MAS modelling organised by CIRAD, France. As a result of these activities, a doctoral research project to establish a capacity for MAS modeling has been approved.

1. Introduction

C.T. De Wit (1974), the 'author intellectualis' of the Wageningen School of Production Ecology, defined agriculture as harnessing the energy of the sun by plants for human needs. This definition emphasises a-biotic factors, such as sun energy, water and nutrients, as inputs into crops and livestock that produce a desirable output. Production based on

[1] The author would like to acknowledge helpful comments by Dr. F. Bousquet, Dr. C. Leeuwis and Prof. R. Rabbinge. The author remains entirely responsible for the contents.

efficient resource use is the desirable outcome of agriculture, and agricultural science has the task to develop the 'best technical means' to achieve it.

The development of crop growth modelling in this tradition globally has been very influential. This modelling is based on mathematical equations, with coefficients and values for variables based on empirical scientific research. It uses a systems approach that allows for inter-disciplinary integration and accumulated achievement among major disciplines, such as agronomy, physiology, soil science, plant breeding and ecology. Based on such work, powerful computer-based models have been built which for major food crops can indicate necessary interventions at the field, farm and regional levels in order to realise targets built into the models. Modelling is replacing costly (field) experiments. For example, one can do fertiliser response experiments by varying the virtual inputs of nitrogen (e.g., SARP rice models). Symptomatic for the rise of the importance of systems modelling is the fact that new buildings, such as that for the Institute for Forest and Nature, planned in the early nineties, now have many empty laboratories because the emphasis has shifted from laboratory experimentation to computer modelling.

An important use of systems modelling has been the calculation of the potential number of people that the world can feed, given its a-biotic resources (Penning deVries, et al., 1995). With an established practical ceiling of plants' capacity to transform sun energy at about 10 tons per ha, such calculations lead to far more optimistic estimates of the maximum supportable population than estimates based on trends (Schipper, 1998). Furthermore, the models allow 'scenario studies' based on varying key target variables in complex matrices describing land use and on identifying the consequences for other relevant variables (WRR, 1992). To the extent that economists use linear programming techniques and production functions assuming utility maximisation, their work can be closely integrated with crop modelling (e.g., Schipper, 1998), be it that, by using linear programming techniques which incorporate assumptions about farm management and infrastructure, they impose limitations on production that lead to less optimistic estimates than modelling based on a-biotic factors.

A typical example of this systems modelling approach is SHAred REsources in the Sahel (SHARES) which provides a framework for integrating the earth and life sciences. The SHARES land use analysis procedure incorporates a descriptive ('the facts'), an explorative ('the options'), and a planning ('implementation') phase. That is, 'facts' are gathered in a number of villages and fed into a model simulating regional attainable crops growth. This model allows identification of options for improvement. In the third phase, these options will be explored with villagers. The basic role of modelling in design is clear: it provides science-based options which can be introduced to farmers or other potential users.

Drawbacks of conventional modelling

Production ecological modelling has its drawbacks. In the first place, by focusing on a-biotic factors one can easily come to the conclusion that, given their exposure to sunlight and assuming an adequate provision with fertilisers, high rainfall areas in the South can become breadbaskets. In actual fact, present land use, market infra-structure, political instability, administrative weakness, low farm gate prices (partly as a result of import of cheap food), and other factors, have so far kept production level well below the 10 tons deemed potentially possible. One can also argue (Koning, 1999) that global factors disallow the translation of population growth into higher food prices and hence into a Boserupian investment in agriculture, and lead, instead, to a Malthusian scenario. In this light, the emphasis on a-biotic factors and on technical research to realise the potential 10 tons, or even to change plants' potential beyond 10 tons, seems to ignore some of the key factors involved in food security. Such modelling might well lead to estimates of a sustainable world population at a specified point in time which are totally unrealistic at that point in time.

A second question with respect to the usefulness of the models is whether the production attainable on the basis of the models is ecologically feasible. Studies of large, complex eco-systems led Holling and his colleagues to conclude:

> "Success in managing a target variable for sustained production of food or fibre apparently leads to an ultimate pathology of less resilient and more vulnerable eco-systems, more rigid and unresponsive management agencies and more dependent societies" (Holling, 1995: 29).

It is unlikely that the complex biosphere of which we are part can be transformed into a sustainable production machine for a few agricultural crops to feed billions of humans. In that sense, production ecology, with its emphasis on a-biotic factors and lack of attention to the complex web of life (Capra, 1996), seems remarkably lacking in ecological perspective. In fact, production ecology seems to be blind to the fact that the production of food on this earth is not only limited by the amount of land on which a-biotic factors would allow production of 10 tons per ha, but also by the limits of the earth as an ecosystem. A typical example is that the use of modern agricultural production techniques has generally led to a sharp reduction of the organic matter content of soils (typically from as high as 10% to 1.5%). As a consequence, vast amounts of carbon dioxide that were stored in the soil have been released into the atmosphere (Allessandro Bozzini, pers. com.).

A third drawback of systems modelling is that they are based on a-biotic factors and do not allow for cognitive processes. As we shall see, it is especially this aspect that is the focus of this chapter.

A final drawback with respect to systems modelling in the production ecology tradition is the limited extent to which it is applied. When the Wageningen satellite research unit in Costa Rica recently was closed down, the general conclusion was that very little use had been made in policy making of the models that had been built to support policy making. The same conclusion was reached by the protagonists of twenty years' systems modelling work in Mali that was otherwise recognised to have excellent quality (Breman, pers. com.). Research is under way to analyse the reasons for this limited impact (IFDC, 1999).

Towards modelling Multi Agent Systems

Whatever its possible drawbacks, production ecology and its approach to simulation modelling have continued to dominate the mission and choices of Wageningen University and Research Centre (WUR). In the C.T. de Wit Research School on Production Ecology, "eighty tenured staff members and 150 PhD candidates work on developing the building blocks and concepts for new forms of agricultural practice" (Rabbinge, 1999). This work continues to exert major influence on international agricultural research.

This author has been among those who has tried to develop an *additional* perspective for a good many years. This search partly has been inspired by the conviction that an agricultural centre for scientific research and university teaching becomes more interesting and inspiring, and more attractive to students, if it is engaged in 'a battle of paradigms'.

More importantly, the contract of agriculture with society, and hence the reasons why society should fund a WUR, are rapidly changing (e.g., Proost & Röling, in press). Conflict and war, lack of access to *available* food, healthy food, and the destruction of ecological services and natural resources especially by agriculture, are becoming relatively more important than increasing agricultural production and efficiency (reflected in the continued decline of global food prices). The word 'relatively' is not used lightly here. A continued focus on high quality technical agricultural research continues to be an essential ingredient of any high level scientific agricultural establishment. The objection regards the dominance of such a focus at the expense of attention to other issues, even if the dominance is well earned and continues by the default of contending perspectives. The objection also regards the dominance of the approach to systems modelling because of the shortcomings identified above.

The objective of this paper is to present and explain an additional type of systems modelling that does take into account the complex and interactive nature of sustainable development and the role of cognitive agents in it. In the second section, the paper presents a perspective on 'the soft side of land' which looks at land use as emerging from human learning, interaction and institutions. The section will also examine some key mechanisms involved in alternative modelling of land use.

The third section deals with modelling itself. The dominance of production ecology has been earned, not in the least because it has been able construct working models that have been able to deliver practical results. So far, the work on the 'soft side of land' or 'social agronomy', though promising in terms of theoretical and empirical results, has not produced models which could provide a basis for accumulating and integrating knowledge, and/or tease out key interactive mechanisms involved in the sustainable use of land. The third section examines a new form of modelling, based on object-oriented computer languages and new interface software. These forms of modelling derive from work on distributed artificial intelligence (DAI) and Cellular Automata (CA). This paper will focus on modelling Multi Agent Systems (MAS) which seems to hold promise for simulating complex land use issues that emphasises the interaction and learning of autonomous cognitive agents (Bousquet et al, 1996; Gilbert & Troitszch, 1999). A special feature of

MAS is that it allows examination of the *emergence* of complex macro phenomena from relatively simple micro activities (Epstein & Axtell, 1996: 33). It is a form of 'bottom up', the 'collective power of small actions rippling upward, combining with other small actions, often recursively so that action would beget reaction, until a recognisable pattern of behaviour emerges' (Levy, 1992: 105).

2. The soft side of land

Sustainability

The best way to explain the difference between the soft and hard sides of land is through the definition of sustainability. Hard definitions emphasise biophysical attributes of ecosystems and often focus on thresholds below which land use becomes unsustainable, such as bio-diversity, carrying capacity, or sustainable take-off. Determination of the 'ecological footprint' allows assessment of the 'hard' ecological impact of different life styles. There is no doubt that such attributes which people consider to be 'hard' and trustworthy are very important when it comes to alerting people to the 'objectively true' consequences of their activities. A similar observation can be made with respect to economists' use of contingent valuation to get at the 'true value' of ecological services and natural resources for purposes of national accounting.

It is now widely recognised that 'it is impossible to work with an objectively fixed elaboration of sustainable development' (WRR, 1995: 5). 'The concept of Environmental Use Space (EUS) which has become an established feature in many studies of sustainability, implies that it is possible scientifically to determine the limits to the burden that may be imposed on the environment. This, however, fails to do justice to the value driven and hence political nature of the choices that have to be made' (ibid.: 6). Operationalisation of sustainable development into policy 'is unable to circumvent the uncertainties associated with the interdependence of environment and society', hence we are dealing with 'sustained risks, a lasting phenomenon' (WRR, 1995: 5).

Soft definitions go much further and define sustainability in constructivist terms: sustainability is 'an emergent property of a soft system' (Bawden and Packam, 1992). In other words, sustainable land use is defined as the outcome of human interaction and agreement, learning, conflict resolution and (collective) action. Soft definitions do not in any way conflict with hard ones. They look at the same thing from a totally different perspective. Whereas hard definitions typically emphasise the state of the ecosystem that results from external perturbations, soft definitions emphasise the human conflict, negotiation, learning and instrumental activity of which (lack of) sustainability is the outcome. Where humans increasingly can be regarded as a major force of nature (Lubchenco, 1998), soft definitions are becoming increasingly useful.

Box 1: The Naardermeer

A typical example of the difference between hard and soft definitions is provided by Holland's oldest nature conservation area, the 'Naardermeer', a wetland near Amsterdam. One can take a 'hard' look at it in terms of the number of bird species, their rate of reproduction, the bio-physical quality of the water, desiccation, the impact of the recent invasion of foxes on the spoonbill, and so forth. In fact, a considerable number of people is engaged in monitoring such aspects. Luckily the results show recent improvement, especially in water quality and quantity.

What such a hard approach does not do, however, is to *explain* the recent success. That is only possible with a soft approach which emphasises the nature of the social processes that were involved, especially the negotiations among farmers, communities, provinces, ministries, and water management boards that can all significantly affect the state of the wetland, and the 'Natuur Monumenten' organisation which manages it. The wetland is part of an area marked by complex multi-purpose land use, crossed by a railroad, power lines and one of the busiest motorways in Europe, and is characterised by highly intensive dairy farming. The area is subject to multiple regulatory frameworks at community, water management board, provincial and national levels. Individuals have options to resist deals that emerge from institutional negotiations. Two brothers who own a farm at the interface between the Naardermeer and the Ankeveense Plassen (another nature conservation area) provide an example. Opening a corridor at that interface would consolidate two presently fragmented nature areas and therefore help achieve an important objective of the government's Nature Policy Plan (create nature areas at a scale at which requisite diversity in populations can be maintained). However the two brothers have so far refused to accept any offer of alternative equally high quality land, additional financial incentives and so forth. There is nothing one can do but wait till they stop farming (pers. com. S. Fokkema). In the soft perspective, then, sustainability of the lake is determined not by natural forces, but by people and their decisions.

Leading ecologists have taken a similar perspective. Studies of disaster and regeneration in large and complex eco-systems, such as the New Brunswick forests, the Everglades, the Columbia River and the Baltic Sea, by Holling and his colleagues (Gunderson, et al, 1995) have brought them to realise the central role of humans as a major force of nature. It is the nature of the human management that determines the ecological outcome.

> "The essential point is that evolving systems require policies and actions that not only satisfy social objectives but also achieve continually modified understanding of the evolving conditions and provide flexibility for adapting to surprises" (Holling, 1995: 14).

Hence, their ecological analysis leads Holling and his colleagues to identify important implications for human behaviour that they call *adaptive management*. Adaptive management is a guiding principle for the design of the interface between society and biosphere, between community and eco-system.

> "The release of human opportunity requires flexible, diverse and redundant regulation, monitoring that leads to corrective action, and experimental probing of the continually

changing reality of the external world" (Holling, 1995: 30).

This is fundamentally new in the sense that the dominant criteria for societal design emphasise the linear growth of consumption and exploitation. Adaptive management emphasises social learning about the complex adaptive systems of which we are part. It looks at economic uses of nature and at policies as experiments (Lee, 1993: 8). As a general principle, adaptive management needs to be translated into concrete experimentation, monitoring, probing and other forms of learning, conflict resolution and concerted action.

Adaptive management emphasises the soft side of land (Jiggins and Röling, in press). The concept challenges agricultural research institutes and universities to take the soft perspective on board and develop it into a dimension of scientific endeavour and professionalism. In particular, this means that science and the professions incorporate a concern for social learning among the human actors involved in managing ecosystems and collective action to manage those systems at appropriate levels. Collective action involves conflict resolution, negotiated agreement on values and goals, on monitoring systems, sanctions and mechanisms for surveillance, and hence on institutional change (Ostrom, 1998; Steins, 1999). Instead of assuming non-controversial causes for problems and defining clear-cut goals for centrally-managed action to remove them, effective adaptive management recognises the non-linear, complex dynamics involved. Such management involves steps such as (1) recognising that we do not know, (2) accepting that we can never solve the problem but only improve the problem situation, (3) keeping alive interactive visioning among stakeholders, (4) and discovering what we prefer by taking action (Geldof, 1999).

In the space available, it is impossible to provide an overview of what is presently known about the key processes involved in the soft side of land. Suffice it below to provide some key principles required for understanding the potential of MAS modelling for adaptive management. These principles will also show why modelling the soft side of land is a totally different enterprise from modelling 'hard' crop growth.

The social construction of reality

Human behaviour is not so much determined by cause and effect, as by peoples' construction of reality, i.e., their *reasons* (e.g., Berger and Luckman, 1967;Woodhill and Röling, 1998). Biologists (Maturana and Varela, 1987) have established that organisms' perception of their environment is not based on objective projection of the environment on their nervous systems. Such a projection is impossible because the nervous system informationally is closed. It operates on different principles (synapses, neurons, micro-currents, etc.) than the light waves that allow vision and projection. But the environment can *trigger* changes in the nervous system that we call perception.

Modern physicists have come to similar conclusions with respect to science as a way to perceive the environment. Thus Roy Frieden from the University of Arizona speaks of 'the possibility that physical laws occur as answers to questions', and states 'through the very act of observing, we thus actually define the physics of the thing measured'. John Wheeler, a prominent physicist from Princeton University says 'observer participancy gives rise to information and information gives rise to physics'. Thus 'reality', or at least the laws of physics, are created by observation and are subject to the inherent limited capability of humans to extract information from the environment. This explains why all of physics can be expressed terms of differential equations which reflect the operation of the human mind (Matthews, 1999).

These observations accord with the counter-intuitive social science insight that 'Reality is socially constructed' (Berger & Luckman, 1967). Everything that people want, see, do, believe, learn and so on is mediated through language and social relationships. For example, study of chatting among farmers has shown that chatting has important functions beyond 'exchanging information'. It also allows the participants to construct concepts, agree on acceptable action, and develop norms for acceptable action (Darré, 1985). The social construction of reality is especially evident from studies of the way in which different groups 'make sense' of their world and act on the basis of that sense making. The recognition of such 'multiple perspectives' is now seen as an essential condition for good governance of complex societies (Wagemans, 1987 and 1998).

It is important to point out that a *constructivist* view does not necessarily imply a *relativist* view ('anything goes if reality is constructed'). In fact, constructivism combines very well with realism. As the biologists would put it: changes in the environment can trigger changes in the nervous system of an organism which lead it to 'bring forth *a*, not *the* world (Maturana & Varela, 1987).Yet it cannot be *any* world. The world brought forth has to allow the organism to maintain effective coupling with its environment. In this respect, 'knowledge is effective action in the domain of existence' (Maturana & Varela, 1987). Reality is constructed and empirically adequate at the same time (Van Fraassen, 1980).

In all, human behaviour is not driven by natural laws of cause and effect about which one can build objective quantitative knowledge. It is driven by reasons, human intentions, perceptions, inferences, capabilities, and repertoires of action, all based on, and mediated by, learning, negotiated agreement, culture and language, and the social structures to which people belong. This is the messy 'soft' (some prefer 'complex') world with which we increasingly have to deal because of the dominance of people as a major force of nature and as an inescapable factor in explaining the behaviour of complex adaptive systems.

Soft systems thinking is a typical example of this principle (Checkland, 1981). Systems do not exist. Systems are constructs that perhaps are helpful to deal with complex phenomena. Soft systems are systems that only exist if the people constituting them agree to treat the interaction among themselves, or between themselves and their environment, as if it were a system. A soft system is thus composed of people who acknowledge that they share a problematic situation, and agree on common goals, on common explanations of the problem, and on concerted action. Soft systems methodology (SSM, Checkland, 1981), and the RAAKS methodology based on it (Engel & Salomon, 1997), aim to take people through a learning trajectory that allows them to construct a soft system. For soft system thinkers, it is not goal seeking behaviour that is the problem but the goals themselves. That is where the conflict is. Hard systems are a subset of soft systems: not only are all systems socially constructed, but most systems with apparently unproblematic goals and boundaries eventually turn out to be systems determined by human intentionality with arbitrary boundaries. Soft systems methodology adds a specific focus to the constructivist perspective: it emphasises the process through which individuals learn to become a collective, with a shared problem definition, shared goals and an ability to engage in concerted action.

Cognition

Cognition is the process of life. All organisms are characterised by cognition, that is, they can (a) perceive changes in their environment, (b) they have some emotion against which to assess those changes and (c) can take some action based on this assessment, as is shown in figure 1 (Maturana & Varela, 1987; Capra, 1996). Action in the environment can lead to changes in the environment that can again be perceived (feedback). Feedback can lead to adaptation of emotion and action. That is, organisms can learn. Experience and learning can lead to a repertoire of potential actions, and to the development of an 'inference machine'. Thus crows which see dutiful Dutch farmers mow around meadow birds' nests have learned to infer that there must be some tasty eggs in the patch of grass left standing.

'Hard' modelling cannot deal with such adaptive cognitive systems. Yet cognitive processes and agents are extremely important for understanding the soft side of land. Human *intentionality*, for example, is a crucial aspect of sustainable land use. Economics has dominated our ideas on intentionality. It assumes people to have some 'utility function', i.e., preferences or benefits they seek to optimise. Assuming such goals, economics can then focus on rational goal seeking behaviour and work on 'hard' models guided by rational choice. In that sense, economics is an axiomatic science.

The issue of rationality is very important for dealing with sustainability in the 'soft' sense. If people do indeed have a set of preferences which determines what is 'rational choice' and which expands as a function of being exposed to advertisements, the demonstration of wealth by others, etc., there is little hope for adaptive management, or the future for that matter. Adaptive management assumes that people's intentionality can be shaped by learning about the state of their environment and by understanding the complex processes involved. More importantly, it assumes that intentionality can be shaped by reciprocal agreement to restrict use of the environment and restrain greed. This is a hot issue in research on common property resource management and social dilemmas (e.g., Ostrom, 1992). Is rationality based on given preferences and driven by greed, or is rationality an inherent need to bring coherence among the elements of the cognitive triangle.

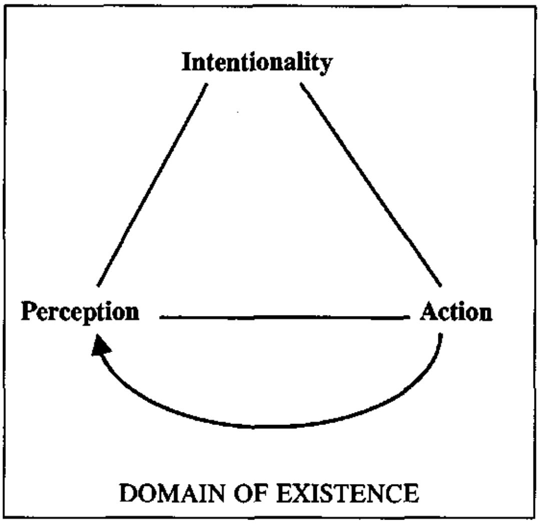

Figure 1: Santiago theory of cognition (after Maturana and Varela, 1987; Capra, 1996)

Perception, of course, is a key element of the cognitive system that is of direct importance for modelling. How do people perceive their environment? What do they observe and what inferences do they make? The discussion of the social construction of reality and multiple perspectives above is of direct relevance for the nature of perception of human cognitive systems. The notion of a cognitive system (figure 1) merely places the constructivist perspective on the nature of knowledge in a framework which links it to intentionality and action.

Perceptions tend to be shared or inter-subjective. It impossible to be human without partaking in an inter-subjective reality world which is shaped by history, culture, and language. But at the same time, perceptions might differ and lead to conflict. Effective collective action, for example with respect to sustainable resource use, often requires considerable attention to creating a common perspective on problems, diagnosis and possible solutions. The interactive use of simulation models is one method that has been used to create a shared perspective on a complex ecosystem. I shall come back to this issue in the last section of this paper. Suffice it to say here that, in the US especially, the implementation of adaptive management has focussed on the interactive use of simulation models to help policy makers, agency directors and other stakeholders learn to take better decisions about complex ecosystems (Gunderson, et al (b) 1995; Light et al, 1998; Jiggins & Röling, in press).

Facilitating collective perception raises an important issue. Can a group of stakeholders learn to act as a cognitive system in the sense that they share perceptions, intentions and agree to engage in collective or concerted action? How can coherence among the three elements be maintained in such a collective system? What are the institutional implications? These seem vital questions. Answering them is a necessary condition for the adaptive management of complex ecosystems at whatever level.

A final aspect of cognition worth mentioning here is Clark's (1996) notion of the '*embodied mind*', which fits well with Maturana & Varela's (1987) definition of knowledge as 'effective action in the domain of existence'. According to Clark, new research in cognitive psychology shows that the brain does not house a central deliberative authority that ultimately guides and controls decisions. In fact, human brains work much as those of animals. What makes 'thinking' possible is not the brain in itself, but the embodied mind, that is the working of the brain in conjunction with action and with the use of artefacts such as language, drawings in the sand, and computers. Computer simulation, as in MAS, actually expands the embodied mind and our ability to think.

As we shall see, the 'agents' in multi-agent systems are cognitive systems. For example, an early tradition in MAS modeling was the 'practical reasoning agent' and the belief-desire-intention (BDI) model. 'BDI agents are characterised by a 'mental state'.... An agent's practical reasoning involves repeatedly updating beliefs from information in the environment, deciding what options are available, 'filtering' these options to determine new intentions and acting on the basis of these intentions' (Jennings et al, 1998). In other words, simulated agents have the same three basic components as cognitive systems.

Actor orientation

Norman Long (e.g., Long & Long, 1992) has developed a Wageningen school of actor oriented sociology that has been influential in relativating the erstwhile focus on 'social systems' or other macro forces, that were assumed to determine individual behaviour. The word 'system' still makes Wageningen sociologists shiver. In Long's vision, an actor is an autonomous agent who can, even in the most miserable circumstances, exert some agency, i.e., make a difference. This perspective is also expressed in Van der Ploeg's (1994) well-known 'farming styles' research. That research was the first in the Netherlands[2] to present a credible challenge to the dominant agricultural science perspective of linear uniform 'progress' towards modernity based on the utilisation of scientific knowledge. Van der Ploeg showed that farmers make very different choices, even in the same economic and technological context.

Actors struggle in an 'arena' or 'battlefield of knowledge' to realise their projects, enlist others in their projects, etc. The outcome of any actor's intervention, be it a development planner, government or what have you, is never predictable in advance, but the resultant of

[2] Internationally, Farming Systems Research was earlier both in demonstrating the interaction of farmer style preference in biophysical contexts and in defining criteria and procedures for clustering these as distinct evolutionary pathways. See Michael Collinson's (1999 in press) edited volume on the history of the FSR movement (Janice Jiggins, pers. com.).

complex social processes, including conflict, negotiation and power (Long & Van der Ploeg, 1989). Planning to achieve desirable outcomes through development projects or other interventions is tantamount to 'social engineering', which is about the worst sin in Long's book.

Actor oriented sociology has been preconceived in its one-sided emphasis on strategic rationality. There is little interest in 'collective agency' or in creating agency at a higher level of social aggregation, even if an actor admittedly can be a group or collective. An interest in sustainability assumes interest in changing the '*arena*' of struggling actors into a '*platform*' for resource use negotiation or collective action (Röling, 1994; Röling and Wagemakers, 1998; Dangbegnon, 1998; Steins, 1999). This interest can therefore not draw much from actor oriented sociology, and must look for inspiration elsewhere, for example in game theoretical models of social dilemmas and the shift from selfish to co-operative behaviour. One of the attractions of MAS is that it promises the researcher to carry out thought experiments with respect to changing arenas to platforms. The actor-oriented approach can help us to critically think through these thought experiments.

Participation

Participation goes beyond the *instrumental* logic of the scientist who might be tempted to engage in 'social engineering' and also beyond the *strategic* logic of either the economist who assumes competing selfish actors in pursuit of advantage, or the actor oriented sociologist who looks at the world as an arena of struggling actors in pursuit of selfish projects. The participatory approach reflects the belief that it is possible to intervene in such a manner that the intended beneficiaries are neither a passive 'target group' of receivers who are manipulated, or opportunists who strategically seek to use the intervention for their own benefit. Instead, the intended beneficiaries can be active 'participants' and co-managers in their own development effort, who are involved in the negotiation of desirable outcomes, the planning of joint activities, and the implementation of those activities, and who commit themselves by contributing their resources and labour (e.g., Groot, in prep.).

Learning

The overview of soft mechanisms can be summarised by the term *learning*. Learning and especially social learning (i.e., shared learning among stakeholders) has been identified as the key social process in adaptive management (Parson and Clark, 1995; Maarleveld, in prep.). Learning is a key aspect of cognitive systems, as we have seen, in that learning involves change in any or a combination of the elements of the cognitive system (figure 1). In fact, Kolb's (1984) famous learning cycle in many ways overlaps with the model of the cognitive system proposed by Maturana & Varela (1987). But learning also involves conflict and negotiation. Leeuwis (2000, in prep.) is convinced that it is more useful to look at participation and learning as forms of negotiation than as consensual approaches to reach agreed-upon goals.

In all, learning is the key to modeling the soft multi-agent system from which sustainable land use might emerge. This is quite a step. Environmental economists (e.g., Van Ierland, 1996) claim that, if the market fails, only fiscal policy or regulatory measures can save the day. With our focus on learning we open up a totally different approach to sustainable land use that goes beyond the 'best technical practice' of the agricultural scientist, as well as beyond the fiscal policy and measures proposed by the environmental economists. But it is rather uncharted a course. And modeling a world of learning agents remains a potential rather than a proven possibility.

The soft perspectives enumerated above show that modeling that does justice to the soft side of land needs to be different from the hard crop modeling of production ecology. It is impossible to develop hard natural laws about human behaviour unless one assumes people's goals, and that is something economists might do, but we explicitly do not want to do. In fact, variability and dynamism in people's goals is an essential aspect of sustainable land use. Given that people's behaviour cannot be captured in laws, and hence in general variables and coefficients which can be used in hard science modeling, we must look for forms of modeling that allow for situated, autonomous, interacting and cognitive actors, whose activities have a collective impact on their environment that lead to system feedbacks from which they can learn.

3. Multi-agent Systems (MAS)

Definitions

Jennings et al (1998) define an agent as:

> "a computer system, situated in some environment, that is capable of flexible autonomous action in order to meet its design objectives".

'Situated' means that the agent receives sensory input from its environment. 'Autonomous' minimally means that the agent is able to act without the direct intervention of humans and has control over its own actions and internal state. In a more expanded sense, autonomy means that agents are capable of learning from experience. 'Flexible' means that agents are (a) responsive to what they perceive in their environment, (b) pro-active in that they are able to exhibit opportunistic, goal-directed behaviour and to take initiative, and (c) social in the sense that agents should be able to interact with other agents and humans in order to complete their own problem solving or help others. 'It is the presence of all these attributes in a single software entity that provides the power of the agent paradigm and which distinguishes agent systems from related software paradigms, such as object-oriented systems, distributed systems and expert systems' (Jennings et al, 1998). It is obvious that agents in the sense used here are cognitive systems (fig. 1).

Agent systems can be composed of a single agent. 'However, the multi-agent case, where the system is designed and implemented as several interacting agents, is arguably more general and more interesting from a software engineering standpoint. Multi-agent systems are ideally suited to representing problems that have multiple problem solving methods, multiple perspectives and/or multiple problem solving entities. Such systems have the traditional advantages of distributed and concurrent problem solving, but have the additional advantage of sophisticated patterns of interaction. Examples of common types of interaction include: co-operation (working towards a common aim), co-ordination (organising problem solving capacity so that harmful interactions are avoided or beneficial interactions are exploited), and negotiation (coming to an agreement which is acceptable to all parties involved). It is the flexibility and high-level nature of these interactions which distinguishes multi-agent systems from other forms of software and which provides the underlying power of the paradigm' (Jennings et al, 1998). These characteristics seem to be MAS simulation eminently suitable for modeling the soft side of land.

Comparison with plant growth models

A first point to establish is that multi-agent modeling works on very different principles from systems modeling thus far prevalent in Wageningen. These other principles have become possible because of the development of such object-oriented computer languages as Smalltalk which focus on classes of objects, on relationships among objects (e.g., inheritance or parentage), and on attributes of (classes of) objects, and which contain procedures for activating interactions among objects. Like Prolog, LISP and other languages used by AI researchers, Smalltalk is designed for tasks that involve manipulating symbols rather than numbers. One can use mathematical equations in combination with agent modeling (e.g., Jansen & de Vries, 1998) but this potential is not dealt with here.

Agent modelling leads to outcomes in the form of visual images that reflect the situation in the 'virtual society', the 'virtual ecosystem' or other simulated situation after a certain number of cycles. Usually the outcome is represented as a matrix of cells with agents situated in the matrix. One can also express the outcome as graphs which show the development of key parameters, such as the mortality of agents, the health of the virtual ecosystem and so on (e.g., Epstein & Axtell, 1996). Since the initial conditions often have some element of randomness (e.g., the assignment of agents to cells or 'patches' on an environmental grid), different runs can have totally different outcomes. In that case, the outcome of agent modeling is an average of the outcomes that is dependent on the decision about the number of runs that is sufficient to establish a pattern.

This aspect of agent modeling has given rise to criticism by game theorists, who claim that agent modeling can lead to spurious conclusions because it is not based on theory. Thus Binmore (1998) critically reviews Axelrod's well known (e.g., Ridley, 1996) claim, based on an evolutionary simulation, that *tit-for-tat* was the most numerous of all the surviving strategies for playing prisoner dilemma games, and therefore a suitable paradigm for human co-operation in a wide range of contexts. After presenting evidence that 'in the long run, mean machines triumph', Binmore concludes that:

> "the simulation data on which Axelrod bases his conclusions is woefully inadequate, even if one thought that his Norms Game were a good representation of the Game of Life in which real norms actually evolve. One simply cannot get by without learning the underlying theory. Without any knowledge of the theory one has no way of assessing the reliability of the simulation, and hence no idea how much confidence to repose in the conclusions that it suggests.... I do not think one can escape from the conclusion that the evidence from computer simulations he offers in support of his ideas has only rhetorical value. His methodology may table some new conjectures that are worth exploring. But such conjectures can only be evaluated in a scientific manner by properly controlled robustness tests that have been designed using a knowledge of underlying theory".

Such criticism is important for our evaluation of the usefulness of MAS for simulating the soft side of land. MAS modeling implies special attention to theory development (see also Gilbert, 1995, below). Such theories need, of course, not be mathematical formula, but they need to be explicit and assessable. For example, the *emergence* of complex system states at the macro level from relatively simple behaviours at the micro level should not be left unexplained (Jennings et al, 1998).

Applications

Multi-agent systems have been developed for applications other than land use (it is CIRAD in France that has pioneered that particular application, as far as this author knows). In their 'roadmap' of agent research and development, Jennings et al. (1998) describe MAS as originating from Distributed Artificial Intelligence (DAI), which has historically been divided into two main camps: Distributed Problem Solving (DPS) and Multi-agent Systems (MAS).

> "DPS considers how a particular problem can be solved by a number of modules, which co-operate in dividing and sharing knowledge about the problem and its evolving solutions. In a pure DPS system all interacting strategies are incorporated as an integral part of the system. In contrast, research in MAS is concerned with the behaviour of a collection of possibly pre-existing autonomous agents aiming at solving a given problem. A MAS can be defined as a loosely coupled network of problem solvers that work together to solve problems that are beyond the individual capacities of knowledge of each problem solver. These problem solvers, agents, are autonomous and may be heterogeneous in nature. The characteristics of MAS are:
>
> - Each agent has incomplete information, or capabilities for solving the problem, thus each agent has a limited viewpoint;
> - There is no global system control;
> - Data are decentralised;
> - Computation is asynchronous." (Jennings et al, 1998).

Although many problems remain, MAS have so far been used in manufacturing, process control, telecommunications systems, air traffic control, traffic and transportation management, information filtering and gathering, electronic commerce, business process management, entertainment and medical care.

Of interest for us (and for economists) is the use of self-interested multi-agent interactions centred around negotiation. This work is still in progress. The main characteristics of negotiation that are taken into account are (Jennings et al, 1998): '(a) the presence of some form of conflict that must be resolved in a decentralised manner, by (b) self-interested agents, under conditions of (c) bounded rationality, and (d) incomplete information'. Zeng & Sycara (1997) presented a Bazaar negotiation model which included multi-agent learning through agent interaction.

> "The benefits of learning, if any, on the individual utilities of agents, as well as the overall (joint) system were examined. The experimental results[3] suggest that: (a) when all agents learn, the joint system utility is near optimal and agents' individual utilities are very similar, (b) when no agents learns the agents' individual utilities are almost equal, but the joint utility is very low, and (c) when only one agent learns, the individual utility increases at the expense of both the individual utility of the other agents as well as the overall joint utility of the system" (Jennings et al, 1998).

The research on self-interested agents seeks to design mechanisms such that if agents follow these mechanisms, the overall system behaviour will be acceptable. This research typically deals with problems such as tragedy-of-the-commons outcomes, oscillatory behaviour, sub-optimal, meta-stable states which persist for long periods, and lack of truthfulness on the part of individual agents (Jennings et al, 1998). This type of research comes very close to the issues we intend to address with respect to modeling the soft side of land.

The use of MAS in social science research

Nigel Gilbert of the Department of Sociology of the University of Surrey, editor of the Journal of Artificial Societies and Social Simulation, has made a major contribution to the understanding of the use of MAS in social science (Gilbert, 1995; Gilbert & Troitzsch, 1999, see also: Conte et al, 1997). Says he:

> "Paradoxically, one of the main advantages in simulation is that it is hard to do. To create a simulation model, its theoretical suppositions need to have been thought through with great clarity. Every relationship to be modelled has to be specified exactly, for otherwise it will be impossible to run the simulation. Every parameter has to be given a value. This

[3] The present author would like to point out that 'experimentation' as used here for *in silico* manipulation of conditions is confusing, especially since he believes that it is crucial to separate (a) theory development, (b) empirical research and (c) computer simulation.

discipline means that it is impossible to be vague about what is being assumed. It also means that the model is potentially open to inspection by other researchers in all its detail" (Gilbert, 1995).

Gilbert also explicitly mentions as a benefit of 'dynamic micro-simulation' that it can be used to explore the long-term macro consequences of individual social action. But using simulation for social science work also has disadvantages:

(a) One needs to estimate many parameters for which no adequate data exist. It is difficult to obtain sufficient data to formulate the model with precision;

(b) Simulations require considerable computational resources. "Models of agents that that communicate with each other and that act on the basis of 'quite sophisticated cognitive processing' require a great deal of computation, as the simulated processes for each agent are complex and have to be activated on each round... simulating inter-agent communication means that as the number of agents is increased, the amount of computation required goes up as the square of the number of agents because each agent can potentially communicate with each other agent. Hence DAI-based simulations tend to involve rather few agents, often not more than about fifty" (Gilbert, 1995). Though computation power has, of course, improved since Gilbert wrote, the experience at CIRAD with CORMAS (see below) seems to lead to the same conclusion. One is typically dealing with a limited number of agents in an 'environment' of a 50x50 matrix, of which the boundaries might either be hard edges, or pasted (i.e., the matrix forms a three-dimensional solid torus).

(c) It is difficult to validate the models built. 'There is an understandable temptation to tinker with the model until it produces results which are close enough to those expected and then to conclude that the model is therefore valid' (Gilbert, 1995). Ideally, a simulation should produce behaviours which match those of the target for all possible inputs, but in practice it is impossible to assess this. This problem reflects the criticism of the work of Axelrod by Binmore (1998) mentioned earlier. Of course, this problems also concerns 'hard' modellers in economics and production ecology.

(d) Gilbert (1995) calls a 'test bed' the platform for simulation which provides a rule interpreter for agents. Usually such test beds are written specifically for simulations and are not easily accessible or available for other researchers. Luckily, CORMAS provides a ready platform for land use simulations, built on Smalltalk language and Visual Works as interface.

On the whole, however, MAS seems a promising approach for social science modeling, a conclusion also drawn for Cellular Automata (CA), a form of modeling that is similar to

MAS but derives from efforts to simulate life, initiated especially by Chris Langton at Santa Fe (e.g., Levy, 1992). Malsch (1997) raises the interesting point that we do not only face the need to formalise sociology by using DAI techniques, but also the need to technologically exploit social metaphors and sociological concepts for the further development of distributed computer systems.

Current status of MAS in Wageningen social science research.
Jacques Weber, the former director of CIRAD-GREEN in Montpellier, an inter-disciplinary unit of CIRAD[4] that has since been re-organised out of existence, was the one whose enthusiasm for MAS inspired this author's interest in the subject. Weber was using a 'patrimonial approach' in Madagascar to help local communities establish negotiated agreements about the management of community forests on the basis of a very long time perspective which featured the interests of the children and grandchildren and used back-casting from that far future to the present to establish agreements on sustainable forest management (Weber, 1996). In this empirical context, he used MAS, not as an alternative for theory development or empirical research, but as an *additional tool* which could help him do thought experiments and possibly establish simple rules of engagement among community actors at the micro level that could help explain the success or failure of community forest management at the macro level.

As a result of this acquaintance with MAS, the Wageningen Department of Applied Computer Science mounted a MSc project (Groenveld, 1998) that used CC+ computer language and Sugarscape software (Epstein & Axtell, 1996) to develop a basic framework for multi-agent modelling. This MSc project also identified a great deal of literature which showed a rapidly increasing world-wide interest in MAS[5]. At the time, the MSc project failed to identify anyone in 'greater Wageningen' who was using MAS. Consequently, the MSc project led the Departments of Applied Computer Science and Communication and Innovation Studies to submit a research proposal to the Mansholt Institute to establish a permanent capacity to do MAS modeling in WUR. The proposal was successful: the submitting departments have each been granted a four year scholarship for a PhD student. At the time of writing, the two research posts had just been advertised and no experience had been gained.

In the mean time, this author participated in a two week course in MAS modeling given by CIRAD in Montpellier by former students of Weber. It trained participants in the use of Smalltalk as an object-oriented computer language, using Visual Works as an interface, and CORMAS (a CIRAD product) as the software platform or test bed (e.g., Bousquet et al, 1996; Bousquet et al, 1998). The training also attracted a PhD student from WUR's

[4] CIRAD: Centre de Coopération Internationale en Recherche Agronomique pour le Développement
[5] Examples are: Epstein & Axtell, 1996; Gilbert & Troitzsch (1999), Conte et al (1997), and Jennings et al (1998). Journals are Autonomous Agents and Multi-Agent Systems (see references) and the Journal of Artificial Societies and Social Simulation (see references).

Department of Development Economics who had become acquainted with MAS and Smalltalk through LEI/DLO. Later it turned out that one of the researchers from LEI/DLO, Dr A. Ligtenberg, had been seconded part-time to WUR's Department of Land Surveying and Remote Sensing. He has made a proposal to the 'Knowledge Unit Social Sciences' for using Cellular Automata and Multi-agent Simulation for actor-directed land use models.

Those at WUR who are interested in MAS intend to co-ordinate their activities. Given the incipient stage of development of MAS at WUR, this paper cannot go beyond providing a preliminary impression of the potential of MAS for modeling the soft side of land based on the MSc project, available literature and the CIRAD course.

Impressions from the CIRAD course

A two week course in rapid French of which the present author picks up say 75% is admittedly no basis for definitive judgement about the usefulness of MAS, especially if one takes into consideration the fact that the present author uses computers in the same way his father used an automobile. It remains a strange and not completely trustworthy gadget that might explode in his face anytime. But perhaps these two handicaps provide a more acid test for the usefulness of MAS simulation as a robust tool than the assessment of a whiz kid who is used to clicking away.

The course has now been given a number of times, in English in the autumn of 1999 in Bangkok. This means that CORMAS itself has also been translated. Before one was faced on the screen with a strange mixture of English derived from Smalltalk and Visual Works, and French derived from CORMAS. The course consists of a number of blocks:

(a) Theoretical introductions into complexity and the management of resources, modeling, systems (attractors, differential systems), resource management models, cellular automata, agents and multi-agent systems, etc.;
(b) Demonstrations of existing models such as an effort to explore a hypothesis of Jacques Weber about the non-linear relationship between forest cover and population with a Malthusian and a Boserupian outcome; Sugarscape; SeaLab, an analysis of the behaviour of pelagic fishes and the factors that influence the choice between an obstinate strategy looking for the same environmental conditions as during birth, and an opportunist strategy to find optimal environmental conditions (Bousquet, 1994); and Barreteau's (1998) doctoral work on the viability of small scale irrigation schemes in Podor, Senegal;
(c) Practical work behind the computer in using Smalltalk, Visual Works and later CORMAS behind the computer in groups of two;
(d) Teamwork by pairs of participants to build a working simulation for a simple problem. The resulting models were presented to the whole group at the end of the course.

CORMAS is a platform for using Smalltalk and Visual Works. It is designed to make it easy to do multi-agent modeling. It has three types of entities: spatial, social, and passive. It provides ready protocols for the operation of models. It contains examples of models from which whole sections of programme can be copied. A simulation like Sugarscape which took two months for a 'stagiaire' to do from scratch (we had a similar experience in Wageningen), took only half a day with the existing structure of CORMAS.

CORMAS seems easy to use. The present author did his practical work together with an agronomist with considerable computer skills who was in fact a trouble shooter for computer problems in her department. The practical work lasted no more than two days in all. At the end, we had a fairly complex model up and working, though not without with considerable help from the course facilitators. The logic of Smalltalk is difficult to grasp at first and will need much more time to learn so well that one can carry out simulations independently.

The logic of CORMAS itself is somewhat easier to grasp but still requires a rigorous understanding of the process of defining, first, classes of objects (spatial, social or passive) in terms of their attributes, procedures, initialisations and dynamics; second the preparation of the control and evolution of the running of the model; and third the preparation of the observation of the simulation in terms of the grid, the symbols used, etc. All the young PhD candidates at CIRAD who were working with CORMAS seemed to need regular help from the pros. Developing a capacity for MAS modeling at WUR would assume support from professionals thoroughly versed in agent modeling.

The demonstration of models that had been developed by CIRAD researchers was interesting because it showed some strengths and weaknesses of MAS modeling. It seems that simulations should not be used to closely reflect an empirical situation. Modeling should focus instead on making clear particular aspects or relationships. Modeling should also not be looked upon as stand-alone research, but as a support of empirical research and theory development. Finally, the demonstrations showed the crucial importance of defining clearly what one wants to achieve. In fact, modeling requires a careful design of the modeling in terms of the major theoretical perspectives, and in terms of the detailed steps required to develop the model. This phase tends to be neglected in the hurry to get to the modeling itself, but seems crucial if one wants to avoid creating a model that 'works' but that has lost its meaningful scientific purpose.

4. The interactive use of MAS

By interactive use of MAS we mean the use of MAS *with* students, stakeholders in a resource, or the people whose behaviour one tries to model. Such interactive uses have been studied for example for GIS (e.g., Lansing, 1991; Gonzalez, in prep.). Barreteau (1998) has tried to use MAS interactively but found the interface too complex. He opted instead to develop a role-playing simulation game based on the results of his modeling of the social factors affecting the viability of small-scale irrigation schemes. He thus brings into practice the distinction that Chapman (1987) makes between gaming simulation, which involves role playing by 'live people', such as for example Africulture (Chapman, Jiggins & De Zeeuw, 1990) and *in silico* simulation of agents' behaviour.

Dörner (1996) of Bamberg University in Germany has identified a very important use to which MAS could be adapted. His interesting study of how people handle complex problems in interaction with computer simulated complex environments has shown how difficult people find it to actually deal with complex situations. His findings illuminate the psychological factors that bear upon human planning and decision making. His book is called 'The Logic of Failure' and shows that 'complicated situations (here simulated on the computer NR) seem to elicit habits of thought that set failure in motion from the beginning. From that point, the continuing complexity of the task and the growing apprehension of failure encourage methods of decision making that make failure even more likely and then inevitable' (Dörner, 1996:10). Given that people trained in agricultural science are increasingly likely to have to deal professionally with complex eco-systems with an important 'soft' element, it seems important to explore the use of MAS for purposes of training students in managing complex systems. Such training will need to follow Dörner's approach in which he and his colleagues provided a living interface between the person and the computer programme.

5. Conclusions

MAS seems to be an area of computer simulation that is very promising for WUR research and teaching in social science, interactive land use design, and sustainable agriculture. In fact, it is to be expected that, in future, such research and teaching might be unthinkable without MAS. That is, it is highly likely that (a) theory development, and (b) empirical research, now the main ingredients of work on the soft side of (sustainable) land use, will in future be complemented by (c) multi-agent modeling.

However, there are still many problems ahead. Designing and building agent systems is difficult. 'Most extant agent system applications are built by, or in consultation with, designers and developers who are themselves active in the agent research community' (Jennings et al ,1998). That is why this author has insisted that MAS applications in WUR social science and land use planning departments be developed in co-evolution with agent research at the Department of Applied Computer Science.

In their recent overview, Jennings et al (1998) also mention major technical impediments to the widespread adoption of agent technology: (a) the lack of a systematic methodology enabling designers to clearly specify and structure their applications of multi-agent systems, and (b) the lack of widely available multi-agent toolkits which industries can adopt and use relatively easily for a range of applications. 'The former means that most extant applications have been designed in a fairly ad-hoc manner... what is required is a systematic means of analysing the problem, of working how it can best be structured as a multi-agent system and of determining how the individual agent can be structured'. We feel that this issue will require considerable attention if we want to use MAS in a credible manner. Thinking through 'thought experiments' in virtual societies through MAS requires careful and transparent theoretical specification. But we feel that this, in fact, is one of the greatest benefits of using MAS, especially in social science.

The second impediment, the lack of toolkits mentioned by Jennings et al (1998), for our area of application (sustainable land use) seems to have been at least initially solved by the development of CORMAS by CIRAD. CORMAS can be used by everybody and contributions to its further development by whoever can make them, is welcomed by its developers.

In all, this author feels that MAS modeling offers a practical contribution to the Wageningen work on social agronomy, the soft side of land, actor oriented sociology, interactive land use planning and interactive design of sustainable agriculture, that we can not afford to ignore. In fact, our review suggests that MAS modeling is able to take into account the social mechanisms which were identified in section 3 as characterising the soft side of land, and to explore artificial societies to identify the key factors involved in agents, and human actors, learning to use the land in a sustainable manner.

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Chapter 7

A methodical way of prototyping integrated and ecological arable farming systems (I/EAFS) in interaction with pilot farms *

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Abstract

A methodical way of prototyping Integrated and Ecological Arable Farming Systems (I/EAFS) in interaction with pilot farms is presented. It concerns a comprehensive and consistent approach of 5 steps. Step 1 is establishing a hierarchy of objectives considering the shortcomings of current farming systems in the region. Step 2 is transforming the objectives in a set of multi-objective parameters, to quantify them and establishing a set of multi-objective farming methods to achieve them. Step 3 is designing a theoretical prototype by linking parameters to farming methods and designing the methods in this context until they are ready for initial testing.

Step 4 is laying out the prototype on at least 10 pilot farms in appropriate variants and testing and improving the prototype (variants) until the objectives, as quantified in the set of parameters, have been achieved (after repeated layout). Step 5 is disseminating the prototype (variants) to other farms with gradual shift in supervision from researchers to extensionists.

This methodical way is being elaborated and tested by a European network of more than 20 research teams, sponsored by the European Union (AIR-concerted action). The teams express their achievements in a consistent set of 6 parts of an identity card of their prototype. The 6 parts of the EAFS-prototype of the author's team are presented to illustrate the methodical way. Part 6 presents the state of the art. It shows that the results desired are progressively being achieved, which may be considered as the best proof of the effectiveness of prototyping.

1. Introduction

The European Union (EU) is facing an agricultural crisis with two major symptoms: deterioration of rural income and employment and deterioration of environment, nature and landscape. The basic mechanism is a continuous intensification causing surplus production and price fall on the one hand and ecological deterioration on the other hand. Therefore, a

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crucial question for the Common Agricultural Policy (CAP) is to alleviate the symptoms of intensification on the short term and to find a sustainable solution on the long term. In the early 1990s, various EU-countries started promoting Integrated Farming Systems to alleviate the agricultural crisis, when drastic reductions in inputs of pesticides and fertilisers were achieved with initial prototypes on experimental farms. Subsequently, in 1993 the EU decided to sponsor a network of research teams on prototyping Integrated Arable Farming Systems (IAFS). The setting up of the network should be combined with development and standardisation of the methods of prototyping in a concerted action within the third EU framework programme for agricultural research.

The objective of this paper is to explain and illustrate the methods of prototyping as developed by the research network. Most research teams joined the network to develop IAFS prototypes feasible for the main group of farms. This group must try to be competitive on the world market, based on high and efficient production, and this gives only limited scope for pursuing non-marketable objectives such as environment, and nature/landscape. Therefore, a more consistent integration is needed for such long term objectives. Consequently, many research teams also or exclusively develop an IAFS for the long term, albeit that this IAFS is as yet only feasible for pilot groups of farms. Contrary to short-term IAFS, these long-term IAFS place income/profit subordinate to environment, and rely on ecologically-aware consumers willing to pay premium prices for food products with high added value and a credible label.

In the short-term IAFS, Chemical Crop Protection is minimised to the benefit of the environment (Integrated Crop Protection). In the long-term IAFS, Chemical Crop Protection is fully replaced by a package of non-chemical measures, to achieve ambitious objectives in environment, nature/landscape and quality and sustainability of food supply. So, long-term IAFS are based more on ecological awareness and knowledge than short-term IAFS. Therefore, our prototypes of long-term IAFS are simply called EAFS (Ecological Arable Farming Systems), and short-term IAFS are referred to as IAFS.

Organic systems can be considered to be a forerunner of EAFS, but they have no quantified objectives in environment and nature/landscape and as a result, they need to be considerably improved to become acceptable to the majority of consumers. Nevertheless, organic farming has a strategic significance to Europe because it is the first example of the market model of shared responsibility of consumers and producers for the rural areas. Therefore, many research teams are collaborating with a pilot group of organic farms which have primarily been selected for their willingness to achieve more than is required by current minimal guidelines of the EU organic label.

Selected on a set of general and specific criteria, 22 research teams from 14 EU and 3 associated countries have been brought together into the network, since the start in 1993 (Fig. 1). Together they invest more than 30 scientist years per annum in prototyping. This paper focusses on a methodical way of 5 steps developed within the network as a common frame of reference for prototyping I/EAFS. The consecutive steps are presented and illustrated by the state of the art of the author's own project on EAFS with a group of pilot farms (NL 2), started in 1991.

2. Methodical way of prototyping I/EAFS (5 steps)

Building on initial experience with an experimental farm at Nagele (Vereijken, 1992) and the input of the research leaders from the network, prototyping of I/EAFS has been elaborated in a methodical way of 5 formal steps (Vereijken, 1994, 1995, 1996). (Outline 1). The outcome of these 5 steps is expressed in parts of an identity card for the prototype to facilitate the cooperation within the team and the exchange with the other teams in the network. In the following sections the 5 steps are explained in more detail and illustrated by the various parts of the identity card of our prototype EAFS for the central clay region in The Netherlands (NL 2).

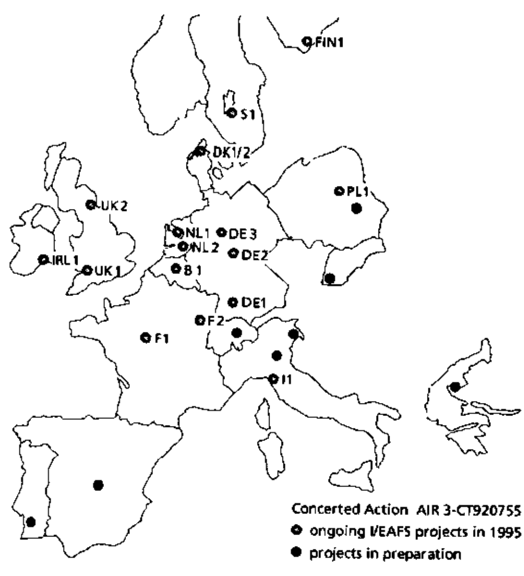


Figure 1. European network of research teams prototyping I/EAFS

Outline 1. Methodical way of designing, testing, improving and disseminating prototypes of Integrated and Ecological (Arable) Farming Systems (I/EAFS).

(1) *Hierarchy of objectives:*
making a hierarchy in 6 general objectives, subdivided into 20 specific objectives as a base for a prototype in which the strategic shortcomings of current farming systems are replenished (Part 1 of the identity card of a prototype).

(2) *Parameters and methods:*
transforming the major specific objectives (10) into multi-objective parameters to quantify them, establishing the multi-objective farming methods needed to achieve the quantified objectives (Part 2 of the identity card).

(3) *Design of theoretical prototype and methods:*
designing a theoretical prototype by linking parameters to farming methods (Part 3 of the identity card), designing methods in this context until they are ready for initial testing (Multifunctional Crop Rotation as major method and Part 4 of the identity card).

(4) *Layout of prototype to test and improve:*
laying the prototype out on an experimental farm or on pilot farms in an agro-ecologically appropriate way (Part 5 of the identity card), testing and improving the prototype in general and the method in particular until (after repeated laying out) the objectives, as quantified in the set of parameters, have been achieved. (Part 6 of the identity card).

(5) *Dissemination:*
disseminating the prototype by pilot groups (< 15 farmers), regional networks (15 - 50 farmers) and eventually by national networks (regional networks interlinked) with gradual shift in supervision from researchers to extensionists.

Hierarchy of objectives (step 1)

Table 1 presents 6 general values or interests involved in agriculture, each subdivided into 3 or 5 specific values or interests. The first step for prototypists of farming systems is to establish a hierarchy of objectives within this framework, taking into account the shortcomings of farming systems in the region and the targeted contribution the prototype should deliver to improve the situation in the short term (IAFS) or the long term (EAFS).
The procedure is simple: in the first round the general objectives are rated from 6 to 1 in descending order of importance. In the second round the specific objectives within each general objective are rated from 3 to 1 in descending order of importance (in food supply by 3, 2, 1, 0, 0 because there are 5 specific objectives, not 3).

By this procedure the author's team has drawn up the hierarchy of objectives as step 1 in pilot project NL 2 (Fig. 2). It clearly shows we want to prototype an EAFS, building forth on organic farming as a forerunner and improving it on 3 strategic shortcomings: nutrient management, care of nature and landscape and quality production.

This hierarchy of objectives should not be considered as just the vision of our prototyping team. Though we proposed it, the group of pilot farms has taken it over after ample discussions during several study meetings. In our experience, the hierarchy of objectives is a simple and effective instrument to achieve consensus between researchers and farmers. It could also be a good instrument to achieve consensus if more parties would be involved, such as organisations of consumers or environmental groups. In that case a useful procedure would be to first let the various parties draw up their own hierarchy of objectives. Secondly, the various hierarchies should be highlighted and critically examined. Thirdly, a common hierarchy of objectives should be negotiated, based on a thorough weighting of the various arguments and sealed by a memorandum of mutual understanding or rather an agreement of cooperation and mutual support.

Table 1. General and specific social values and interests involved in agriculture*

Values and interests (not in order of importance)			
General	Specific	General	Specific
Food supply		Abiotic environment	
	quantity		Soil
	quality		Water
	stability		Air
	sustainability		
	accessibility	Nature/Landscape	
Employment			Flora
	farm level		Fauna
	regional level		Landscape
	national level	Health/Well-being	
Basic income/Profit			farm animals
	farm level		rural people
	regional level		urban people
	national level		

* Simplified from (Vereijken, 1992)

In Flevoland (NL 2) abiotic environment is the main objective, ahead of nature/ landscape and food supply.

Although pesticides have been abandoned, abiotic environment remains of primary concern since soil fertility in EAFS is chiefly maintained by recycling organic waste, especially manure. Because organic fertilisers generally contain nutrients in ratios which do not correspond with the crop needs, accumulation and eventually leaching of certain nutrients can only be avoided by sophisticated nutrient management focusing on agronomically desired and ecologically acceptable nutrient reserves in the soil.

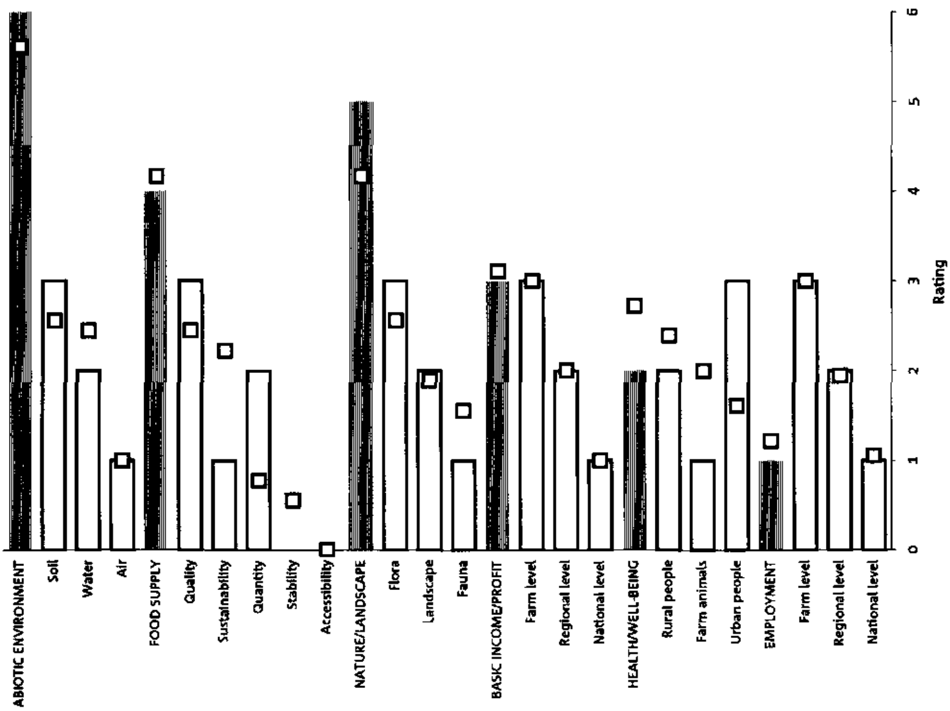


Figure 2. Hierarchy of objectives in EAFS prototyping in Flevoland (NL 2) as an example of Part 1 of a prototype's identity card in the I/EAFS-Network (squares - average of 9 European EAFS prototypes, rating explained in text).

Nature/landscape is the second main objective, since current organic farming has no explicit guidelines and technology for this increasingly scarce commodity. An ecological infrastructure will overcome this shortcoming and stimulate ecologically-aware consumers to switch to ecological products. In Flevoland, development of an ecological infrastructure will focus on vegetation of the ditch sides, attractive to man and animals.

Table 2. Parameters and methods in EAFS prototyping in Flevoland (NL 2) as an example of Part 2 of a prototype's identity card in the I/EAFS-Network

Top 10 of objectives	Top 10 objectives quantified in multi-objective parameters (defined in outline 2)	Top 10 objectives achieved by multi-objective farming methods (defined in outline 2)
1. Abiotic environment-Soil	1.1 EEP-soil = 0	1.1 - 1.4 MCR
	1.2 20 < PAR < 30 * PAB > 1 if PAR < 20 PAB < 1 if PAR > 30 **	1.2 - 1.4 ENM
	1.3 x < KAR < y * KAB > 1 if KAR < x KAB < 1 if KAR > y **	
	1.4 PNL (0-100 cm) < 70 kg ha^{-1}	
2. Nature/Landscape - Flora	2.1 INRI > 5% farm area	2. INR (target species sowing included)
	2.2 PSD > 50 INR^{-1} of a farm	
	2.3 PSDN> 20 INR $section^{-1}$ (100 m)	
3. Food supply - Quality	3.1 QPI > 0.9 $crop^{-1}$	see 1
4. Abiotic environment - Water	4.1 EEP-water = 0	see 1
	4.2 ANL < 11.2 mg l^{-1} (EU-norm) see 1	
5. Nature/Landscape - Landscape	5.1 FDI > 10 flowers m^{-1} (Apr-Oct)	see 2 (bird habitats included)
	5.2 SED> 7 per farm see 2	
6. Basic income/Profit - Farm level	6.1 NS > 0	6.1 FSO
	6.2 HHW < 25 hours ha^{-1} see 3	see 1 and 2
7. Food supply - Quantity	see 3	see 1 and 2
8. Health/Well-being - Urban people	see 1-6	see 1 and 2
9. Basic income/Profit - Reg. level	see 1-6	see 1, 2 and 6
10. Abiotic environment-Air	10.1 EEP-air = 0(see 1)	see 1
	Total parameters: 12 EU, 4 local	Total methods: 4 EU, 0 local

* Pw and K counts are the usual parameters of Available Reserves of P and K in the Netherlands.

For K the optimum range depends on clay and organic matter contents and varies from farm to farm.

** If actual PAR or KAR is in optimum range, PAB or KAB = 1.

Food supply is the third main objective, with the focus on an optimum balance of quantity and quality, as an indispensable basis for basic income/profit and health/well-being. This balance, called quality production, requires new and sophisticated technology, including a multifunctional crop rotation as a major substitute for external inputs, notably pesticides.

Parameters and methods (step 2)

Having put the objectives in a hierarchy prototypists need to transform them into a suitable set of parameters to quantify them. Subsequently, the quantified objectives are used as the desired results at the evaluation of the prototypes. Prototypes are tested and improved until the results achieved match the desired results.

Given the overwhelming number of parameters available, there are two major reasons for not using a large set. Firstly, using a large set is time-consuming and expensive. Secondly, doing so does not assure that the objectives are integrated which is crucial because the objectives may conflict in many ways. Consequently, prototypists must first identify a limited set of multi-objective parameters, to ensure that the objectives are integrated sufficiently. Additionally, they must establish a set of specific parameters for those objectives that are not or only insufficiently integrated by the set of multi-objective parameters.

To develop I/EAFS prototypes in which potentially conflicting objectives are sufficiently integrated, prototypists need a suitable set of farming methods and techniques. Current methods and techniques mostly serve one or two of the set of objectives and harm the others. Chemical crop protection is a clear example. Therefore, it should first be looked for integrating methods and techniques which bridge the gaps between conflicting objectives and are not harmful to the others. Additionally, specific methods may be established aimed at major specific objectives that are insufficiently covered by the set of integrating methods.
In this way the authors's team has quantified the objectives and established the methods as step 2 in pilot project NL 2 (Table 2). In the first column of Table 2 the top 10 of specific objectives is listed, drawn up from the hierarchy of objectives (Fig. 2) by multiplying the ratings of the specific objectives by the ratings of the general objectives which they belong to. In the second column of Table 2, the top 10 of specific objectives has been transformed into and quantified by a set of 16 parameters, of which 12 are on a shortlist of the I/EAFS network and 4 have a local status. In the third column of Table 2 the 4 farming methods are listed, needed to achieve the top 10 of specific objectives, as transformed into the set of 16 parameters. The 16 parameters and 4 methods are briefly defined in Outline 2.

Outline 2 Brief definitions of the 16 parameters and 4 methods used to quantify and achieve the top 10 of specific objectives for the prototype EAFS in NL 2 (as listed in Table 2).

A. Parameters

1.1. Environment Exposure to Pesticides-soil (EEP-soil) = active ingredients (kg ha^{-1}) * 50% degradation time (days).

1.2. P Available Reserves (PAR) = Pw count in NL = mg l-1 P2O5 in the cultivated soil layer, 1:60 extracted with water. P Annual Balance (PAB) = P input / P output.

1.3. K Available Reserves (KAR) = K-count in NL = mg K2O in 100 gram air-dry soil from the cultivated layer, 1:10 extracted with 0.1 n HCl. K Annual Balance (KAB) = K input / K output.

1.4. Potential N Leaching (PNL) = kg ha-1 Nmin in the soil layer 0 - 100 cm at the start of the period of precipitation surplus, e.g., N leaching.

2.1. Infrastructure for Nature and Recreation Index (INRI) = share of farm area managed as a network of linear and non-linear habitats and corridors for wild flora and fauna, including buffer strips.

2.2. Plant (target) Species Diversity (PSD) = number of species/INR of a farm, with conspicuous flowers by colour and/or shape, attractive for fauna and recreationists.

2.3. Plant (target) Species Distribution (PSDN) = mean number of target species/100 m of INR.

3.1. Quality Production Index (QPI) crop $product^{-1}$ = Quality Index (QI) * Production Index (PI) crop $product^{-1}$ = (achieved price kg^{-1}/top quality kg^{-1}) * (on market kg ha^{-1}/on field kg ha^{-1}) crop $product^{-1}$. ($0 \leq QPI \leq 1$)

4.1. Environment Exposure to Pesticides-water (EEP-water) = EEP-soil * mobility. (Mobility = Kom-1 and Kom = partition coefficient of the pesticide over dry matter and water fractions of the organic matter fraction of the soil).

4.2. Actual N Leaching (ANL) = mg l^{-1} Nmin in drainage water, mean for period of precipitation surplus.

5.1. Flower Density Index (FDI) = mean number of flowers/m/month of Infrastructure Nature/ Recreation.

5.2. Side-Elements Diversity (SED) = number of small landscape elements diversifying the INR.

6.1. Net Surplus (NS) = total returns minus all costs, including an equal payment of all labour hours.

6.2. Hours Hand Weeding (HHW) = mean number of hours ha^{-1} in hand weeding.

10.1. Environment Exposure to Pesticides-air (EEP-air) = active ingredients (kg ha^{-1}) * vapour pressure (Pa at 20 - 25°C).

B. Methods

1.1.-1.4. Multifunctional Crop Rotation (MCR) = a farming method with such alternation of crops (in time and space) that their vitality and quality production can be put safe with a minimum of remaining measures or inputs.

1.2.-1.4. Ecological Nutrient Management (ENM) = a farming method with such tuning of input to output of nutrients, that soil reserves fit in ranges, which are agronomically desired and ecologically acceptable.

2. Infrastructure for Nature and Recreation (INR) = such layout and management of a network of landscape elements, that it is accessible and livable to wild flora and fauna and attractive to urban and rural recreationists.

6.1. Farm Structure Optimisation (FSO) = a mostly indispensable method to render an agro-ecologically optimal prototype also economically optimal, by establishing the amounts of land, labour and capital goods, which are minimally needed to achieve the desired Net Surplus.

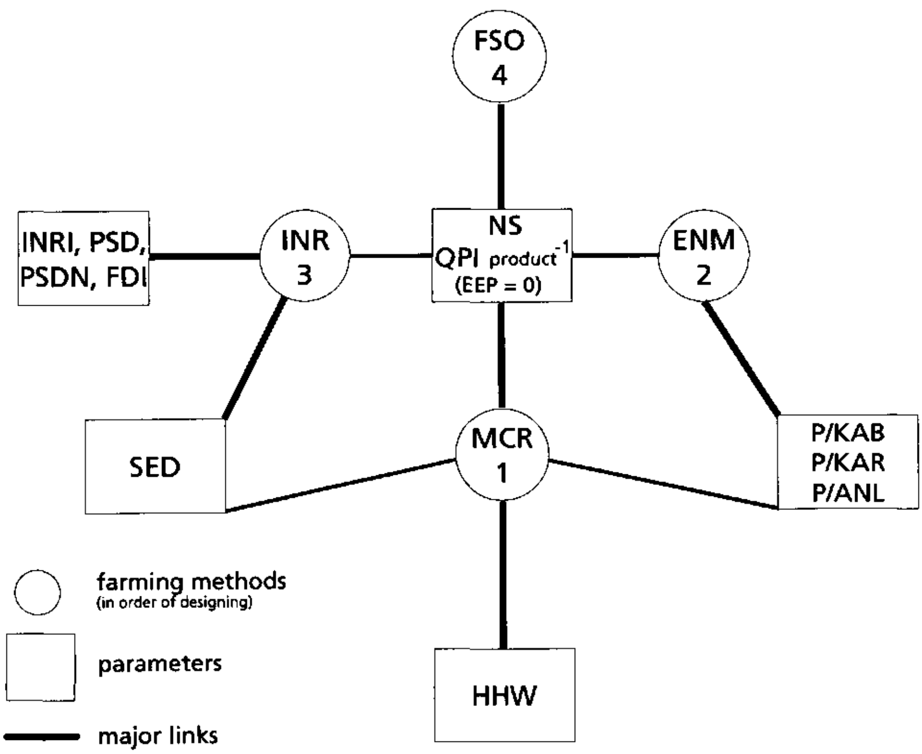


Figure 3. Theoretical prototype for EAFS in Flevoland (NL 2) as an example of Part 3 of a prototype's identity card in the I/EAFS-Network (see Outline 2 for explanation of parameters and methods).

Design of theoretical prototype and methods (step 3)

Most of the methods of the European shortlist have to be designed or redesigned, because they are non-existent or not ready for use. However, they cannot be designed independently from each other and in arbitrary order, because they should be multi-objective and should achieve the set of objectives quantified by the set of parameters within a consistent farming system and by mutual support. Consequently, in step (3) we first establish major and minor links between the methods and the parameters they should help to achieve in a theoretical prototype before proceeding with designing the methods in their appropriate context.

In this way we have designed a theoretical prototype and the methods in this context as step 3 in pilot project NL 2 (Fig. 3). This theoretical prototype shows the major and minor methods needed to achieve the desired results for each objective, e.g., for each parameter. Vice versa, it also shows which parameters are supported by a method and thus indicates the potential impact of a method. Consequently, the theoretical prototype defines the context and the order of designing the methods.

In Flevoland, the major 10 objectives as quantified in 16 parameters are achieved by 4 multi-objective methods and made ready for use in the order that follows.

(1) Multifunctional Crop Rotation (MCR) is the major method to achieve desired results in Quality Production Indices (QPI product^{-1}) without using pesticides (EEP=0), Net Surplus (NS), Hours Hand Weeding (HHW) and Soil compaction Risk Index (SRI). It is also a method supporting P and K Annual Balance (P/KAB), P and K Available Reserves (P/KAR), N Available Reserves (NAR), N Drainage Water (NDW) and Bird Species Diversity (BSD).

(2) Ecological Nutrient Management (ENM) is the major method to achieve desired results in P and K Annual Balances, P and K Available Reserves, N Available Reserves and N Drainage Water. It is also a method supporting Quality Production Indices (without using pesticides) and Net Surplus.

(3) Infrastucture for Nature and Recreation (INR) is the major method to achieve desired results in Infrastructure for Nature and Recreation Index (INRI), Bird Species Diversity, Plant Species Diversity (PSD) and local parameters of flora: Plant Species Distribution (PSDN) and Flower Density Index (FDI). It is also a method supporting Quality Production Indices and Net Surplus.

(4) Farm Structure Optimisation is the finalising method to achieve the desired result in Net Surplus, if the current amounts of land, labour or capital goods of a pilot farm fail to do so with the agronomically and ecologically optimised prototype EAFS. Currently, it is not clear if FSO is needed. Therefore, it is not developed yet.

In all theoretical prototypes of the I/EAFS-Network, Multifunctional Crop Rotation (MCR) plays a central role as a major method to achieve desired results in the multi-objective parameters of soil fertility and environment (SRI, EEP, P/KAR etc.), as well as in the Quality Production Indices (QPIs product^{-1}) and the major parameters of economic and labour efficiency (NS and HHW). Consequently, MCR should be designed primarily to provide for a well-balanced 'team' of crops requiring a minimum of inputs that are polluting and/or based on fossil-energy (nutrients, pesticides, machinery, fuel) to maintain soil fertility and crop vitality as a basis for quality production (Outline 3).

Outline 3. Procedure of designing a Multifunctional Crop Rotation (MCR) for I/EAFS.

(A) Identifying and characterising potential crops for your region or farm:
- making a list of crops (set-aside included) in diminishing order of marketability and profitability (≥ 6 crops for IAFS and ≥ 8 crops for EAFS);
- characterising the crops in their potential role in the MCR in biological, physical and chemical terms, as is done in Table 3A.

(B) Drawing up an MCR based on (1) and simultaneously fulfilling a multi-functional set of demands:
- filling the first rotation block with crop no. 1.;
- filling subsequent blocks while preserving biological soil fertility by limiting the share per crop species to ≤ 0.25 in IAFS and ≤ 0.167 in EAFS and the share per crop group to ≤ 0.50 in IAFS and ≤ 0.33 in EAFS;
- filling subsequent blocks, while preserving physical soil fertility by consistently scheduling a crop with a high rating of soil cover (erosion-susceptible soils) or effect on soil structure (compaction-susceptible soils) after a crop with a low rating, overall the MCR resulting in a soil cover ≥ -1 in IAFS and = 0 in EAFS and a soil structure ≥ -1 in IAFS and ≥ 0 in EAFS (ratings explained below Table 3);
- filling subsequent blocks while conserving chemical soil fertility by consistently scheduling a crop with a high rating of N transfer before a crop with a high rating of N need and a crop with a low N transfer before a crop with a low N need, overall the MCR resulting in an N need ≤ 3 in IAFS and ≤ 2 in EAFS;
- filling single blocks by 2 or 3 crops with corresponding characteristics, if needed for reasons of limited labour capacity or limited market demand;
- ensuring crop successions are feasible in terms of harvest time, crop residues and volunteers from preceding crops.

Being the central method, and also the first to be designed, MCR is an appropriate Part 4 of the identity card, after theoretical prototype as Part 3.

Table 3 presents the MCR of one of the 10 pilot farms in NL 2 as an example of Part 4 of the identity card of an EAFS prototype. Format A first presents the selection of the most profitable crops eligible for the MCR of the pilot farm in question, with their major characteristics concerning biological, physical and chemical soil fertility. Subsequently, format B presents the MCR which optimally complies with the multifunctional set of demands.

Table 3. Multifunctional Crop Rotation for EAFS in Flevoland (NL 2) as an example of Part 4 of a prototype's identity card in the I/EAFS-Network A. Selection of crops by pilot farm 6 (crops in order of profitability). See next page for explanation of notes.

A. Selection of crops by pilot farm 6 (crops in order of profitability).

crop no.	biological		physical (ratings)				Chemical (N ratings)	
	species	group[1]	cover[2]	rooting[3]	compaction[4]	structure[3] +4	uptake[5]	transfer[6]
1	carrot	umbel.	-2	1	-4	-3	4	1
2	potato	solan.	-2	1	-2	-1	5	2
3	onion	lil.	-4	1	-2	-1	4	1
4	celeriac	umbel.	-2	1	-4	-3	4	1
5	sugar beet	chen.	-2	1	-4	-3	5	1
6	pea, bean	leg.	-2	2	-1	1	0	2
7	wheat	cer.	-2	3	-1	2	4	1
8	oats	oats	-2	3	-1	2	3	1
9	barley	cer.	-2	3	-1	2	3	2
10	Grassclover	leg.	0	3	-1	2	2	2
mean of crop selection			-2.0	1.9	-2.1	-0.2	3.4	1.4

B. Multifunctional Crop Rotation of pilot farm 6.

block no.	Crop No.	biological		physical (ratings)		Chemical (N ratings)		
		species	group[1]	cover[2]	structure 3+4	uptake[5]	transfer[6]	need[7]
I	1/5	carrot/sugar beet	umbel./chen.	-2/-2	-3/-3	4/5	1/1	3/4
II	6	pea, bean	leg.	-2	1	0	2	-1
III	2	potato	solan.	-2	-1	4	2	2
IV	10	grassclover	grass/leg.	0	2	2	2	0
V	3/4	onion/celeriac	lil./umbel.	-4/-2	-1/-3	4/4	1/1	2/2
VI	7	wheat	cer.	-2	2	4	1	3
VII								
VIII								
Mean of crop rotation		share species^{-1} ≤ 0.167	share group^{-1} ≤ 0.25	-1.8	-0.2	3.2	1.5	1.6

1) Genetically and phytopathologically related groups, such as cereals, legumes, crucifers and chenopodes, composites, umbellifers, liliaceae. All subsequent blocks of perennial crops are counted as 1 block.
2) No cover in autumn and winter = -4, no cover in autumn or winter = -2, all others = 0 (green manure crops included).
3) Cereals, grasses and lucerne = 3, root, bulb and tuber crops = 1, all others = 2 (green manure crops included).
4) Compaction by mowing in summer = -1 and autumn = -2, lifting in summer = -2 and in autumn = -4.
5) N uptake by crop from soil reserves: legumes = 0. All other crops: 25-50 kg ha-1 = 1, 50-100 kg ha-1 = 2, 100-150 kg ha-1 = 3, 150-200 kg ha-1 = 4, etc.. (N uptake = N product + N crop residues).
6) N transfer is the expected net contribution of N to subsequent crop, based on N residues in the soil after harvest, N mineralisation from crop residues and N losses by leaching and denitrification. In this rating, the effect of green manure crops should be included. N transfer < 50 kg ha-1 = 1, 50-100 kg ha-1 = 2, 100-150 kg ha-1 = 3.
7) N need (block x) = N uptake (block x) minus N transfer (block x-1). N need is net N input to be provided by manure or N fertiliser.

Layout of prototype to test and improve (step 4)

Step (4) implies testing and improving the prototype until the objectives as quantified in the set of parameters have been achieved. Because it is the most laborious and expensive step, requiring at least a full rotation of the prototype on each field (4-6 years for IAFS-EAFS), it is crucial that all preceding steps have been followed with the greatest accuracy. Therefore, it is useful to take a critical retrospective view before proceeding to step (4):

- does the hierarchy of objectives really cover the shortcomings of conventional arable farming (IAFS) or organic farming (EAFS) in the target region (not too low ratings for 'new' objectives such as nature and too high ratings for 'old' objectives such as basic income/ profit to ensure that one is really innovating and not just slightly ahead of the main group of farmers) (step 1)?
- have the objectives really been transformed in the appropriate set of multi-objective parameters (not too few but certainly not too many parameters!) and has each objective been quantified appropriately (not more but certainly not less ambitious than needed) and has the appropriate set of methods been established (not too many single-objective and too few multi-objective methods) (step 2)?
- should the theoretical prototype be redesigned to link up with possible changes in the first two steps (step 3)?

Testing a prototype means laying it out on an experimental farm or on a group of pilot farms and ascertaining if the results achieved correspond with the desired results.

If all the methods of the theoretical prototype have been designed, an initial layout is not very complicated in the case of an experimental farm, providing a possible supervising committee and the farm manager think it acceptable and manageable. However, much more time is generally needed to come to a first layout for pilot farms (Outline 4).

Outline 4. Preparations to come to a first layout of a theoretical prototype on pilot farms.

(1) Forming a pilot group:
- generating interest by articles in agricultural periodicals or by public meetings;
- inviting potential pilot farmers to attend study meetings;
- selecting pilot farmers according to general criteria such as being full-timers on farms of sufficient size, having appropriate production activities, being located in the region, having a particular soil type etc., but also according to agro-ecological criteria such as field adjacency and field size.

(2) Making a variant of the prototype for each pilot farm, in interaction with the farmer:
- variant of Multifunctional Crop Rotation (in time and space);
- variant of Integrated or Ecological Nutrient Management;
- variant of Ecological Infrastructure Management;
- etc.

The basic task of I/EAFS designers, to replace physico-chemical methods by biological methods and techniques, requires an appropriate concept:

I/EAFS is an agro-ecological whole consisting of a 'team' of steadily interacting and rotating crops, plus their accompanying (beneficial or harmful) flora and fauna.

The designer's task can thus be specified: design a rotation with a maximum of positive interactions and a minimum of negative interactions between the crops. These interactions strongly influence physical, chemical and biological fertility of the soil and consequently vitality and quality production of the crops. However, a Multifunctional Crop Rotation (MCR) cannot cope with semi-soilborne and airborne harmful species. Therefore, an agro-ecologically optimum layout of I/EAFS should meet additional criteria (Outline 5). In line with these criteria, we have designed an appropriate agro-ecological layout for any EAFS variant on the 10 pilot farms in NL 2 (Fig. 4).

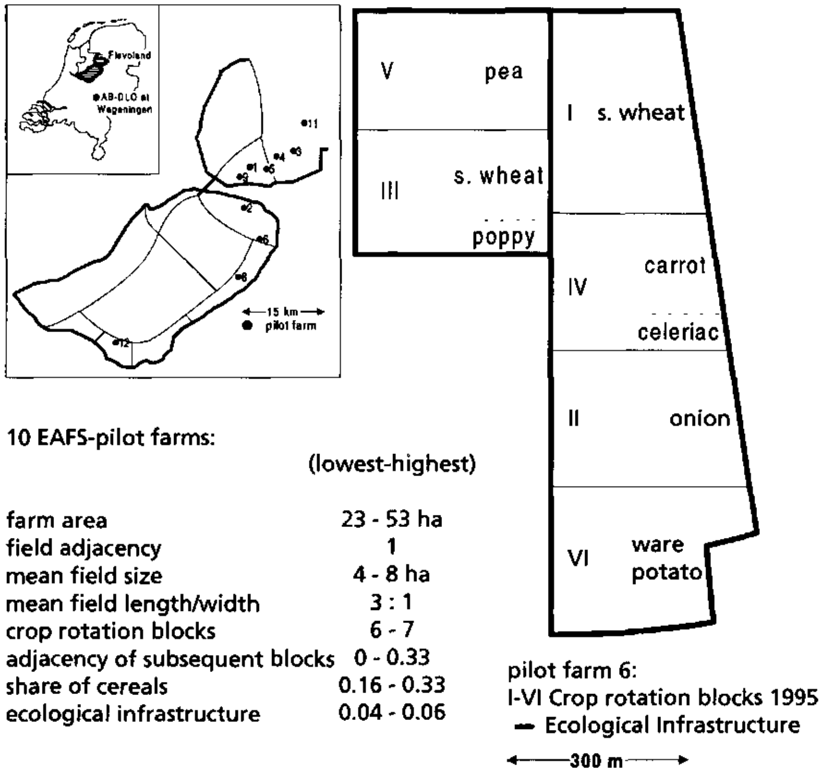


Figure 4. Layout of EAFS pilot farms in Flevoland (NL 2) as an example of Part 5 of a prototype's identity card in the I/EAFS-network.

Outline 5. Criteria for an agro-ecological layout of I/EAFS.

(1) *Field adjacency = 1*
All fields of a farming system should be adjacent to each other, to obtain an agro-ecological whole as a prerequisite for an agro-ecological identity.

(2) *Field size ≥ 1 ha*
To obtain a prototype farming system with sufficient agro-ecological identity, the fields as sub-units have to be of a minimum size.

(3) *Field length/width ≤ 4*
Round or square fields contribute optimally to the agro-ecological identity of a farming system. Therefore, a maximum is to be set to the length/width ratio of fields, to limit the loss in identity.

(4) *Crop rotation blocks ≥ 4 (IAFS) or ≥ 6 (EAFS)*
The shorter the crop rotation, the greater the biotic stress on the crops and the need for external inputs to control that stress. Therefore, crop rotation is required based on 4 (IAFS) or 6 (EAFS) rotation blocks, at least (crop rotation in time).

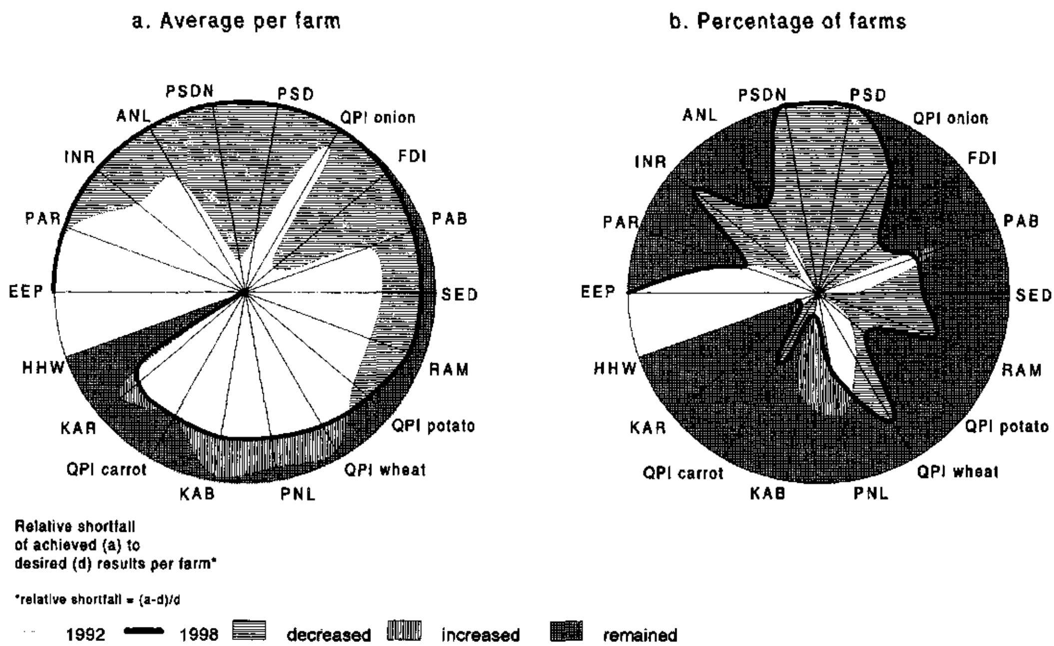
(5) *Adjacency of subsequent blocks = 0*
Harmful semi-soilborne species are to be prevented from following their host crop by a crop rotation without any adjacency of subsequent blocks to ensure crops are not just moved to an adjacent field from year to year (crop rotation in space).

(6) *Share of cereals ≤ 0.5 (IAFS) or ≤ 0.3 (EAFS*
The larger the share of cereals in rotation, the greater the biotic stress and the need for external inputs for this crop group, the largest in European arable farming. Therefore, the crop rotation should have a maximum of 0.5 (IAFS) or 0.3 (EAFS) of cereals.

(7) *Ecological Infrastructure ≥ 5 % of I/EAFS area*
To bridge the gap between 2 growing seasons, airborne and semi-soilborne beneficials need an appropriate ecological infrastructure of at least 5 % of the farm area.

By laying out a prototype it can be tested. By testing it will appear to what extent the desired results for any parameter have been achieved. If a shortfall appears between achieved and desired results, the prototype should be improved in the parameter in question, by adjusting the major or minor methods involved according to the theoretical prototype. The state of the art in step 4 for EAFS in NL 2 clearly shows, which of the 16 parameters still have to be improved before the prototype is 'all round' (Fig. 5). It also proves that our prototyping is effective, considering the clear progress from 1992 to 1996.

Improving a prototype is a matter of relating the shortfalls between achieved and desired results to the methods and improving them in a targeted way. Such shortfalls between achieved and desired results may arise from one or more of the following 4 causes: the method(s) in question is not ready for use, or not manageable by the farmer, or not acceptable to the farmer or not effective. In positive terms, step 4 (testing and improving) has been finalised if the prototype in general and the methods in particular fulfil these 4 consecutive criteria.



Parameters (in ascending order of relative shortfall)	Desired results per farm	% farms	Achieved results per farm	% farms	Main causes of shortfall in 1998	Methods first of all to be improved in: Readiness for use	Acceptability	Manageability	Effectiveness
EEP = Exposure Environment to Pesticides	0 (air, water, soil)	90	0	100					
PAR = P Available Reserves	20 < Pw-count < 30	90	29	40	slow response				
INR = Infrastructure for Nature and Recreation	0.05	90	0.06	80					
ANL = Actual N Leaching	< 11.2 NO3-N mg/l	90	11.1	50					
PSDN= Plant Species Distribution	> 25 species/INR-section (100 m)	90	26	100					
PSD = Plant Species Diversity	> 50 species/INR	90	57	90					
QPI = Quality Production Index (onion)	> 0.9	90	0.9	70					
FDI = Flower Density Index (apr.-sept.)	> 10 flowers/m INR/month	90	10	40	slow response				
PAB = P Annual Balance	0.8 < PAB < 1.2	90	1.25	50	ENM			ENM	
SED = Side Element Diversity	7	90	7	50	INR		INR		
RAM = Relative Area according to MVM	0.95	90	0.9	60					
QPI = Quality Production Index (potato)	> 0.9	90	0.8	30	MCR	MCR*1			
QPI = Quality Production Index (wheat)	> 0.9	90	0.7	70					
PNL = Potential N Leaching	< 70 kg/ha (0-100 cm)	90	85	40	ENM	ENM			
KAB = K Annual Balance	0.6 < KAB < 1.0	90	1.2	10	ENM			ENM	
QPI = Quality Production Index (carrot)	> 0.9	90	0.7	40	MCR	MCR*1			
KAR = K Available Reserves	14 < K-count < 20	90	25	10	ENM			ENM	
HHW = Hours Hand Weeding	< 500 h/farm (own labour capacity)	90	137	10	MCR	MCR*2			

*1 Biological control of non MCR sensitive diseases
*2 Various measures against non MCR sensitive weeds

Figure 5. State of the art in prototyping EAFS in Flevoland (NL 2), 1992 - 1997 (Part 6 of the prototype's identity card). The prototype is all-round if achieved results match the desired results.

Consequently, improving the prototype implies the following procedure (Outline 6).

Outline 6. Procedure to improve prototypes of I/EAFS

(1) Establishing which parameters have shortfalls between achieved and desired results
(2) Establishing from the theoretical prototype which methods are involved
(3) Establishing which criteria are not yet fulfilled by these methods:
- ready for use;
- manageable by the farmers;
- acceptable to the farmers;
- effective.

(4) Establishing targeted improvements to meet the successive criteria
(5) Laying out and retesting

The 4 criteria will have already received much attention before the prototype is laid out for the first time, especially in the case of testing and improving a prototype on pilot farms. Commercial farmers want to be sure a prototype is feasible and all its methods are safe! Nevertheless, on-farm testing will certainly bring to light various shortcomings of individual methods, which should be improved based on the set of 4 criteria.

One major reason why a method may not appear ready for use, is unexpected occurrence of factors which interfere to such an extent that the method needs to be revised to include these factors and their effects. As a result, methods will gradually evolve from simple and subjective to comprehensive and objective. Examples:
- management factors such as choice of crops and varieties, machines, fertilisers, pesticides;
- agro-ecological factors such as pests, diseases, weeds, and physical and chemical soil status.

Even if ready for use, a method may still not appear to be manageable to the farmers, for several reasons. Examples:
- planning or operations too complicated;
- too laborious to fit into the labour film;
- too specific to be carried out with the usual machinery.

Even if ready for use and manageable, a method may still not appear to be acceptable to the farmers, for several reasons. Examples:
- too high costs and/ or too few benefits, at least in the short term;
- too little confidence in utility and/or effectiveness.

Even if ready for use, manageable and acceptable, a method may still not appear to be effective to achieve the desired result in a certain parameter. This conclusion may be premature, in case of parameters with a slow response. Apart from this, the major reason why a method indeed may not be effective is that the theoretical prototype is too simple or distorted considering the method and the parameter in question. Examples:

- the method needs support by another method;
- the method has only a minor influence, another method should be established as the major method.

Because most parameters are under control of more than one method, and many parameters have a slow response, effectiveness is the most difficult and also the most time-consuming of all 4 criteria to establish.

Testing and improving a prototype will take at least 4 years for I/EAFS and 6 years for EAFS, corresponding with one run of the prototype as a complete crop rotation on each field, before reliable responses of abiota (soil, groundwater) and biota (crops, flora and fauna) are obtained. The effectiveness of the methods and the overall prototype can only be established on the basis of these reliable responses in terms of the multi-objective parameters.

Theoretically, the number of years needed for step 4 would be the sum of the years needed to fulfil the first 3 criteria and the years, needed to fulfil the fourth criterion. In practice however, biota and abiota start developing a response from the first year the prototype is laid out, provided the prototype is well designed and will not change dramatically in subsequent years. As a result, the adaptation of abiota and biota will mostly occur simultaneously with the testing and improving by farmers and researchers, so step 4 could be done in a minimum of 4-6 years. However, this does not imply that all parameters will have achieved a steady state. For example, it may take decades before possible excessive reserves of soil P have been diminished or depleted organic matter reserves have been replenished to desired ranges. Nevertheless, if the shortfalls between achieved and desired results are incontrovertably decreasing from year to year, you may speak about reliable responses proving the effectiveness of the prototype. As a result, the final step of dissemination can be envisaged with confidence.

Dissemination (step 5)

If the first 4 steps of prototyping have been made on a single experimental farm, the prototype cannot just be handed over to the extension service for wide-scale dissemination! It is because such a prototype does not cover region-specific ranges in soil, climate and management conditions, which are crucial for its manageability, acceptability and effectiveness.

Therefore, prototyping on an experimental farm always needs a follow-up with pilot farms to elaborate a range of variants of the prototype. Consequently, prototyping in interaction with pilot farms saves a lot of time and money and is always preferable. In addition, a group of capable and motivated farmers provides an indispensable technological and social base to an innovation project, which should include dissemination throughout the region. For this purpose we have developed a model of interactive prototyping with pilot farms (Fig. 6). Since it has appeared to work quite satisfactory in our EAFS project, we have proposed it as a standard to the teams in the I/EAFS-Network. In case of interactive prototyping with 10 - 15 pilot farms, step 4 can be finalised with 10 - 15 variants of the prototype covering the regional ranges of soil, climate and management. This provides for an excellent base for wider dissemination throughout the region.

The initial group of pilot farms can act as demonstration farms and the farmers can be involved in training and guiding farmers willing to convert. To disseminate the prototype in wider circles regional extension services should be trained to participate and gradually take over the innovation project. The interaction model (Fig. 6) can be maintained to convert groups of farms in a programme of at least 4 years.

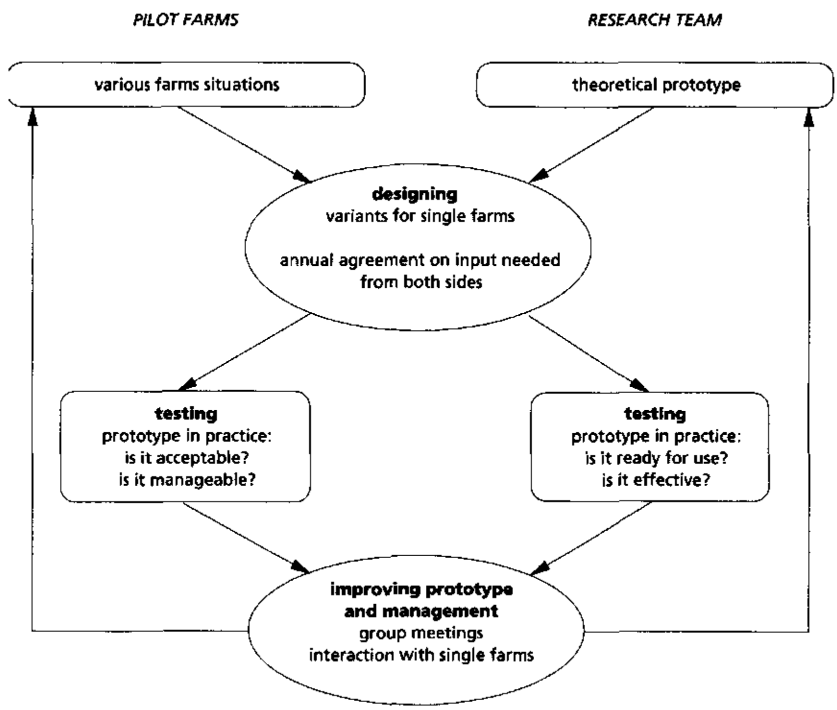


Figure 6. Interactive prototyping: designing, testing and improving a prototype by interaction of pilot farms and research team

3. Discussion

All over the world, agriculture is still being intensified, causing destabilisation of agro-ecosystems and environmental pollution. In developing countries it is understandable for various reasons, especially in those countries where food production can hardly keep pace with population increase. In industrialised countries it is absurd when one considers the growing surpluses of agricultural products, the decreasing income and employment in most rural areas and the growing concern of the consumers about the quality of their food. Fortunately, there is also a growing awareness that these immense problems cannot be solved one by one on an ad-hoc basis, but that a more comprehensive and sustainable approach of agriculture is needed. As a result, several new approaches have been proposed, such as sustainable (Allen & Van Dusen, 1988; Edwards et al., 1990), integrated (Vereijken & Royle, 1989) and alternative agriculture (National Research Council of USA, 1989). However, their use is limited because they are hardly defined in measurable terms, elaborated into concrete farming systems and tested for feasibility. Therefore, the current methodical way of prototyping has been developed to enable agronomists to design, test and improve more sustainable farming systems in interaction with pilot farms.

The methodical way of prototyping I/EAFS presented here has its roots in two global organisations. The concept of IAFS is based on the work of the crop protectionists, assembled in the International Organisation for Biological and Integrated Control (IOBC). Initially, most working groups of IOBC aimed at the control of single pest species. However, this brought about various problems, such as insufficient cost effectiveness and the emergence of new pests. Therefore, they developed a wider scope and aimed at integrated protection of crops. During the last decade, the scope has further been widened to IAFS, comprising the entire crop rotation and also considering soil cultivation and fertilisation (Anonymous, 1977, Vereijken et al. 1986, El Titi et al. 1993). The concept of EAFS has been developed by the teams in the I/EAFS-network, searching for a more consistent and sustainable elaboration of IAFS. They have been inspired by the concept of organic farming, as defined by the standards and guidelines of the International Federation of Organic Agriculture Movements (IFOAM) (Geier, 1991). The great advantage of the organic concept is that it offers a market model of shared responsibility by producers and consumers for a sustainable and multifunctional management of the rural areas as agro-eco-systems. It is expressed by the principle of premium prices for the added ecological value of the products under label. This provides for the necessary economic base for the consistent and sustainable elaboration of IAFS, to be called EAFS. However, EAFS should go further than is demanded by the IFOAM guidelines for organic farming in sustainable and multifunctional management of the environment, nature/landscape and health/well-being of people and farm animals.

The methodical way of prototyping I/EAFS presented here starts at the stage where most farming systems research stops, and that is the stage of analysis and diagnosis (Gibbon, 1994). However, the I/EAFS teams of the EU network, strong in agronomy and ecology, may improve their start by building on a more comprehensive and profound rural and farming systems analysis from research teams, strong in sociology and economy such as those led by Van der Ploeg (1995) and Sevilla Guzman (1994). The methodical way of prototyping I/EAFS presented here is still provisionally elaborated considering the interaction with pilot farmers in general and the last step (5) of dissemination in particular. In this respect, the I/EAFS teams could also benefit from the expertise developed by teams, such as those led by Röling (1994). With this enlargement and reinforcement of their capacity, the teams of the I/EAFS-Network have excellent chances to succeed where up till now most farming systems researchers failed (Gibbon, 1994). Their work comes further than the step of diagnosis and analysis, and includes the subsequent steps of design, layout for testing and improving, and eventually dissemination.

Initial results are encouraging. Most teams are progressively achieving the desired results, although the effectiveness of prototyping can still be improved in various ways (Vereijken, 1996). Nevertheless, the clear progress we achieved in our EAFS prototype for Flevoland (Fig. 5) may be considered as an example of the effectiveness of the prototyping in the I/EAFS network.

The entire methodical way of prototyping I/EAFS has been laid down in a manual (Vereijken, 1999).

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Chapter 8

Integral technology design as a process of learning and negotiation: A social science perspective on interactive prototyping

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Abstract

Building on the experiences with biological pest-control, this chapter takes as a starting point that sustainable agriculture requires the interactive development of knowledge intensive farming systems, technologies and practices. For this purpose, a group a natural scientists has developed an innovative approach called 'interactive prototyping'. This chapter evaluates this approach from a social science perspective. After a brief introduction to the 'interactive prototyping' approach, some of its implicit conceptions of agriculture and change are explicated, and confronted with current views in the social sciences. While it is recognised that the approach is an important step forward, it is concluded that it still relies in part on linear views on the sources and direction of agricultural change, an outdated perception of the role of planning and agricultural extension, and a somewhat one-sided conception of farming. Therefore, a number of conceptual and practical changes are suggested to help improve the overall impact of interactive prototyping. These changes are geared mainly towards enhancing learning and negotiation among a wider set of stakeholders during the prototyping process, in order to improve the capacity to deal with the 'soft' dimensions of technology design.

1. Introduction

In both Western and Southern countries we have in recent years witnessed efforts from within agricultural sciences to (re)convert high input (or 'Green Revolution') agriculture into more sustainable forms of agricultural production. Generally, we see that environmentally friendly forms of crop-protection, nutrient, water and weed management require new production systems, technologies and farming practices, which tend to be more 'knowledge intensive' than those which preceded them (Röling & Van de Fliert, 1994). More 'knowledge intensive' in the sense that these systems, technologies and practices require more delicate, precise and complex forms of observation, analysis and operation at field level.

In mainstream agriculture (as opposed to the relatively small and isolated branches of biological and/or ecological farming) such sustainable technologies and practices have been developed and applied mainly in the domain of crop-protection, and in particular the area of pest-control. The emergence of biological forms of pest-control -which were (re)introduced by entomologists- went along with new forms of agricultural extension, most notably the Farmer Field School approach which was developed in the context of FAO's Integrated Pest Management (IPM) programme from 1978 onwards. At present we are witnessing efforts to expand the principles of sustainable pest-control outside the realm of pests, plagues and predators, for example in areas like nutrient management (see e.g. chapter 10), weed management, water management, etc. In relation to this FAO speaks of Integrated Crop Management (ICM).

A number of new obstacles and challenges must be dealt with in achieving the desired shift as described above. Such challenges include the need to (a) extend the paradigm shift implied by biological pest-control to other agricultural networks, (b) deal with an increasingly complex learning process at farm level, (c) adapt extension models and tools, (d) alter the management and organisation of the Agricultural Knowledge and Information System (Röling, 1992) in general, (e) create a conducive political and socio-economic environment for sustainable agriculture, and (f) the need to develop new production systems, technologies and practices. This chapter focuses almost exclusively on this last challenge. In particular, I will discuss an approach towards the design of knowledge intensive production systems, technologies and practices which has been developed by natural scientists in Wageningen (Vereijken & Kropff, 1995; Vereijken, chapter 7). Although this approach is a very promising one, it will be argued that it only partially reflects the 'paradigm shift' that went along with IPM. In relation to this, it is suggested that the methodology might benefit from increased involvement by farmers and social scientists in the process of technology generation. Moreover, it is proposed to adapt the approach in order to enhance learning and negotiation among a wider selection of stakeholders.

2. Building upon the biological pest-control experience

In the face of severe and widely recognised difficulties with conventional pest management practices (resistance of pests to pesticides, health hazards) 'new'[1] technologies for pest management were explored during the late seventies and early eighties, particularly in rice production (Van de Fliert, 1993). Therefrom, it emerged that the strategic use of natural enemies could contribute substantially to reducing the use of pesticides. Maintaining a balance between pests and predators thereby proved to be a delicate and knowledge intensive affair, which required a lot more from farmers in terms of observation, analysis and risk evaluation than before (Van de Fliert, 1993). In relation to this, old methods and approaches in extension appeared obsolete (Röling & Van de Fliert, 1994). In FAO's IPM

[1] The technology was not really new, as the use of natural enemies in order to combat pests has been documented much earlier, that is in the fifties (e.g. Pickett & Patterson, 1950) and even in the twenties (see Flint & Van den Bosch, 1981; Van de Fliert, 1993).

programme on rice, for example, it is now explicit policy that extension agents refrain from both presenting themselves as experts or teachers and providing pre-prepared lectures, recipes and advice. Instead, extension agents are trained to act as facilitators of farmers' learning processes. Within Farmer Field Schools, then, farmers are encouraged to make observations, bring in their own experiences, and draw their own conclusions with regard to maintaining a balance between pests, natural enemies and crop damage. A second example is the horticultural study groups in Dutch glasshouse horticulture. These study groups play an important role in generating horticultural knowledge (Leeuwis & Arkesteijn, 1991; Leeuwis, 1995a), and although they are much more autonomous than Farmer Field Schools, there are many similarities between the two in terms of the nature of the learning processes that takes place. Not surprisingly, then, these study groups have played an important role in achieving a reduction of pesticide-use in Dutch glasshouse horticulture (Proost, 1994).

Both examples illustrate the importance of improving farmers' capacity to learn and experiment (individually and collectively) and decrease their reliance and dependence on external advise (see Van de Fliert, 1993). This in many ways marks a 'paradigm shift' on the side of both farmers and a variety of staff who where working in the area of crop-protection (researchers, extension agents, administrative staff, etc.).

Moving away from the linear 'paradigm'

The perception of farmers as being (or becoming) capable and knowledgeable agents which is implied by this extension approach, is in line with much social scientific research which documented farmers knowledgeability and agency in managing their farming enterprises (Van der Ploeg, 1990; Leeuwis, 1989, 1993). In addition, social scientists have documented the importance of local and indigenous forms of knowledge in agriculture, and farmers' capacity to experiment and generate new knowledge and technology (Van der Ploeg, 1987; Jiggins & De Zeeuw, 1992; Richards, 1985; Chambers et al, 1989; Warren, 1991; Leeuwis, 1995a). Within communication and innovation studies, such insights and experiences have contributed to a 'paradigm shift' as well. This 'paradigm shift' can be briefly characterised by the following insights:

1: Farmers are in many ways 'experts'. Not only do they have detailed knowledge about their own socio-economic situation, production circumstances, and livelihood strategies, but -over time- they have also generated considerable knowledge concerning the technical interrelationships within their local farming system. This knowledge includes tacit knowledge about what scientists' would label 'defining, limiting and reducing growth factors' (Rabbinge, 1993; Rossing et al., chapter 5). Despite farmers' knowledgeability and expertise, farmers are not all knowing and may at times lack the insight and skills to articulate knowledge and draw appropriate inferences. This is especially so when phenomena are involved that are difficult to observe (Richards, pers. comm.) due to either their inherent characteristics (e.g. viruses and nutrient flows) or spatial distance (e.g. migration of insects from other regions). Hence, there is scope for learning and expansion of their knowledge base.

2: The most appropriate way to improve farmers' stock of knowledge lies not so much in 'knowledge transfer', but in improving farmers' capacity to learn and experiment themselves (i.e. enhancing 'discovery' and experiential learning; Kolb, 1984).

3: The facilitation of experiential and discovery learning requires both different organisational arrangement and new practical tools, for example:
- new methods and techniques for observation, demonstration and 'making things visible' (e.g. IPM 'insect zoo's');
- new forms of on-farm experimentation and analysis;
- new modes of exchanging knowledge between farmers (e.g. study clubs and/or Farmer Field Schools);
- new tools for comparison between farms and between years;
- new tools for 'switching' between and co-ordinating distinct domains of farming;
- new methods for speeding up learning processes (e.g. simulation models);
- new procedures and strategies for making inferences and validating knowledge.

These insights imply a move away from linear modes of thinking about the relationships between research, extension and farmers (Röling, 1996). Rather than intermediaries between researchers and farmers, extension agents are to take on the role of facilitators of individual and collective learning processes. In a similar vein, researchers are (at least partly) to become participants in farmers' and/or farmer-induced research.

Towards interactive research

As a necessary (but by no means a sufficient) condition, sustainable farming requires that *new and more sustainable systems, technologies and practices are developed*, which farmers are willing and able to apply and/or adapt.

Here, it is important to recall that biological pest-control was sparked off by the fact that both farmers, scientists and governments recognised that -particularly in rice production- there existed an urgent problem in the area of crop protection (increased resistance of pests against pesticides, health hazards). In fact, it can be argued that the 'paradigm shift' in the area of crop protection described earlier has in part come about under the influence of such jointly felt and acted upon pressures. In some countries this went along with the banning of a wide array of pesticides, which in turn gave a boost to alternative modes of pest management (Van de Fliert, 1993; Proost, 1994). There is evidence that in cases where such stringent policy measures were lacking, IPM has been much less effective (Castella et al, 1995). Nevertheless, the success of sustainable pest-control in rice depended not only on these political pressures and shared problem definitions, but also on the circumstance that a promising technology (natural enemies) was indeed available. However, in other domains than crop protection and other cropping systems than rice the availability and salience of alternative technologies is less evident. And even if basic ideas and technologies exist, there is often a need for them to be adapted and re-designed: as increased 'sustainability' often requires a more precise use of external inputs, and a more refined management and co-ordination of ecological cycles, technologies and practices for sustainable agriculture will have to be better adapted to *locally specific* agro-ecological conditions than conventional technologies. In all, there is a close affiliation between the demise of the linear model of thinking about research, extension and farmers, and the wish to design sustainable agricultural technologies. This is why -in recent years- we have seen many efforts to improve interaction between farmers and researchers in technology development (e.g. Jiggins & De Zeeuw, 1992; Van Veldhuizen et al., 1997). Similarly, while initially the Farmer Field School model was first and foremost an extension approach, we now witness attempts to convert Farmer Field Schools into Farmer Research Groups (see Wipfler et al., 1998; Leeuwis et al. 1998). In the European context, an interactive prototyping approach has been developed in order to arrive at sustainable farming systems, technologies and practices. We will reflect on this latter approach towards integral design in the remainder of this chapter.

3. A prototyping approach towards the design of knowledge intensive production systems, technologies and practices

A inter-disciplinary group of Wageningen natural scientists has developed an approach which is explicitly aimed at the development of sustainable farm production systems and accompanying technologies and practices (Vereijken, 1994, 1995, 1997; Vereijken & Kropff, 1995; Jansma et al., 1994; Rossing et al., 1997). The approach marks quite a radical departure from conventional research practice at Wageningen Agricultural University and other 'fundamental' research institutes, in that it draws heavily on on-farm research and interaction with farmers. Although the approach has met with considerable scepticism and resistance from natural scientists (who felt it was not appropriate for 'fundamental' researchers to engage in joint research with farmers) it is currently applied in a number of European countries (see chapter 7 and Vereijken, 1997). In brief, this methodology consists of the following 5 steps that are conducted by a inter-disciplinary 'prototyping team' (quotes have been translated freely from Vereijken & Kropff, 1995:97; see also chapter 7):

Step 1 (setting objectives)
"Make a hierarchy of 6 general objectives, subdivided into 20 specific objectives, as a basis for developing a prototype in which strategic shortcomings of existing systems are replenished" (see table 1 for the goals taken into account).
From the elaboration of this step by Vereijken & Kropff it emerges that they see 'the designer' of the production system as the one who determines the goals within this framework, whereby the phrasing clearly implies that 'the designer' equals 'the scientist'. The procedure is described as simple and straightforward. In a specific case

study (Vereijken, 1997; chapter 7) it is added that "this hierarchy of objectives should not be considered as just the vision of our prototyping team. Though we proposed it, the group of pilot farms has taken it over after ample discussions during several study meetings. To our experience, the hierarchy of goals is a simple and effective instrument to achieve consensus between researchers and farmers." (1997:237)

Table 1: General and specific values and interests in agriculture (simplified from Vereijken 1992)

Values and interests (in arbitrary order)			
general	specific	general	Specific
Food supply		Abiotic environment	
	- quantity		- soil
	- quality		- water
	- stability		- air
	- sustainability		
	- accessibility		
Employment		Nature/Landscape	
	- farm level		- flora
	- regional level		- fauna
	- national level		- landscape
Basic income/Profit		Health/Well being	
	- farm level		- farm animals
	- regional level		- rural population
	- national level		- urban population

(source: translated from Vereijken & Kropff, 1995; see also Vereijken, 1997)

Step 2 (making goals measurable and identifying methods)

"Translate the 10 main objectives into multiple criteria/parameters for goal achievement, in order to both quantify the objectives, and to identify multi-objective methods which are necessary for attaining the quantified objectives".

It is argued that it is wise to use a minimum number of goal-parameters. This will reduce costs and time expenditure, contribute to the integration of objectives and/or reduce the number of conflicting goals. 'Multi-objective methods' in this context are regarded as 'farming methods' that constitute in fact a collection of technologies and practices that may contribute to attaining the objectives and criteria/parameters. Examples of such methods are a 'multi-functional crop rotation', 'ecological nutrient management', 'ecological infrastructure management' and 'farm structure optimisation' (see chapter 7).

Step 3 (designing a theoretical prototype)
"Design a theoretical prototype by linking the farming methods to goal-parameters, and to further design and operationalise the multi-objective methods until they are ready for a first test".
The theoretical prototype can be represented visually by drawing causal lines between the various multi-objective parameters and farming methods (see chapter 7).

Step 4 (iterative prototyping)
"Apply the prototype in actual practice, and test and improve it until the objectives, as quantified in multi-objective parameters, have been achieved".
As this step may take various years, and is by far the most labour-intensive and expensive one, it is deemed important to reflect again on the previous steps, amongst others in order to check that in the goal hierarchy "the 'new' objectives like nature/landscape are not ranked too low, while 'old' objectives like basic income/profit are ranked too high, so as to ensure that one really innovates, instead of walking just ahead of the main group of farm-enterprises" (Vereijken & Kropff, 1995:102).
The prototype can be tested on an experimental-farm, and/or on several carefully selected 'vanguard' farms[2]. Although this latter option is described as the preferred one (Vereijken, 1997:247), it is acknowledged that it takes a lot of time to create a variant of the prototype on each pilot farm, in interaction with the farmer (Vereijken, 1997:243).
If the multi-objective parameters are not reached, the prototype should be improved. This implies making an inventory of discrepancies between results and parameters and of potential limitations of the various farming methods in terms of readiness for use, manageability, acceptability and effectiveness. On the basis of this the methods can be improved, and tested again. A number of repetitions of this prototyping procedure may be necessary.

Step 5 (dissemination)
"Spread the prototype through groups of vanguard farms (10-15 farms), regional networks (15-30 farms) and finally through national networks, whereby a gradual shift is required from supervision by researchers towards supervision by extension agents".
The authors indicate that this step is least developed. When the interaction between researchers and farmers is completed, the prototype should be handed over to extension, which should take care of further diffusion. As an extension method, it is suggested that the initial group of pilot farms can be used as demonstration farms, and that the farmers "can be involved in training and guiding farmers willing to convert" (Vereijken, 1997:247).

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[2] It is suggested that these farms can be selected on the basis of criteria like interest, full-time employment, size, soil, location, (non-)fragmentedness, physical lay-out, plot-size, craftsmanship and attitude (Vereijken & Kropff, 1995:103).

4. A positive critique of the Wageningen prototyping approach

Although I am sympathetic to the efforts and concerns that are embodied in the prototyping approach, there are a number worries and questions that I would like to raise in relation to it. These queries are intended to spark off a constructive debate between advocates of the prototyping approach and social science scholars.

In essence, my concern is that the methodology -if applied in the way in which it is currently presented- runs the risk of developing technologies which have little chance of being applied widely in actual practice, despite the fact that the scientists involved explicitly aim at making practical contributions towards a more ecologically sound agricultural sector (Vereijken & Kropff, 1995:103). As I have not conducted thorough empirical research on the way the prototyping methodology is used in actual practice, I have to rely on written descriptions of the methodology. However, I do not exclude the possibility that in this case too 'practice' may differ significantly from 'paper'. After all, the texts provided by Vereijken & Kropff are aimed at an in some ways sceptical audience (natural scientists), which may have caused the authors to emphasise particular aspects (e.g. scientific rigour and reproducibility) at the costs of others (e.g. farmer participation). However, even if this were the case it makes sense to critically examine the written account, as it is the main source that technology developers can draw upon. My concern is based on the following observations:

The partial retention of linear discourses and practices

In some ways, the methodology still reflects a linear mode of thinking. First, the impression is given that knowledge and technology generation is primarily the task of the scientists. It is only when a first prototype is available that farmers are seriously involved. Only after the production systems, technologies and practices are 'ready', are they handed over to extension agents, who are supposed to take care of further 'dissemination'. Furthermore, one gets the strong impression that the process is dominated by researchers; it is the researchers who seem to decide in relative isolation about the objectives which are to be achieved, the criteria which should be used to measure goal-attainment, the problems which are to be tackled, and thereby the research agenda. Although in a specific case-study Vereijken (1997) refers to discussions with farmers about setting the goal hierarchy (see above), it is clear that it is designed by scientists, and later 'agreed' upon by farmers. Even if in the prototyping phase (step 4) farmers tend to be much more involved than in conventional agricultural science, their role is described mainly in terms of 'testing'; they are not represented as equal partners in the technology development process. In this respect it is significant that farmers are at no point presented as members of the prototyping team. Hence, the methodology reflects a linear mode of thinking in terms of the order in which knowledge generation, exchange and utilisation takes place. At the same time it assumes rather traditional division of labour between researchers, farmers and extension agents.

The above state-of-affairs underscores that the prototyping approach towards integral design is first and foremost conceived of as a *scientific research* methodology. Given the institutional setting in which the prototyping approach was developed, including the sceptical attitude of fellow scientists, this is hardly surprising, and certainly not an issue that the developers can be criticised for. However, if the prototyping approach is to be developed from a rather unique research experience into a wider strategy for developing viable and locally specific sustainable farming systems, the strict association with 'scientific research' may be less helpful. In fact, a student evaluation of the prototyping trajectory on which Vereijken reports in chapter 7 reveals that a tension existed between 'learning' and 'research' aspirations. The primary motivation for farmers to participate in the trajectory was to engage in a progressive learning process on ecological farming. Even if the overall farmers' evaluation was positive, a considerable proportion of farmers felt that -after a while- the project became less informative. This was because newly emerging questions and issues for investigation could not be incorporated without disturbing the on-going testing of the prototype (Smilde, 1998). This suggests that the rhythm and purpose of scientific research may not always be compatible with the logic of farmer learning, and that a scientific approach may unnecessarily slow down an innovation process. In addition, various studies have shown the limitations of both organising technology development as a linear process and maintaining a strict division of labour in terms of the knowledge processes that different actors engage in (Kline & Rosenberg, 1986; Röling, 1988, 1991; Engel, 1995; Vijverberg, 1997; Van der Ploeg, 1987). In particular, there is a high risk that production systems, technologies and practices that are developed in this manner insufficiently anticipate the problems, conditions and aspirations of those who are supposed to apply them. In other words: the technologies developed may be badly targeted.

A uni-linear development direction

The issue of targeting brings me to a second type of linear reasoning that seems implicit to this prototyping methodology. The methodology is clearly directed towards developing one idealtypical type of farming. This is reflected in the fact that only one set of objectives is being used, resulting in one particular prototype, aimed at a carefully selected and relatively homogeneous group of farmers. The use of the term 'vanguard' farm (Vereijken & Kropff, 1995:103) coincides with the frequently used classification of farmers into categories like 'frontrunners', 'followers' and 'laggards', which seems to suggest that it is expected that other farms will follow automatically in applying the technological packages that are developed, while again others may 'lag behind'. In this view, there is only one development path, which sooner or later all farmers will have to walk if they wish to survive as farmers. Hence, the methodology reflects a rather uni-linear perception of the direction in which agricultural development takes place as well.

Recent research has shown that a variety of viable patterns of farm development exist, and that there is a great deal of diversity amongst farmers, both in terms of the conditions in which they operate and in terms of the strategies they adhere to (Van der Ploeg, 1990; Leeuwis, 1993; see also chapter 7). There seems to be little effort within the methodology to anticipate this diversity. This implies that the technologies that are being developed are likely to suit only a very particular sub-section of the farming population. At present, for example, it seems that the methodology is applied to suit the needs of those who are already committed to ecological farming, and are in the most optimal position to engage in it. Although this choice may serve a particular political agenda (e.g. showing that radical forms of ecological agriculture can work technically), one wonders to what extent the production systems that are developed will contribute to the 'ecologisation of agriculture at large' to which the designers are committed.

The conception of farming as a technical system

The advocates of the Wageningen prototyping approach explicitly regard farming as a purely technical phenomenon when they argue that:

> "The main task of designers of farming systems is to ecologise agriculture by replacing physical-chemical methods by biological methods. This requires an appropriate conceptualisation of a farm; an ecological farm is an agro-ecological whole which consists of a 'team' of steadily interacting and rotating crops, plus their accompanying (beneficial or harmful) flora and fauna." (Vereijken & Kropff, 1995:103)

From a social science perspective this conceptualisation completely misses the point that any change or 'replacement' that is made in a farming system can only come about by a change in human conduct. Hence, human beings are an inherent part of a farm, and it is of little use to artificially separate them, especially not if one desires to change human behaviour. If one wishes to contribute to change, it is crucially important to understand first and foremost *why* farmers are using particular farming practices, i.e. why they are forging particular technical interrelations. Experience teaches that farmers may have a variety of reasons for managing their farms in the way they do. These reasons may be of a perceptual and cognitive nature, but may also relate to particular social (including economic) interests, social conditions and/or conflicts. Consequently, the 'social logic' of current management practices may well find its origin beyond the immediate boundaries of the farm. Moreover, farmers' 'logic' has been shown (Van der Ploeg, 1990; Leeuwis, 1993) to encompass a much wider array of 'objectives' than the ones that are taken into account by Vereijken & Kropff (see table 1). Understanding this 'social logic' is of crucial importance for identifying areas where learning, intervention and/or research may be needed and/or promising.

The Wageningen prototyping approach seems to assume that providing a comprehensive technological package that implies a radical change in all domains of farming at the same time, is the most efficient and effective strategy for change. This is a questionable assumption. For this to happen on a significant scale, it would probably require military-like imposition or an equally radical change of the social environment in which conventional farmers operate. While the first option seems undesirable, the latter seems very unlikely. Hence, a more gradual approach, which takes the existing social and technical systems, technologies and practices as a starting point, may in the end be more productive in bringing about sustainable forms of agriculture amongst a significant number of farmers. In practice, there will be a maximum degree of change and learning that farmers can accommodate at a particular point in time.

Elements of blue-print planning

In many ways the Wageningen prototyping approach constitutes a planned approach towards production system and technology development. Early models of planning represented planning as a logical series of steps from situation A to situation B in a largely predictable world (Long & Van der Ploeg, 1989; Brinkerhoff & Ingle, 1989). In later models of planning it was realised that the social world is inherently unpredictable, and that therefore planning could be much more fruitfully organised as a process of goal-seeking, learning (Brinkerhoff & Ingle, 1989) and negotiation (Leeuwis, 1993, 1995b). In part, the Wageningen prototyping approach seems to reflect this latter notion of planning, as it clearly provides opportunities for an iterative learning process (in step 4). However, it is clear from the descriptions by Vereijken & Kropff (1995:104) that during this learning process the objectives remain unchanged. In other words: the route towards goal-attainment may change, but not the objectives that have been set at the outset. Studies of planned intervention and technology development (Leeuwis, 1993; 1995b) suggest adherence to one's original goals may be rather unproductive. In fact, it may result in a certain amount of blindness towards promising alternatives and productive compromise.

5. Towards an alternative strategy for the design of promising production systems, technologies and practices

It is always relatively easy for social scientists to raise critical questions and point out that natural scientists neglect the social dimensions of farming and farm development. It is more difficult to conceptualise how social scientists, natural scientists and farmers might productively work together in processes of innovation. Few attempts in this respect transcend a rather unspecific plea for inter-disciplinarity, or overtly optimistic reliance on participatory processes. In the following, I will make an attempt to become somewhat more specific.

First and foremost, it is important to conceptualise at an ontological level what a deliberate attempt to design new production systems and technologies *is*. I propose that we look at such an effort as organising a process among various stakeholders to bring about 'new arrangements' between the social world and technical/natural world. Such 'new arrangements' do not only include biotic and a-biotic artefacts and associated social practices, but also innovative problem definitions and viable forms of organisation that support new practices. Thus, 'a design' is a multi-layered phenomenon (see also chapter 1). In addition, the nature of the process itself is multi-dimensional as well. Firstly, it involves a series of individual and collective *decision-making processes*, as a number of choices must be made during the process (which will in many cases be organised as a *project*). Secondly, it involves a *process of learning* (both individually and collectively), as a basis for project decision-making by the various stakeholders. Most importantly, it involves a *process of negotiation* among the stakeholders. This is because any meaningful change and breakaway from the status quo is likely to be accompanied by tensions between those who are involved and affected. In this context, choices that are made, and the knowledge claims on which they are based will almost always be subject to dispute. Hence, the need to somehow reach compromise, consensus or accommodation. It is important to realise that when different stakeholders are involved in a technology development project these three processes (project decision-making, learning and negotiation) take place simultaneously.

Given the nature of 'design processes' it is fundamentally impossible to predict in advance what the outcomes will be. Especially in the case of knowledge and technology generation it is self-evident that the outcomes of experiments in the a-biotic and biotic world are uncertain. It is even more uncertain how human beings will respond to such outcomes. More in general, it is impossible to know in advance what the outcomes will be of human negotiation processes, as this depends on people's capacity to creatively define and draw upon resources, while at the same time one has to reckon with all sorts of unintended consequences of -and unacknowledged conditions for- human action (Giddens, 1984). Moreover, design processes take place over a period of time, in which a number of unexpected developments may take place inside and outside the design process.

Although one cannot predict outcomes, there are some regularities in human interaction. Insight into such regularities may help to organise and influence design processes in such a way that productive outcomes may emerge (see e.g. Van Meegeren & Leeuwis, chapter 12). In the absence of a clearly worked out methodology, I will take the Wageningen prototyping approach as a point of departure, and suggest a few changes and additions to it. In doing so, I will first argue in more general terms that the philosophy of the approach needs to be adapted in several respects. Subsequently, I will pay attention to the role which different actors (and in particular social and natural scientists) may play during the development process. Finally, I will suggest some modifications of the various 'steps' in the Wageningen prototyping approach. All this under the assumption that the Wageningen prototyping approach is to be further developed into an approach that tries to maximise the chances of developing widely applicable sustainable production systems, technologies and practices.

Adapting the philosophy

As we have seen, the prototyping approach towards integral design can be characterised as a 'scientific research' methodology. At the same time it is a highly structured and planned approach with an emphasis on the 'decision-making' dimensions in the design process. Thereby, it adopts a fairly narrow conception of what it is that needs to be designed (i.e. new biotic and a-biotic artefacts and related practices). In view of the above conceptualisation of 'design', I suggest that the prototyping approach needs to extend its horizon of design towards problem definitions and organisational arrangements. This may -for example- require that part of the 'experiments' carried out relate to new social arrangements (e.g. market arrangements, organisation of labour) rather that farming methods.

At the process level, the learning and negotiation dimensions of design must be much more explicitly developed. This implies among other things that the approach needs to become more flexible in terms of the research agenda it addresses, and pay more attention to enhancing discovery learning, for example by borrowing from the Farmer Field School experiences. It also means that the approach must include a language for dealing with conflicts concerning objectives, problem definitions, research strategies, etc.

Including new actors, adopting different roles and tasks

Apart from natural scientists, I would propose the inclusion of a few new actors as 'equal' partners in the development process. Firstly, I feel that the immediate beneficiaries (a diverse group of farmers) deserve a more prominent place in the methodology. The same holds (albeit at a somewhat later stage) for other societal stakeholders on whose co-operation the application of innovations may critically depend (e.g. consumers, interest groups, government; this is recognised by Vereijken as well, see chapter 7). Eventually, these are the actors who have to negotiate and work towards sustainable forms of agriculture. Secondly, I feel that somehow social scientists need to be involved in order to provide critical insight into the social system in which technical practices are embedded. In essence, the role that natural and social scientists are to play in processes of technology development is similar. Both can be looked at as resource persons, who provide (requested or un-requested) inputs and feedback to those who are involved in learning and negotiation. In order to be able to give feedback -a crucial mechanism for learning- natural and social scientists need to engage in research in order to both understand the situation that actors find themselves in and identify constraints, opportunities and options. However, a certain degree of modesty is required from practically-oriented social scientists and natural scientists; their role is not so much to lead and direct the innovation process, but to contribute to it whenever necessary. More specifically, I see the following tasks:

For natural scientists:

(1) Answer questions about technical relations that emerge in the learning, negotiation and project decision-making process, and engage in research when no plausible answer can be given.

(2) Inform stakeholders about their own perspective on sustainability problems, and -if necessary- engage in exploratory research in order to identify the most problematic practices.

(3) Respond to the stakeholders' 'what if' questions in relation to possible interventions. Thereby, all sorts of computer simulation and/or optimisation models can be used as a means to 'speed up' the learning process (calculating possible consequences can be a lot quicker than actually testing interventions over a series of years). It is important that the validity and relevance of the outcomes of such simulation or optimisation exercises is critically discussed with the stakeholders. Moreover, these models should not be used as black (or magic) boxes in the hands of researchers, but should developed into transparent tools for learning.

(4) Design insightful tools for learning and demonstration.

(5) Assist stakeholders in setting up and evaluating on-farm experiments.

(6) Comment upon technical inferences and arguments which actors bring to bear in the learning, negotiation and project decision-making process.

(7) Bring in experiences from the past or from other regions and researchers.

For social scientists:

(1) Answer questions that arise with respect to the social processes which shape technical practices and relations, and engage especially in qualitative research in order to gain insight into the social logic of particular practices when no plausible answer can be given.

(2) Inform stakeholders about their understanding of the social system, and -if necessary- engage in exploratory research with respect to the 'structure' of the social system: what are the rules, knowledge-repertoires, cultural repertoires, and resource divisions on which actors draw in reproducing the system?

(3) Do research on the social logic of particular technical practices.

(4) Investigate the potential social consequences of proposed interventions or alternatives, and give advice on intervention strategies that may help stakeholders to realise their goals.

(5) Contribute to the development of insightful tools for learning and demonstration, for example on the basis of didactic insights and game theory.

(6) Comment upon social inferences and arguments which actors bring to bear in the learning, negotiation and project decision-making process.

(7) Bring in experiences from the past or from other regions and researchers.

(8) Support the facilitator of the process, and reflect on the process itself (see below).

It is clear that the involvement of various stakeholders requires that the process be guided and monitored by a *facilitator*. This facilitator is supposed to be knowledgeable about supporting and directing learning, negotiation and project decision-making processes, and should be familiar with the language and culture of both farmers and researchers. Such a 'new style' extension professional could be supported by earlier mentioned social scientists. Naturally, all sorts of strategic questions play a role in facilitation. Who will be involved in what? How does one get different people around the table? Which methods & tools for work and debate can be used? Clearly, a facilitator is not in control of everything, but he or she should optimally use the available space for manoeuvre.

Finally, it is important to realise that innovation does not match well with bureaucracy (Leeuwis, 1993, 1995b). Conditions need to be provided, therefore, that the involvement of various actors does not lead to endless procedural difficulties. This implies among other things that the members of the innovation team must have a certain mandate and freedom for manoeuvre.

Modifying steps of the Wageningen prototyping approach

In relation to the foregoing, various adaptations will have to be made to steps that at present constitute the Wageningen prototyping approach.

In the first place, it is clear that a preparatory step (*Step 0*) must be included before Step 1. During this step the initiators (be they researchers, farmers, policy makers or extension agents) of the development trajectory need to explore which actors may fruitfully *form a development team* around the preliminarily identified topic[3]. At this point, it may already be useful to do some exploratory social science (field or literature) research in order to assess which groups or categories of farmers may have similar problems, and may reach some productive consensus on solutions. Here it is important to try to compose an optimally heterogeneous group of farmers and researchers. If the interests and practices in the domain(s) at stake diverge too much, it is likely that no productive convergence can be secured (see Leeuwis, 1993, 1995b).

Second, the step of 'setting objectives' (*Step 1*) within the Wageningen prototyping approach should in my view be reworked into a step in which members of a newly formed development team identify and prioritise several broad directions for research after exploring the various problem perceptions[4], interests and opportunities. Thus, this step eventually results in the *contours of a research agenda* which reflects a negotiated compromise in terms of the societal objectives and interests which are being served by this

[3] One could argue that the topic at stake should be left open at this stage. However, in actual practice it is only very seldom that a development trajectory is initiated (and funded) without at least a rough idea of what is to be done. In my view, it is quite legitimate to start from such an initial idea, provided that there is scope for adaptation if necessary.

[4] Vereijken (1997:21) stresses the need for more elaborate problem analysis as well. However, Vereijken hereby emphasises the role of social scientists. I also feel that social scientists can play a useful role, although in the problem analysis they are just one of the parties involved. In the preparatory phase, however, their role may have to be more dominant.

agenda. Thereby the goals and interests that are taken into account cannot be determined in advance, as they are the outcome of a largely unpredictable negotiation process. Moreover, I feel that it would only complicate matters if one attempted to arrive at a single goal hierarchy on which all actors agree. Rather, I propose to accept that the different actors involved in the process have (and will always have) different goal hierarchies, and instead strive at finding a compromise in the form of broad directions for research.

In line with the newly proposed Step 1, the step of 'making objectives measurable and identify methods' (*Step 2*) will have to be altered slightly as well. In this step, then, the broad directions for research that are already agreed upon in Step 1 are to be further *operationalised and translated into concrete research projects*. Thus, this step still involves the identification of potential changes in agricultural technology and farming practices (i.e. 'multiple-objective methods') of which the feasibility and effectiveness must somehow be further explored. Furthermore, it must be collectively decided how (which research design) and where (on farm, in a scientific laboratory, in a computer simulation or on an experimental facility) this exploration is to take place. It seems less desirable to define in great detail the precise 'parameters for goal attainment' as these criteria will probably vary for different actors. Nevertheless, it is useful to identify the main variables that are to be measured. On the basis of these measurements, the different actors can -at a later stage, i.e. Step 4- decide for themselves whether or not the technologies and practices are to be further adapted. Clearly, this step of further refining the research agenda implies a continuation of the negotiation (and learning) processes that were started in the previous step.

The purpose of *Step 3* of the Wageningen prototyping approach ('developing a theoretical prototype') remains essentially the same, namely to further design and operationalise the technologies, practices and research strategies involved. However, a greater variety of actors are involved in this process that was envisaged in the original approach.

Similarly, the function of the 'iterative prototyping' step (*Step 4*) remains largely unchanged. Still the main idea here is to test and adapt -in an iterative manner- both the technologies and practices under consideration, and the research strategies with which they are being explored. An important difference with the original approach, however, is that there are no fixed or undisputed evaluation criteria which can be applied to unequivocally assess the research findings. Hence, this step implies an interpretative struggle, and a continuous re-negotiation and re-definition of the further research activities that are to be undertaken.

Finally, it is still useful to think of a 'dissemination' step (*Step 5*) in connection with the technology development process. However, it is less desirable to conceptualise this step as the 'closing' step of the approach. In fact, the adaptations that I have suggested to the Wageningen prototyping approach can be seen as an effort to build in continuous communication with those who are supposed to use the innovations. Hence, the 'extension' process runs parallel to the whole procedure. In addition to a continuous communication and participation effort, I think several other modifications of the extension activities within the Wageningen prototyping approach are needed. First, I would suggest a less homogeneous choosing of farmers who participate in the technology development process, both in terms of their farming system and strategy, and their spatial location[5]. Secondly, more emphasis must be placed on facilitating communication between the stakeholders represented in the development team, and those whom they are supposed to represent. This is in order to ensure that the learning process that takes place in the development team is transferred to a larger audience.

Table 2 Main conceptual differences between the Wageningen prototyping approach proposed by Vereijken & Kropff (1995) and the adapted version suggested in this paper.

	Wageningen prototyping approach by Vereijken & Kropff (1995)	Alternative suggested in this paper
Conceptual		
Underlying intervention assumption	Development of a radically different farming system is the most efficient and effective strategy towards achieving sustainable agriculture.	Inducing gradual change of the existing farming system is the most realistic option for achieving sustainable forms of agriculture.
Conception of a farm / farming	A farm is an agro-ecological phenomenon, shaped by agro-ecological interrelations and processes	A farm is a socio-technical phenomenon in which agro-ecological relations are purposefully created and shaped in social interaction.
Role of scientists	Dominant; owners of a research process	Resource persons in an innovation process
Role of extension	Disseminate new production systems, technologies and practices	Facilitate the process of learning, negotiation and project decision-making, and transferring the learning process

[5] In the project described by Vereijken & Kropff (1995) all of the selected 'vanguard farms' are located in one particular area (i.e. in the vicinity of the research station) of the Dutch IJsselmeer polders.

Table 3. Main practical differences between the Wageningen prototyping approach proposed by Vereijken & Kropff (1995) and the adapted version suggested in this paper.

	Wageningen prototyping approach by Vereijken & Kropff (1995)	Alternative suggested in this paper
Practical		
Actors involved in the methodology	. Natural scientists . Homogeneous group of farmers	. Optimally heterogeneous group of farmers . Critical stakeholders . Natural scientists . Social scientists . Facilitator
Step 0	(no explicit preparatory step)	**Preparation:** - exploratory research - forming a multi-actor development team
Step 1	**Setting objectives:** - natural scientists make a goal hierarchy	**Setting contours:** - negotiating broad directions for research - no attempt to create a single goal hierarchy
Step 2	**Making objectives measurable and identifying methods:** - define criteria for goal attainment - decide on technologies and practices to be explored	**Further refining the research agenda:** - negotiate technologies and practices to be explored - negotiate basic research set up - negotiate variables to be measured in order to allow actors to make their own evaluations
Step 3	**Develop theoretical prototype** - further design and operationalise the technologies, practices and research strategies involved - emphasis on research in research facilities	**Develop theoretical prototype** - further negotiation on the design and operationalisation of the technologies, practices and research strategies involved - more attention for on-farm research
Step 4	**Iterative prototyping** - adaptations made on the basis of fixed evaluation criteria	**Iterative prototyping** - adaptations negotiated on the basis of interpretative struggle and diverse sets of evaluation criteria
Step 5	**Extension** - through vanguard farms, regional networks and national networks	**Continuation of communication efforts** - through on-farm research and demonstration on diverse farms, regional networks and national networks - facilitate communication between team members and those whom they represent (transferring learning process)

6. Epilogue

In this chapter an attempt has been made to add insights from communication and innovation studies to natural scientists' approaches towards bringing about new technologies and practices for sustainable agriculture. As an example, I have concentrated on the Wageningen prototyping approach that has been developed by natural scientists in order to support the development of ecologically sound production systems. It emerges that there is reason to adapt the methodology in order to better accommodate learning and negotiation processes, and improve its capacity to deal with the 'soft' dimensions of design. In essence, I propose that prototyping be reworked from a 'research' methodology into an 'innovation' approach. Hopefully, the proposed adapted version can serve as a basis for future co-operation among social scientists and natural scientists in Wageningen and elsewhere.

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Chapter 9

Enhancing social cognition for combating the Chinese citrus fly in Bhutan[1]

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Abstract

This chapter shows how new modes of interaction between farmers, researchers and extension agents can contribute effectively to the creation of new forms of social cognition, in the form of viable technologies and social-organisational arrangements for sustainable agriculture. This is demonstrated by means of two detailed case studies, which describe the process of arriving at new technical and organisational strategies for combating the Chinese citrus fly in two Bhutanese communities. The need to carefully match technical and social solutions to pest problems is illustrated clearly, as it appears that communities with different characteristics require differential solutions in both domains. During the design process key factors for success where that (a) research and extension staff worked closely together with each other and with farmers in a process of experiential discovery learning, which guided the setting of research agendas; (b) orchards, farmers' practices and experiences where an important source of feedback; (c) sufficient attention remained for conventional on-station research, next to in-village research; (d) in-village experimentation and on-station research effectively inspired each other, largely because they were 'supervised' by the same persons, and (e) considerable attention was paid to social-organisational issues, social dynamics, and to adapting the technology to social conditions (and vice versa). The chapter also briefly evaluates attempts to scale-up the knowledge intensive and interactively developed strategies for controlling the Chinese citrus fly. It appeared that regular extension service lacked adequate skills and conceptions to introduce

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citrus fly control in a way that was consistent with the nature of the technology. Extension agents resorted to transfer-of-technology modes of operation, and failed both to address social organisational issues and to organise a much-required learning trajectory.

1. Introduction

Bhutan, mandarin, the Chinese citrus fly and social cognition theory

This chapter discusses the development of an Integrated Pest Management (IPM) strategy for the Chinese citrus fly *(Bactrocera minax* Enderlein*)* that causes premature fruit drop in Bhutanese mandarin orchards. It is based on seven years of hands-on field work on IPM in eastern Bhutan and an excerpt of a more extensive study (Schoubroeck, in press a) that covers the biology and control of the citrus fly and documents the way the control method was developed. First, we discuss why the control strategy needed to be developed through a programme in which farmers, extension staff and researchers interacted, rather than by researchers alone. Subsequently, it is described in some detail how such a strategy was indeed developed in two different pilot villages, and which technical and social problems were encountered in these different environments. Finally, the chapter briefly discusses efforts to scale-up the technologies developed through the in-village research programme, and identifies several bottlenecks in doing so through conventional extension strategies.

Bhutan and mandarin

Bhutan is a land-locked kingdom in the Himalayas situated between China (Tibet) in the north and India (Assam and West-Bengal) in the south. The population consists of three major groups: a group of Tibeto-Mongolian origin in the west, a group of Indo-Mongolian in the east and a Nepali group in the south (Hasrat, 1980). The Ministry of Agriculture (MoA) of the Royal Government of Bhutan (RGoB) carries out all agricultural research and extension programmes, assisted by various donors. The country is mountainous and in a few valleys and on slopes of the lower hills farmers grow their subsistence crops. Subsistence farming is sometimes complemented with one or two cash crops for the Indian market, thus enabling rural households to earn some money. Nearby areas in India and Bangladesh have a population of over a hundred million potential consumers that can easily absorb any extra production of cash crops in Bhutan under the present free trade conditions. Mandarin *(Citrus reticulata* Blanco) has always been the most important cash crop of Bhutan (and neighbouring Sikkim). In the 1990s the export value of mandarin equalled the value of all other cash crops together, amounting the equivalent of many millions of US dollars. The local variety is traditional, possibly hundreds of years old, robust and well adapted to the variations in the local climate. It is seed-born and can be multiplied in villages; due to the fact that it is not a grafted variety, so far Bhutan has been spared from citrus virus problems unlike nearby Nepal and Meghalaya where vast areas of citrus have been destroyed by the introduction of greening disease. Yet, the mandarin production is sub-optimal. Individual trees yield the equivalent of 40 tonnes per hectare, while the average production is between 2 and 6 tonnes. The potential production is rarely reached because of nutrient, water and pest management problems. Major pests include mistletoe *(Loranthus spp.)*, the citrus trunk borer *(Anoplophora spp.)*. Premature fruit drop of up to 90 % of fruits is caused by the citrus green stink bug (in low altitude orchards) and the Chinese citrus fly (at higher altitudes). Thus, there is a vast potential to improve the yields of the present variety through improved management. Individual farmers have already developed pest management strategies for mistletoe and the trunk borer. Initially the programme was carried out in relatively high orchards; therefore, this article will concentrate on the development of a control strategy for the Chinese citrus fly.

The Cinese citrus fly

The Chinese citrus fly *(Bactrocera minax)* occurs in China (Yang et al., 1994), in Sikkim (Nath, 1974) and in Bhutan (Bigger et al., 1988). It is a species of the Fruit Fly family *(Tephritidae)*. About ten species of this family inflict vast damage on fruit production all over the world and that is the reason why the group is well researched. Tephritid flies in general are known to be attracted to protein food lures and for many species sex (para-)pheromones have been developed. Most species of the group have more than one generation a year (typically six to ten generations a year). All species feed on fresh plant materials such as flower heads or fruit, some species feed on many fruit species, and others are monophagous and feed on one or a few closely related species.

At the start of the citrus IPM programme, little was known about the particular species in Bhutan. Most of the literature on the fly was in Chinese and therefore inaccessible to us. In the course of time it appeared that the Chinese citrus fly is somewhat exceptional in its behaviour compared to most other fruit fly pests. It has only one generation a year, it employs two rest periods during its life cycle (as puparium and as egg) and it reproduces exclusively on citrus. So far, no pheromones have been found that regulate the fly's mating behaviour. Technical studies showed that the fly oviposits in citrus fruits when they are just over 11 mm, i.e., in mandarin the fly oviposits between June and September. Damage becomes evident in October and November. Eggs in infested fruits hatch and become tiny maggots; their feeding invokes a premature ripening process that makes infested fruits discolour and drop. Maggots feed on the fruit and after making the fruit drop they enter the soil where they pupate, to again emerge as a fly the following April and May. Damage levels vary from year to year; in infested orchards damage usually varies from 35 to 75 %. Over all, control of the fly may lead to doubling of the yield levels in infested areas, i.e., in orchards above 1,100 meters altitude and in shaded orchards at lower altitudes.

Social cognition theory

The process of citrus fly IPM development is described using social cognition theory. Social cognition theory is about human cognition at group level. Douglas (1986) describes how a group develops its own vocabulary that reflects the setting of the group, and shares an interpretation of certain phenomena in language, thus creating a shared reality. Thus social groups, or social institutions, have a reasoning of their own. Individuals live and communicate within a social institution: a farmer lives in a farmer community where he or she finds vocabulary and references for thinking, a scientist refers to peers in his or her scientific discipline. Through continuous communication, individuals conform to the group they belong to by sharing vocabulary, modes of thinking, and values. Such knowledge can easily become a self-propelling reality, even if it ceases to be valid, as groups often have a tendency to be 'self-referential', and fail to absorb relevant feedback from other groups or the natural world. Hutchins (1995) elaborated on social cognition theory by observing the organisation of the navigation of a navy ship. The highly complicated navigation activity is carried out by the particular crew, in which each member has his particular task. Although the role of each individual could be described in prescriptive terms (if we arrive at x, place the relevant map on the desk), each such prescription is 'processed' through the particular human mind. Should the prescription not apply, the individual will go out of the way of the prescription to make sure that his task is performed well. This property makes for a more robust and flexible system, because if one task is not performed well, surrounding individuals will take it over. This is done without any individual having a complete overview of the process. Thus, the group as a whole has a 'social cognition', in Hutchins' case the ability to navigate a ship, for which a certain common language and shared worldview is needed. The example also shows that the idea of 'social cognition' refers not only to cognitive dimensions, but also to forms of organisation, social arrangements, practices and routines. Together, these result in a form of 'collective agency' (Giddens, 1984; Röling, 1996); i.e. the capacity to perform and act in a coherent manner as a group.

For this study it is important to recognise the existence of self-referential knowledge in stakeholder groups in the Bhutanese agricultural knowledge system. Groups of researchers, extension staff and farmers made use of a different vocabulary (in a different language!), and had a different 'worldview'. Effective co-operation within and between these groups in order to generate an adequate IPM strategy for controlling Chinese citrus fly was far from automatic and self-evident. This chapter reports on efforts to link the social cognitions of these different groups in order to enhance collective agency in combating the Chinese citrus fly.

Establishing the need for an interactive process towards citrus fly IPM

The need for an interactive design process emerged during the early years of the eastern Bhutanese plant protection service in 1991-1993. At the time, the research and extension sections of the service were operating in a rather independent manner. Up to that time, the extension service had tried to introduce citrus management technology from elsewhere; i.e. as described in Indian handbooks. The methodology was introduced through an on-going transfer-of-technology programme, modelled after the Training and Visit (T&V) approach. Because of the potential for improvement of production and the sheer insaturable market, the extension section of the plant protection service initiated a programme that concentrated on citrus management in one particular district. We were aware of the extension methodology applied in the Farmers Field Schools in Indonesia (Fliert, 1993) in which farmers were trained to discover about the ecology of rice fields, i.e., the concept of natural control and the consequences for pest control. In the Bhutanese environment, we picked up the element of experiential learning (Kolb, 1984) and tried to incorporate this in the on-going extension routine (Schoubroeck, in press a). The training site was changed from a classroom situation to orchards, and all recommendations were carried out by farmers in practice and checked for their practicability and effectiveness. This slight adaptation of the T&V approach led to the discovery that the original recommendations to control pests such as citrus trunk borer were invalid, and that individual farmers had already developed superior alternatives, that somehow hardly diffused in the citrus growers' communities. Thus, the citrus programme took up the task of reformulating recommendations on the control of key pests based on the extension service's traditional messages, enriched with individual farmers' practices. Furthermore, these recommendations were disseminated over large groups of citrus growing farmers and published in various forums such as the radio and the national agriculture newsletter.

However, for the Chinese citrus fly, farmers were not in a position to develop a feasible control strategy. Firstly, the fly was to be controlled at communal level. Control in individual orchards was unlikely to be effective because flies were known to be flying up to 1,000 m, undoing individual control efforts because of immigration from neighbouring orchards. Moreover, the fly biology was not transparent to farmers. In fact, even extension staff had never laid the link between flies (usually regarded as wasps because of an apparently successful mimicry) flying about in orchards in June-August, and fruit drop, taking place in October-November. The research section of the plant protection service did explorative research on the Chinese citrus fly in 1991-1993. Though this work led to the unveiling of many interesting details of the life cycle, it never resulted in a tested fly control method. Researchers were searching for 'natural control', as it was popular in those circles after the successful prevention of pesticide-induced pests through the FFS in rice in Indonesia. In eastern Bhutan, however, chemical control was rarely applied and yet the fly thrived in mandarin orchards. Research outcomes such as the discovery that mandarin trees teemed with natural enemies hardly impressed citrus farmers during village training. While researchers happily researched such subjects that were of interest in the group of entomologists (i.e., while entomologists conformed to the group cognition within their peer group!), extension staff had no choice but to promote theoretical control options such as hygienic measures. However, due to the feedback loop that had been introduced by changing the training site to orchards, it was found that such measures hardly worked, possibly because only selected farmers carried out such measures, or possibly because hygienic measures did not have the potential to control the pest at all.

The situation developed into a major tension between the extension and research section of the plant protection service. The extension section supposed that the research section was to come up with practical recommendations to control the pest, while every year the research section happily discovered new details on the biology of the fly. In retrospect, this tension is a conflict between two separate social groups with their own social cognition. Because the extension section now had merged its thinking with the interest of citrus growers, it no longer sufficed to receive 'nice stories' for extension activities from research (as used to be sufficient during the pure transfer-of-technology period). It now also demanded that the recommendations be actually effective, thus pronouncing the needs of citrus growers, who saw their cash-generating harvest being halved due to the citrus fly. On-station research alone could not meet such demands because the actual need to develop practical solutions was never felt. Solutions that worked in theory or as carried out by researchers in experimental orchards were the best results possible within these boundaries. Although the information from such research was valuable in designing a practical solution to the citrus fly problem, it covered only technical aspects and was not likely to be robust in a village environment.

Late in 1993, the national plant protection service changed its research policy. It initiated research on confined subjects in in-village research programmes. Besides in-village research, the research group continued on-station research that ensured the relevance of research to the village programmes. The change in research policy was initiated because the team leader of the IPM development project, Dr. H.R. Feijen, recognised that on-station research had little potential to develop solutions for pest problems at farm level. Village research programmes were initiated through the carrying out of a Rapid Rural Appraisal exercise. It soon became obvious that in-village research was of completely different character than on-station research because fields were owned by farmers who had a will and an agenda of their own. The very move from on-station to in-village research thus placed farmers on the agenda of technical researchers.

2. Building effective social cognition for controlling the citrus fly: the case of Am Shing pilot village

A RRA-exercise revealed that the community of Am Shing village in eastern Bhutan was willing to experiment with new orchard management methods. Am Shing is a relatively recent settlement (founded early this century) and includes some 33 households. There are a few lay monks in the village, but religion is relatively unimportant compared to more traditional areas. Each house has up to two hundred bearing mandarin trees, the average holding is about fifty trees while half of the orchards have yet to reach the bearing stage. In 1994 to 1996 staff visited the village five times a season for a few days, and soon a new programme pattern emerged. 'Official' meetings were held at the start of such visits, while later people came with local snacks and drinks and organised social functions. During official meetings, the programme contents were discussed and informal gatherings helped to build a group spirit and to build commitment to realise the programme objectives. The informal gatherings resulted in an atmosphere of trust, and both farmers and staff felt at ease to request for necessary assistance to solve problems felt by either side. Programme staff came to develop an IPM method for the citrus fly; the community carried out experiments and got access to technical information and specialised inputs (such as bait and pesticides) through the programme.

The Am Shing community mastered the skill to seize the initiative in the programme, which programme staff took as an opportunity to be explored. In the citrus IPM programme the village developed a much closer rapport with researchers as compared to earlier development programmes. In the framework of the citrus programme, farmers came up with various management problems they wanted to have solved, such as pests related to fruit quality (i.e., small suckers and scab). Farmers carried out experiments with suggestions and materials provided by research staff, even if staff was not particularly knowledgeable about the problems. Later in the programme, the community regarded periodical drought as a management problem, and asked the research team for assistance by helping to get support for the construction of a small water supply system that would also fulfil drinking water needs.

In the apparently well-organised community like Am Shing, experimentation with new pest control measures (which had never been tested before) proved relatively smooth. Theoretical options to control the Chinese citrus fly included proteinaceous baiting and collecting and destroying maggot-loaded dropped fruit, both to be implemented over the entire village.

Baiting the Chinese citrus fly

In May 1994, the research team showed the attraction of citrus flies to bait to the Am Shing community. The community carried out bait splashes over the entire village (see Box 1) every ten days or so until September. The local extension staff designed a fruit loss recording system for illiterate farmers, and in October-November five individuals volunteered to carefully record fruit drop and take record of the final harvest in two trees each. The same recording was carried out in a neighbouring untreated village. Data thus collected were analysed by the research team, but appeared to poorly represent fruit drop percentages. Even if farmers of non-treated orchards claimed that one-third of fruits had dropped, the thus recorded percentages of fruit drop varied from 2 to 8 %. As an experiment we once dropped 20 marked fruits from the canopy of one tree, and could recover only six from the ground: the rest disappeared in bushes or down the slope. Thus, the fruit drop records did not reflect actual losses and we were not able to present official records of its effects. Am Shing farmers themselves claimed that about 15 % of all fruits had dropped after treatment, compared to one-third in the year before; however, fruit setting had been three times higher, so that in absolute terms, fruit drop had been higher. Moreover, the farmers' assessments may have been tainted by the wish not to disappoint the research team, and were therefore not very reliable. After all the efforts put in the experiment, the researcher then presented the *relative* reduction of fruit drop as a success (which later appeared a valid judgement in view of the fly's behaviour under varying levels of fruit setting). Yet, obviously the lack of presentable data was a serious drawback of the village experiment[2].

Box 1. Control of the Chinese citrus fly through bait-splashing and related luring methods

Poisoned fly attracting substances can be used to lure and kill flies of the Tephritid family in general. In August 1993 a locally available protein substance was found to attract female Chinese citrus flies. With bait it is possible to reduce the fly population with minimal insecticide requirement, so that also the effect on non-target insects is reduced. The bait-poison mixture is best applied spot-wise, and it can be applied by splashing into individual trees with a cup, brush or locally made water piston rather than by expensive and unreliable sprayers. Each bearing tree must be treated with 50 ml bait mixture, compared to the need of up to five litre insecticide solution for a conventional cover spray. A disadvantage of fly baiting is its obligatory village-wide application. Bait attracts flies for about four consecutive days, and in treated orchards flies will reappear from adjacent non-treated areas and undo the fly control effect, and treatments need to be repeated if there is a risk for immigration from elsewhere.

Hygienic measures to control the Chinese citrus fly

Another control option was the destruction of maggot-loaded dropped fruit. For this, the community dug 8 feet (!) deep pits for fruit disposal in every orchard. During the fruit drop period Am Shing community collected dropped fruits and disposed them in pits. An experiment was carried out to establish the emergence of flies from such pits (as illustrated in Box 2). It appeared that natural control mechanisms in the pits killed as good as all pupae and that no additional control measures were required.

Box 2. In-village experimentation with hygienic measures

Farmers disposed maggot-loaded dropped fruits in pits to avoid maggots pupating in the soil thus representing the following year's fly generation. The community carried out the measure beyond expectation, and during the following meeting farmers requested for chemicals to kill citrus fly larvae in pits. Researchers however maintained that deep burying fruits as such would kill flies emerging from pits. The debate could not be settled and it was decided to do an experiment. Pits were filled with thousands of dropped fruits, some pits were treated with chemicals and some were not. Emerging flies would be caught in mosquito nets suspended over the pits. In spring, from pits under both treatments only few flies emerged whereas thousands of maggots had been disposed in the pit (by disposing dropped fruit). Examination of the rotten fruit mass showed that maggots had died through the incapability to reach soil fit for pupation, while mostly ants preyed upon underground puparia. This not only convinced farmers, but also extension staff and researchers, that natural control in pits worked well. The results were incorporated in the on-going extension-

[2] Luckily, a parallel experiment in station-led experimental orchards in the same season showed a decrease in fruit drop percentages from 54% to 17%, which indicated that fruit drop reduction as a result of baiting was not to be ruled out.

program in other areas. Experiments thus developed were in fact modules that could be used in FFS-type of extension programs.

One remark must be made to underline the experimental character of the programme that may heavily draw on farmers' resources. When we later examined the pupae density in cleaned and non-cleaned orchards just before flies would emerge in April, it was revealed that hygienic measures hardly bore the potential to reduce the citrus fly population. Natural enemies grazed orchard soil for pupae down to about 30 pupae (the equivalent of four maggot-loaded fruits) per square meter; even well carried out hygienic measures could never compete with this mechanism (Schoubroeck, in press b). Thus, the community's efforts to dig the 8-feet pits in stony soil probably never contributed to a better citrus production in the village. This underlines that theoretical control options are not necessary practical ones, and that one must be very careful with proposing such measures without reviewing their effectiveness.

The need to develop better monitoring routines

Over all, the experiment showed the lack of a few essential technological components for the development of reliable fly control methods. For example, the community had carried out about twelve bait-splashes over the adult-flying season, while it was quite likely that the fly could be controlled with fewer treatments. In fact, the applied control method could only be characterised as 'IPM' rather than 'chemical control' because of its low pesticide use (1 % of the amount needed for cover spraying); otherwise the method was applied recipe-like and determined by the instruction of the research team rather than based on a fly population monitoring system. Farmers were not yet in a position to develop an intuition on citrus fly control in the absence of easy-to-use population monitoring devices. In the long run the community was never going to carry out twelve bait-splashes per season; possibly four or five was the maximum. Thus, a fly population monitoring method had to be developed on which to base the time and number of bait applications.

Moreover, the inability to reliably establish fruit drop percentages meant that researchers just guessed about the effect of the experiments. A more reliable method of establishing fruit drop was necessary, preferably one that could distinguish between fruit drop caused by the citrus fly and by the citrus green stink bug. Monitoring fruit drop percentages may seem simple at first sight; it turned out to be one of the most difficult components of the research programme. Difficulties were caused by a combination of factors. The relation between fly activity and the fruit drop levels was not known. How do flies select fruits for oviposition and what type of fruits then drops? What is the in-fruit mortality of posited egg clutches? What is the relation between oviposition and fruit drop, in view of possible other drop causing factors? Another problem was the quantification of fruit drop. On-station research revealed that fruit drop percentages within orchards varied among trees: in the same orchard, one tree shed 20 % of its fruits, and another 70 %, while fruit drop in both trees lasted for two months. In addition, it appeared difficult to estimate the final harvest of individual trees. When on-station research revealed that during their oviposition act, citrus flies leave scars in the skin of individual fruit, a pre-drop observation routine was developed and verified in station-led research in research orchards (Box 3).

Box 3. Development of a protocol to establish damage by the Chinese citrus fly.

Initially, drop percentages were established through collecting dropped fruit and estimating fruit remaining in the tree. This method was carried out through weekly collecting and counting of dropped fruits from under selected trees for ten weeks in a row. In relatively flat experimental orchards where staff and students carried out observations, this method worked reasonably well; in villages however it appeared impossible to get reliable drop data. During local festivals farmers failed to do observations and dropped fruit rolled down the slope to disappear into bushes. Thus, more reliable fly activity observation methods had to be developed. Among other methods, a sample of fruits was checked for signs of oviposition. When fruits were superficially peeled, the place where flies inserted eggs into fruits was visible as a black spot. This principle of observation resulted in insight into the fly oviposition behaviour. Flies first oviposit in the biggest citrus fruits in the tree or orchard, irrespective of fruit species and position in the tree. Thus, more vigorous trees (in which fruits are bigger) attract more oviposition activity than declining trees. The main oviposition season is during the period that fruits are between 15 and 22 mm diameter; i.e., for mandarin usually between mid-June and August (depending on the local climate). It took several years to develop these findings into a reliable infestation monitoring routine. After the main oviposition season, sampling and checking the biggest, medium and small fruits in the orchard allows for the comparison of fruit fly activity between years or between villages. Comparing oviposition density in samples from the tree and from the ground allows for the establishment of the relative importance of the citrus fly as a cause of fruit drop. During training, this method was explained to and used by farmers, in particular to make them aware of the timing of oviposition and the quality deterioration characteristics of citrus fly infestation: after all, the fly oviposits in the biggest and most valuable fruits.

An early version of the monitoring routine revealed that after two years the Am Shing community had succeeded in considerably reducing fruit fly damage. In 1996 less than 5 % of fruits was infested by citrus fly (against about 35 % in nearby non-treated villages) which meant that the citrus fly population in Am Shing was nearly extinct. However, some fruit drop by another cause, the citrus green stink bug, still remained. Through the fly activity monitoring routine the most active group of farmers could see that one of the two major causes of fruit drop was checked; however, for most farmers bug-caused fruit drop blurred the evidence for the effectiveness of the fly control method to some extent. This feature meant that the farmers' interpretation of the effectiveness of citrus fly control was not always valid: in fact, a similar research programme on the fruit drop inducing bug needed to be carried out.

The emergence of community intuition and autonomous experimentation on fly control
So far, the Am Shing community carried out measures following technological developments by the research team. A fly-activity-monitoring tool would enable the community to independently decide on measures to be taken. The development of traps enabled the community to carry out measures tailored to the needs they felt, so that the community began to behave in a more autonomous manner. In the second village research season, on-station research had come up with a few fly traps, i.e. the dry-lure trap (based on attraction by smell and an indication that flies could be baited) and the fruit-mimic trap (based on attraction to fruit shapes and an indication that oviposition activity was on-going) (Schoubroeck & Kool-de Rie, in press). Another useful tool was the fly-emergence bottle in which pupae could be kept to establish the fly's emergence period. Although the tools worked in experimental orchards, we did not yet know what device worked best in what period, and how the devices could be used as indicators for possible action to be taken. The fruit-mimic trap attracted flies in June. The Am Shing farmers were provided with some traps and baiting materials to carry out a baiting treatment so that they could figure out how to use them. If fly baiting worked this year, the following year they would have to pay for the materials. The village baiting committee then placed the traps in various orchards. It regularly monitored the traps and baited only after trapping flies; this resulted in farmers carrying out only two bait splashing treatments that year. This, while the researcher would have preferred to play safe and carry out calendar-based treatments, as at the time it was not yet known whether bait-splashing was effective at all. When such was discussed during a research team visit, farmers expressed that they had wanted to cut down on baiting material use in order not to have to buy it in the following year. Thus, farmers used the fly catching devices as population monitoring devices; even if the relation between low fly catches and a low population had not yet been formally made so that the research team felt uneasy about the farmers' decisions. In this, the farmers showed how they used the monitoring tools independently for their own objectives rather than following the staff's guidelines. This both showed the intentions of the community as a whole and the fact that they acted upon these intentions in an organised way.

Further experiments carried out by farmers included the keeping of pupae in jars (some in the upper village and some lower down; some in the open and some near the fire) to determine the timing of emergence under various conditions. Farmers concluded that the warmer the place where the pupae were kept, the earlier the flies emerged. Thus, when again one year later research showed that the best time to attract flies was the fly emergence period (rather than the oviposition period), a brief discussion with the Am Shing community sufficed to make farmers adjust the timing of their bait splashing activities to the optimal attraction period. In this way no extensive experiential learning exercises were needed for farmers to make full use of this finding, because most of them had already constructed a broad concept of the fly's life cycle and could link on-station experimental findings to this concept. The initial investment in farmers' understanding of the problem resulted in later flexibility and effectiveness of their activities.

Building upon existing social cognition and collective agency
In retrospect, the Am Shing community proved an interesting actor as it pulled the programme way beyond its original objective. The village had been selected for the development of IPM for the citrus fly at a time when it was still thought that this pest was equally important in all citrus growing areas and inflicting 35-75 % damage to the mandarin harvest. In Am Shing this appeared not to be the case. Fruit drop was a 35-50 % 'low'; the citrus fly was responsible for possibly two-thirds of all fruit drop; the remaining one-third was probably caused by the citrus green stink bug. Thus, other than in higher situated villages the control of the citrus fly did not lead to double or even triple yields (such as in Dungmin village, next Section); the increase in yield was possibly 'only' 50 % or so. Yet, the community was always eager to receive research staff and attract their attention. The reason for this was that the village community regarded the programme staff as representatives of the government, and that the village had other points on the agenda. In fact, as the programme enfolded, it became clear that the communities' participation in the IPM programme was part of a deliberate strategy to realise other high priority interests, such as the construction of a feeder road and the building of a water supply system for home consumption and orchard irrigation. On this latter priority, the community did indeed manage to make progress through the intermediation of plant protection staff; i.e. they successfully mobilised the IPM network in order to gain access to other governmental services. In all, Am Shing emerges as a community that already operated in a coherent way in several respects prior to becoming an IPM pilot village. That is; the community expressed considerable social cognition and collective agency in areas other than pest management. Building on this existing capacity, it soon developed new social cognition in the area of citrus fly control, and was able to put a flexible and robust organisation in place in order to combat the fly at community level. If one person could not perform a task, another person would soon take up his job for the common purpose of citrus fly control. This capability of the village was one of the main reasons why the programme went smoothly, and why research and extension staff labelled it an 'innovative' village.

The story shows how on-station research was determined by the needs of a practical IPM experiment by farmers, and how research outcomes were immediately applied in the pilot village. On the other hand, throughout the programme, the three stakeholder groups – farmers, extension staff and research staff – had different interests. Researchers wanted to develop a citrus IPM strategy that could be applied all over the area, and used the initiatives of the Am Shing community to identify shortcomings in the control and pest monitoring tools available. This set the on-station research agenda that resulted in tools useful for the village programme. However, the development of tools then took one or two seasons, and by the time they became operational the village programme was coming to an end, showing once more that the rhythm of technology development does not necessarily coincide with the logic of governmental policies and projects (see also Leeuwis, 1995). For the research staff, control of fruit drop was important as evidence for the success of the programme and for ensuring continued support by farmers (and, through them, of village and district authorities). For farmers, citrus pests represented only one of the many constraints for a better living. They carried out the fruit drop control experiments in order to get further access to government services - a service that the researcher could not deny after the farmers' overwhelming support for the IPM experimentation programme.

In the next section a more complex situation is discussed. In Dungmin village, apart from the technical issues, problems in the domain of community organisation affected the development of citrus fly IPM.

3. Complications in building effective social cognition: the case of Dungmin pilot village[3]

Apart from the Am Shing programme, a parallel research programme was carried out in another village, i.e., Dungmin, eastern Bhutan. In Am Shing, the farmers' community took care of the organisation for citrus fly control. The previous section showed how in Am Shing fly monitoring routines were essential for building farmers' intuition that was used to organise pest management activities concerted over the entire community. Unlike in Am Shing, in Dungmin the community was initially not in a position to carry out proposed fly control measures. Organisational patterns in the community did not favour communal action for fly control. Therefore the extension staff attempted to enhance the internal organisation of the village. This resulted in experimentation not only on technical issues, but also on social arrangements necessary for technology to be effective. These two dimensions of innovation appeared almost inseparable, which is why we discuss them simultaneously. In the next sections several episodes and aspects of the Dungmin experience are highlighted.

The development of a fly baiting method in Dungmin

In technical terms, Dungmin is an ideal place for experimentation with citrus fly control. The village has about 1,200 bearing trees, it is isolated and situated on a north-facing slope which means that fruit drop is heavy (50-75 %) and exclusively caused by the Chinese citrus fly rather than a mix of pests. This means that in October-November the orchards' soil is orange with dropped fruit and that farmers look at their trees with fear: how much fruit will be left for sale this year? Theoretical control options were the luring of flies through proteinaceous baiting, and the cleaning of orchards of dropped fruit so as to reduce the following year's fly population. In August 1993, just before the pilot village activities started, a proteinaceous bait had been identified, that was provided in September 1993 to

[3] The Dungmin village programme has been video-filmed; Kleinheerenbrink and Schoubroeck (1993b and 1994) and Kleinheerenbrink (1996) show discussions, interviews with farmers and experimentation activities in various phases of the programme.

the Dungmin community to carry out three bait-splash treatments in all orchards in the village. This was the first of a series of activities to control the fly, as illustrated in Box 4.

Box 4. The interaction between developments in pest control technology and pest control organisation.

When the attraction of the fly to protein bait was demonstrated in Dungmin village, farmers immediately requested for a programme to control the fly. In most fruit flies, eggs hatch and damage fruits within weeks after oviposition. Thus the first proposed timing of the fly luring strategy was linked to the *fruit drop period*. Extension staff organised fly baiting activities (Box 1). Farmers carried out three splash treatments in September; yet, fruit drop was heavy in 1993, and obviously the proposed control method was ineffective.

So, in 1994 it was decided to link the baiting activity to *the oviposition period* that was yet to be identified. The Dungmin extension staff kept bait-monitoring traps in the village from late May onwards, and when he caught flies, he checked them for eggs. In late June the first egg-loaded flies were spotted. However, in that year the Dungmin community did not manage to carry out a complete fly baiting schedule, and fly control failed. In on-station research a parallel experiment was carried out, and fruit drop reduced from 54 % in an untreated orchard, to 17 % in a treated. In the following year it was tried to replicate the on-station success in Dungmin village by setting up a fly control organising committee that managed to carry out eleven bait splash treatments to cover the entire oviposition period. Fruit drop reduced and some 80 % of fruits remained in the tree compared to only 65-25 % in other years (i.e. fruit drop reduced from maximum 75 % to about 20 %). Thus, citrus fly baiting resulted in a production volume roughly double the level of earlier pinnacle harvests (as measured by the volume and duration of transport in that year).

In 1996 the first author had taken up the plan to prepare a scientific publication on citrus fly control for which quantitative data to show the attraction pattern of the fly over time were needed. By that time dry lure traps had been developed that worked throughout the adult flying season. This research revealed that fly control as achieved in 1994 and 1995 could not exclusively be attributed to the attraction properties of the bait. Attraction to bait during the oviposition period (in June-August) appeared to be weak, and was many times stronger during the *fly emergence period*, in April-May. Control so far achieved was probably not by attraction, but by random touching of the bait by flies flying about in the upper canopy of treated trees. In such trees, about 5% of the canopy surface is 'poisonous', while flies tend to fly to another spot every 20 seconds during the oviposition period; this implies that the chances of touching bait are still considerable even without attraction.

Moreover, in 1996 again the Dungmin community had difficulties organising baiting activities. The implementation of twelve bait splashes in a season appeared to be problematic (baiting had again been carried out incompletely) and even extensively trained people never mixed different components in the proposed ratios. Some farmers made the mix according to the smell they perceived, rather than based on the behaviour of flies. One line of research was to find out whether pre-mixed quantities of chemicals (bait, insecticide and sticker to be solved in one bucket of water) worked as well as loose components mixed just before splashing. They did. Once houses had to pay for the baiting materials, another problem emerged. People felt uncomfortable contributing money for baiting materials that were community-owned and that they never got in hand. Research was therefore geared towards developing individual-owned baiting materials, preferably applied in a single treatment. As the fly emergence season attraction to protein soaked wicks in dry lure traps was very good, in the following season we tried to find out whether rain-protected protein soaked wick in trees were effective in controlling the fly. Such wicks could be produced at 4 Nu (about 0.10 US$) for one tree. This was a few times the price of community-owned splashes but still valued only a small fraction of potential profits. Yet, farmers were much more willing to pay for such things than to pay for materials to be applied on communal basis. Innovative Dungmin farmers placed such fly luring devices all over the village in 1997, but that year the fly emergence period was rainy and cold so that we could not collect evidence on the working of the fly control method It has to be further tested. By this time the involvement of researchers in the citrus fly control programme ended because of administrative reasons, and farmers said they would continue to experiment.

Box 4 shows how, in pilot village research, *social* aspects of the control programme to some extent directed the *technical* subject for research. In principle, this implies that variable social settings require differential technical research, as illustrated by the development of methods to control the fly. The well organised Am Shing community took the responsibility for a rather clumsy control method, i.e., carrying out twelve bait splashings during the fly's oviposition period, including mixing of various chemical components into the proper solution. In Dungmin this method never worked unless extension staff kept a role in organising it. The village was organisationally divided, people had a hard time properly mixing the bait solution (insecticide once finished in three splashes rather than in the 12 splashes provided for) and people quarrelled over the responsibility of carrying out control measures. Thus, it was the 'unfavourable' Dungmin social setting that highlighted the need for organisationally simpler bait application methods (such as illustrated in Box 4). This gave rise to technological innovations we never would have thought of based on the Am Shing programme or on-station research alone. This illustrates that in different communities, different priorities for research will emerge. However, had an easy control method been developed up to conclusion, the Am Shing community would surely have preferred it over the more complicated method used so far.

The use of monitoring tools as such does not lead to the building of community intuition

The character of the Dungmin community and its unstable support for the citrus IPM programme led to a particular use of fly monitoring tools. A programme that demands strong commitment from a community is barely welcome if it does not soon lead to tangible results, be it in the shape of better yields, or in the form of other incentives for involved farmers. Whenever on-station research had developed a monitoring tool, it was taken to farmers in villages and tested for its practical value. In Am Shing these devices were immediately used to adjust the community's investments in fly control to a minimum. In Dungmin, however, the continuous flow of new tricks appealed only to a few interested farmers, but nevertheless helped to justify the activities of the research team in the village as long as improved yields had not been achieved. One must realise that for over two years neither the team nor the community knew for sure whether the programme would indeed result in reduced fruit drop. Fly monitoring tools helped not only to show interested individuals the dynamics of fly behaviour, but also to motivate programme staff. For example, in mid July 1995 the Dungmin community was proud of itself as it had carried out two bait splashes (rather than the five required by that time) and it was difficult for staff to challenge this self-confidence. When recently developed traps caught quite a few flies, staff re-gained the courage to instruct the citrus committee to carry out splashes as per the proposal. Staff badly needed such 'support from facts' in order to stimulate the community not to stop baiting after an incomplete treatment. In the Dungmin programme, monitoring tools enabled staff rather than the farmers' community to know what direction the programme was going and what problems to anticipate. Only a few individual farmers put in enough effort to be able to build a complete picture of fly biology and the relation between 'catches' and eventual losses. These 'innovative' farmers were not in a position to take over the initiative of the programme because many competing sentiments developed in the community.

Thus, for most people in the community the success of the programme was best expressed in terms of harvest volumes. Most farmers seemed neither interested in actual loss figures, nor in a better understanding of the crop ecosystem or the community's organisation capability. Unlike in Am Shing, the community did not intend to pull the programme beyond its original objective. People were just interested in better yields, and staff made considerable efforts to collect relevant data.

Table 1. Development of fruit drop percentages and harvest volumes during the programme period. Natural fluctuation in fruit drop moves between 35 and 75%. For further explanation, see the text.

	1993	*1994*	*1995*	*1996*	*1997*
Mistletoe control	-	+	++	++	++
Relative fruit setting (avg. = 1)	0.4	0.8	1.4	1.4	1.0?
Citrus fly control (# bait treatments out of max. 12)	0 (3 too late)	3-5	8-11	1-4	0
Estimated fruit drop[1]	72 %	26-31 %	5-15 %	35-40 %	33-75 %
Estimated total harvest (tonnes)[2]	13	35	80	60	25?

[1] In 1993 and 1994 fruit drop percentages were recorded by counting dropped fruit; in 1995-1997 they were derived from fruit samples' infestation. 1994-1997 figures are based on data from three sub-villages.

[2] Derived from the duration of transport (in weeks) and the estimated number of horses and people carrying mandarins to the Assam market.

Table 1 gives the development of harvest volumes and fruit drop during the programme period (1993-1995) and the years to follow (1996-1997). Fruit drop and harvest were broadly a function of citrus fly control and fruit setting. In general, the natural variation in fruit setting is around 300 %; the programme started in a year with low fruit setting. Fruit drop percentages vary naturally from 35 to 75 %; fruit drop reduced after controlling the citrus fly in 1994 and 1995. The 1994 fruit drop percentage was just below the lower end of the natural fluctuation level, although farmers did not attribute the relatively low fruit drop to their baiting efforts. Mistletoe and fruit drop control resulted in record harvests in 1995 and 1996; the regular fruit transporting season to the market two day's walk away was extended by weeks and in the late marketing season Dungmin was the only supplier of mandarins. After the responsibility of the programme was handed over to the Dungmin community, early in 1996, farmers baited less and fruit drop again increased.

Citrus fly control is not compatible with dominant social cognitions in the religious domain

When late 1993 we initiated the Dungmin pilot village programme, we hardly anticipated that social dynamics would be so important in in-village experimentation activities. In hindsight, we were quite naïve in thinking that the community would carry out the measures we proposed, thus enabling us to evaluate the technology we had designed. Soon it appeared that in-village experimentation goes along with dynamics that differ vastly from the earlier training-and-visit and even experiential learning routines. During the era of technology transfer, the achievement of on-station fly control with investments of only a few percent of the potential profits would have been a tremendous success. Such spectacular results would have been brought to farmers by the extension service through village level training. Our village experimental programme showed that such an approach could never have worked to have farmers control the fly. Due to the characteristics of the citrus fly, the entire community had to support the carrying out of an experiment in one way or the other. In villages such as Dungmin, such support needed to be developed and negotiated. To this end, staff needed to get acquainted with the community and started visiting gatherings such as religious ceremonies in individual houses during which informal contacts were laid and maintained. When station-based plant protection staff visited the village (every two moths or so), quite a few villagers used to come to the extension staff's residence to prepare and share food and discuss issues relevant to the programme. This allowed staff to keep track of sentiments regarding the programme in the village. When at times individual villagers developed adverse sentiments on the programme, staff visited them to discuss problems in a confidential atmosphere (i.e., over a glass of local beer). Thus, staff initiated experimental activities and simultaneously tried to create an atmosphere conducive to carrying out experiments.

A closer look at the interests of the involved stakeholder groups may give clarification. The plant protection staff wanted to carry out an experiment and needed success within one or two years. For this, staff had to invoke the interest of extension staff and farmers. Raising the interest of the extension staff was relatively easy: he was, just like the plant protection staff, an outsider to the community, he understood the experimental character of the programme and received intensive supervision and recognition from a person higher in the hierarchy. Thus, extension staff took the responsibility of day-to-day programme co-ordination and gathered information on social dimensions of the programme. The position of farmers was more problematic. They were to invest time to treat their orchards (with experimental materials provided for free). To some extent they had to violate a religious value that forbids killing of insects. Their reward would be a possibility of obtaining better yields, which could not however be guaranteed, as the programme was experimental in character. When the programme failed to achieve instant-miracle results (like those often effectuated by local lamas' rituals), a play of influence and networking emerged. As is demonstrated in Box 5, religious beliefs and hierarchies played an important role in the skirmish around the in-village experimentation programme.

Box 5. Walking the tightrope in order avoid opposition by the religious establishment

One of the most influential people in Dungmin village was the local lama, who, through his religious position, could not possibly support a programme in which the killing of citrus flies was an essential component. His family was one of the wealthier families in the village with vast interests in the mandarin trade. Until the RRA-exercise, for most people fruit drop was a phenomenon apparently steered by supernatural powers, against which the lama and his helpers performed general religious ceremonies that "*sometimes work, sometimes don't work, but in any case render peace of mind.*" The catching of a few citrus flies during training sessions and demonstration of their role in invoking fruit drop took this phenomenon out of the realm of religious mystery and placed it, for many farmers, in the domain of comprehensible phenomena. The lama probably did not view this move as a threat to his position (there were enough unexplained phenomena left), although the following fly control activities were against the values he was expected to defend. The programme staff thought it necessary to discuss the inherent sinful component of the IPM programme with the lama and farmers. A meeting was organised to which several leading farmers and the lama were invited. The lama delegated his son who also held an important religious position and who was more in touch with modern developments. During the meeting, staff explained that through fly baiting and hygienic measures, only damaging insects were killed, and that cover sprays would kill many more and also beneficial insects (a general notion from IPM theory!). After some arguing up and down the lama's son grudgingly agreed not to oppose the programme, although he declared that he himself would not actively participate in it either.

This meant that for that particular year, the religious establishment would not oppose the programme. Yet, the bait-treatment was not carried out too well: the community managed to carry out only 3-5 bait treatments against the 12 proposed, which resulted in incomplete fly control. The following year one incident showed that not all community members were convinced the programme was beneficial to the village. After a new citrus committee was installed with some young and enthusiastic members, one enterprising farmer soon returned to programme staff to lay down his function. He appeared to be a lay monk, and after his arriving home in his new function, his parents seriously reprimanded him for taking up such a sinful task. This showed that some households still opposed the programme for its killing of insects, even if this had gone unnoticed to staff. Possibly low-profile opposition played a role in poor programme support. Another incident showed that not all indifference or opposition could be traced back to religious sentiments, but more to a general thinking in mystical relationships between phenomena. In the hot and humid summer of 1995 an unidentified branch-dying disease broke out in Dungmin. Soon rumour spread that the bait treatments caused this disease, and some farmers wanted to suspend baiting activities and ban the entire programme from the village. This time the good relations between staff and villagers paid off. Research staff came to discuss the issue, and at the appearance of programme staff in individual houses, opinion-leaders said they had reconsidered their judgement. Some farmers had noticed that apart from treated trees, also some untreated trees showed the same symptoms, and they concluded that there was no causal relationship between splashing and tree deterioration. When later that year the village obtained a record harvest, adverse sentiments were stifled in enthusiasm over the programme.

The Dungmin experimental programme can be described as an encounter between mystical thinking and thinking in causal relations, a collision of value systems of different stakeholders complemented with a cat-and-mouse play of attribution of failure and success. In other words: a confrontation between two incompatible social cognitions with respect to how agricultural problems should be explained and dealt with (i.e. IPM versus religious ceremonies). In this struggle, the village-based extension staff needed outside support not only to remain accepted within the village, but also to keep a core of causal thinking alive. During the disease outbreak as illustrated in Box 5, also the extension staff seriously wondered whether the disease could have been caused by the bait splash treatment. If he were not supported by outside research staff, he would have avoided further deterioration of orchards and his position in the village by suspending the programme. Similarly, the research staff sometimes needed backup from supervisors, in order not to get lost in social tinkering that governed the village programme. In this, we do not want to pretend that the core input from the programme was free of poorly defendable relationships and values. The belief that baiting could control flies had never been proved, and later it appeared that the control effect of baiting during the oviposition period was more by random touching of flies to insecticide rather than by baiting effects. Similarly, hygienic measures appeared not to be capable of controlling the fly. In such an environment we sometimes doubted the justification of our own work, the introduction of so-called causal thinking in the community. It must be clear that these dynamics forced programme staff to combine technical thinking with an effort to understand and anticipate social processes.

Over all, the Dungmin programme showed that experimentation with the community as a counterpart was a much more complicated process than in Am Shing. Being a much older and larger (100 versus 33 households) settlement, Dungmin has a strong religious establishment, including a well-respected lama. In the absence of strong religious leadership, farmers in Am Shing tended to be less strict in following religious prescriptions, and were more open to alternative social cognitions. In Dungmin, a heightened awareness of technical aspects of IPM appeared to be only one of many factors governing the community's acceptance or non-acceptance of particular innovations. Positive and negative sentiments on the programme came up as a result of social dynamics rather than its technical soundness, particularly before the community had seen control activities result in better yields. The community was, in practice, still deliberating whether they wanted to abandon the dominant social cognition or not, and staff had to take up a social role and discuss the pros and cons of their perspective on the matter. For this, on the one hand, staff had to put effort into becoming an acceptable partner in the opinion making process. On the other hand, in order not to end up in an ordinary power game with established opinion-leaders, staff had to make sure that discussions were confined to overseeable social dilemmas with clear practical consequences. In technical terms, not only farmers, but also the staff itself had to be fully aware of the validity of the claims made about the beneficial effects orchard treatments could have. The success of on-station fly control in 1994 morally supported staff in the conviction that fly control could be effectuated in Dungmin village as well. Still, as long as farmers had not experienced themselves that yields were improved, support from the community could hardly be counted upon. Some farmers were stable programme supporters, mainly because of their close relations with staff and because of the sentiment that *"something should be done to develop this village"*. Programme staff tried to provide these individuals with reasonable arguments as an alternative to mystical relationships that occasionally undermined public support for the programme.

4. Station-led research enriches in-village experimentation and vice versa

Section 1 shows that on-station research alone could not provide the technology needed to achieve citrus fly control by farmers in villages. Yet, after initiating the village experimentation programmes, on-station research was not abandoned. The reports of IPM development in Am Shing and Dungmin refer several times to on-station research, not only as a 'source of technological inspiration' at the beginning of the programme, but also as the provider of technological tools during programme development. Station-led research did not always have a straight application in villages, although the research team was now fully aware of the technological needs of village programmes and could thus develop theoretical notions into tools for the village programmes. To put it more bluntly, the research team's exposure to farmers and administrators forced it to not only think in terms of scientific processes, but also to link these to practical circumstances. Thus, the research group placed itself into a field of influence in which technology is eventually appreciated for its applicability. Yet, in on-station research, the research team kept a bit of academic freedom, in which it could fiddle around creatively with notions from literature and field observations. We can point out a few moments in the development of the fly control strategy where this creative space provided essential ideas for continued technology development. It was undoubtedly essential for the success of the programme to not only think in 'process' terms but also in technological terms. Without the freedom to make explorations outside narrowly defined community agendas, the programme would have ended up experimenting with poorly substantiated control strategies rather than critically discussed technical control options. The difference with the earlier on-station research programme was the fact that one researcher co-ordinated both the on-station and in-village programmes, which meant that there was no informational gap between the two, so that on-station research results could be immediately applied in villages. Here, we have to stress that the close relations between the two are essential. It was not so much 'research facts' that the researcher took to villages, but more apprehensive notions obtained from both poles in the programme. From the Am Shing case (section 2) it might be concluded that the village programme needed a fly trap, so on-station research developed one. The real process was more diffuse: farmers had caught flies flocking on early developing lime fruits; fruit fly literature reported on the use of ball shapes as fruit fly traps; in on-station research we pasted developing fruits with non-drying glue to establish the oviposition period and caught flies, we experimented with ball-shapes of different colours in different citrus trees and came up with a fly trap to be used in early-developing varieties that could be used in village programmes. Other traps and infestation monitoring tools were developed in a similar diffuse way. Any more 'cognitive distance' between in-village and on-station research would have reduced the innovative power of the combination of the two. Thus, we feel that on-station and in-village research should be carried out by the same persons, rather than by two separate sections of the same station.

Another argument for maintaining different types of research is the fact that in exploratory research, such as the initial research on the citrus fly, opportunities for progress depend on observations made by chance. Because experimentation now took place in three places (on-station and in two villages) and by different actors, more 'lucky' observations were done and definitely, technical progress went much faster than during the time when research was done in one place and one person, on-station alone. The fact that the fly had only one generation a year meant that research had to be carefully planned, as the next experiment could only be done one year later. Therefore, it was always good to carry out experiments in two or three places at a time, so that possible failure in one place was backed up by valid observations in another. The different stakeholder groups doing research resulted in emergent properties that further justify a combined on-station and in-village programme. In the Am Shing case, for example, it is narrated how farmers used newly developed traps to monitor the local fly population and reduce the number of bait applications. The researcher felt that this use would possibly make that year's control efforts ineffective; yet, farmers were apparently eager to use monitoring tools as a source of information for decisions. The researcher decided to figure out if and how the devices could be used for monitoring the fly population. Students attached to the research station carried out season-long trapping observations and they found that flies were best attracted to protein during the emergence period rather than just before oviposition (Box 4). This was a novelty in fruit fly literature in which multivoltine flies are better studied than single-generation fruit flies. The fly's early attraction to baits allows for pre-monsoon control of the fly to avoid the heavy shower season of June-August, when bait is easily washed away and flies are active only during the few sunny spells.

There is yet another reason why on-station research should not be neglected. Both case studies show that in-village research is governed not only by technical, but also by social dynamics. When in 1994 extensive control efforts in the two villages did not result in a convincing reduction of fruit drop, we did not know what to attribute the 'failure' to. Farmers could have carried out the control measures poorly, or the technical method as such did not work. Luckily, we had the backing of a successful station-led experiment, which showed a convincing reduction of fruit drop after baiting. In other village experiments it appeared difficult to collect zero-treatment data from villages, as we were obliged to explain our sample taking to the orchard owner. Quite a few farmers did whatever they could (including approaching the district administrator for their orchard to be taken up in the experiments) to be included in the full treatment schedule. In on-station research such incidences occurred less. Thus, on-station research was able to give us confidence that we were technically on the right track, and that further investment in village-implemented experiments was justified. In this way, on-station research provided the programme with a 'save haven' from in-village dynamics and a relatively quiet place to develop tools and notions for village-implemented experiments. The metaphor of a 'safe heaven' was valid in another aspect. Whenever villages were inaccessible (due to roadblocks, high officials' visits, political reasons, etc.), station-led work could continue in the experimental orchards near the station and did not come to an immediate stand still.

Finally, for technical reporting too, on-station research is essential. When working out the mass of technical data collected over the years, we found that almost all data sets collected from the village programmes were either incomplete, inconsistent with each other or lacked control treatments, etc., even if we had made great efforts to collect presentable data. This, while much more time had been dedicated to making the village programmes work and monitoring their results than to on-station research. Villages were large experimental units, the research team could handle but a few, and citrus fly infestations appeared to vary widely within and among villages so that it appeared difficult to establish the relation between situation, treatment and infestation levels. That is why nearly all presentable data were collected at the station's premises. Thus, while the village-led research may have led to a valuable process and has greatly determined on-station research, the technological proceeding is mainly based on students' observations that were carried out on-station. As proper documentation is the corner stone of both long-term progress and exchange with staff working in other contexts, we conclude that in many circumstances on-station research is an essential component of village-based research. To be clear: for such research to have significance, findings and needs in one place should determine the agenda in the other place and vice versa. Similar experiences have been reported by van Weperen et al. (1998) in the transition to Integrated Farming in the Netherlands, in which farmers needed the back-up of on-station experiments to risk a reduction in the fertiliser inputs on their land. An on-station component may be less necessary in research on transparent pests in which farmers can oversee the consequences of control actions immediately. On-station research may be impossible if research components cannot be transferred to the station premises (such as wild boar studies, or studies on village-managed soil fertility). Thus, the initiation of a research station-managed component in such programmes is highly dependent on the characteristics of the problem under research.

5. Scaling-up of citrus fly IPM

Scaling-up in neighbouring villages by programme staff

In 1994, the programme staff measured fruit drop percentages in a few villages close to Dungmin for comparison with the treated village. This resulted in informal contacts with neighbouring citrus grower's communities up to two hours walk from Dungmin village, where people became interested in carrying out citrus fly control. The following activities in those 'outreach' villages went more smoothly than the earlier activities in the original experimental village. In contrast to Dungmin, in the outreach villages communities organised baiting independently because they were small and in each village one individual farmer (usually a woman village leader) was in a position to co-ordinate the fly baiting activities. The extension staff visited the villages once or twice during the following season, and individual farmers visited the extension staff whenever they felt a need. During follow-up training, extension staff presented the new tools and briefly discussed organisational matters. Such tools were then used for monitoring purposes just like in the original village. After the baiting season, research staff visited villages to evaluate baiting activities and to establish infestation levels. This programme soon resulted in a reduction in losses, and by 1996 three out of four participating communities carried out citrus IPM independently, including collection of money, and procurement and application of citrus fly bait.

The outreach village activities show that scaling-up of technology as developed in experimental villages is not a time-consuming task, as the initial experimental programme had suggested. The communities easily developed a social cognition needed for proper implementation of fly baiting. The outreach-programme was carried out by a thoroughly experienced extension staff, which apparently put him in a position to successfully carry out scaling-up activities in other villages. He knew how to approach the communities and how to effectively facilitate the organisation of village-wide baiting activities. Moreover, in view of the positive results of the Dungmin programme, farmers were ready to participate in the programme without initial problems such as those encountered in the experimental programme. This combination of factors meant that the introduction outside the original experimental village could be done apart from the main programme. This suggests that scaling-up of technology developed in experimental villages is a relatively easy task that can be carried out by extension staff as part of their regular tasks.

Scaling-up citrus fly IPM by the regular extension service

The scaling-up experiences close to the research villages suggested that citrus fly IPM was now developed well enough to be disseminated over large areas, and the regular extension service took up the package in its programme. Two years of monitoring and involvement of the plant protection research section in the regular extension programme revealed that this was an over-optimistic assumption. In one district, despite extensive efforts to have fly control introduced all over the district, the extension service hardly succeeded in introducing the method in any of the villages. This, while the district extension service itself was reasonably motivated and entertained -in principle- support by policy makers to introduce the technology.

Reasons for the failure were many (see Schoubroeck, in press a), and include a number of bottlenecks in the policy environment. Policy makers and donors in Bhutan continue to model their extension organisation after international policies rather than on local examples, resulting in poor opportunities for extension staff to work in a collaborative process with farmers and research. More in general, in the administrative culture in Bhutan it is not very common to work in an interactive mode, and thus reward structures for doing so are lacking. The support from policy makers was further hampered by the fact that policy makers had little involvement with the IPM programme during its lifetime. Thus, they lacked detailed knowledge about the conditions that contributed to the programme's success, and felt insufficient 'ownership' to push through. Most importantly, however, it appeared that the regular extension service lacked adequate skills and conceptions to introduce citrus fly IPM in a way that was consistent with the nature of the technology. Research and extension staff continued largely to operate according to the transfer-of-technology doctrine, which assumes that technology can be produced and disseminated *irrespective* of its social environment. Our case studies have shown that technical and social organisational dimensions are almost inseparable, which implies that extension staff not only need to deal with social organisational issues, but also need to build in space for adapting technological designs to specific social contexts. Moreover, one cannot 'transfer' a technology that has been designed in an interactive process without 'transferring' at least part of the learning process which led to its development (see also Röling & Van de Fliert, 1994). Of course, it would be impractical to start all over again with interactive technology design in each village where citrus fly IPM might be relevant. At the same time, one cannot expect communities to organise themselves effectively if they lack a shared insight into the complexities of citrus fly control, i.e., an understanding of the need to operate in a carefully co-ordinated manner. Thus, it is imperative that extension and research staff set out to organise a discovery learning trajectory in order to both gain support for community action and identify necessary adaptations. Moreover, they must purposefully deal with all sorts of problems that may occur in the realm of community organisation. The regular extension service in Bhutan simply lacked the necessary insight, skill and institutional structure to do so. The outreach activities from the Dungmin programme show that community IPM can indeed be relatively easily introduced on a larger scale when such skill, insight and institutional opportunities are available.

6. Conclusion

In this chapter we have seen how intensive interaction between farmers, researchers and extension staff has indeed resulted in the identification of viable technical and organisational strategies for combating the Chinese citrus fly. That is; through collaborative learning, groups with largely separate social cognitions gradually developed an -at least partly-shared social cognition for dealing with the citrus fly. For all stakeholders, this interactive design process implied quite a radical mental and operational shift. However, it is important to recall that this shift was effectively induced initially by relatively 'small' changes in the existing transfer-of-technology mode of operation. Most importantly, shifting the extension training sites to farmers' orchards resulted in new and very effective forms of feedback, provided by the orchards (trees, mandarins, citrus flies, etc.), farmers' practices and perspectives. Using this feedback as a resource, the extension staff was able to strengthen its position vis-à-vis research staff, and make new demands on the latter. Eventually, this contributed to an experimental change in research and extension policy, which turned out to capture the enthusiasm of all parties involved. Key elements in the new mode of working where among others that (a) research and extension staff worked closely together with each other and with farmers in a process of experiential discovery learning, which guided the setting of research agendas; (b) orchards, farmers' practices and experiences remained an important source of feedback; (c) sufficient attention remained for 'traditional academic' on-station research, next to in-village research; (d) in-village experimentation and on-station research effectively inspired each other, largely because they were 'supervised' by the same persons, and (e) considerable attention was paid to social-organisational issues, social dynamics, and to adapting the technology to social conditions (and vice versa).

However, the two case studies also demonstrate that there are limits to marrying fundamentally different social cognitions. In the absence of strong religious leadership and convictions, the Am Shing community was more willing to draw upon (or 'surrender to') the Western epistemic culture that research staff adhered to than the inhabitants of Dungmin village. Moreover, being relatively small, the Am Shing community tended to be less divided than Dungmin, and already expressed considerable collective agency in other domains than fly control, which proved a fertile ground to build upon. The problems encountered in Dungmin show that interactive technology design in many cases will not be a smooth process, as it can affect a variety of social interests. Even if considerable attention was paid to dealing with the social dynamics in Dungmin, a systematic and informed strategy –for example on the basis of negotiation theory (see Van Meegeren & Leeuwis, chapter 12)- for dealing with emerging conflicts was lacking. A prospective and systematic strategy might have resulted in fewer tensions and more creative and 'sustainable' compromises between the different social cognitions.

Finally, it can be concluded once again that the scaling-up of knowledge-intensive and interactively developed strategies for community IPM is possible, but requires a considerable re-orientation of conventional research and extension organisations. New role perceptions, insights, extension methods, skills, project horizons, opportunities for collaboration, and reward structures -to name a few- are necessary for this purpose.

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Chapter 10

Designing Integrated Nutrient Management systems in sub-Saharan Africa[1]

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Abstract
Soil nutrient depletion has been identified as one of the major constraints to food security and economic development in rural areas of Sub-Saharan Africa (SSA). Development of Integrated Nutrient Management (INM) systems is seen as one of the most appropriate options to address this problem. The hard system studies observe that 'in order to obtain high and sustainable agricultural production in SSA, internal flows of organic materials, and inputs that are free-of-charge should be maximised, non-useful losses minimised, whereas the use of external inputs should be optimised with respect to capital and labour'. Low adoption rates of these technologies triggered the debate for a paradigm shift from 'hard-systems' technology development aiming at adoption towards a 'soft-systems' context-oriented approach emphasising learning aspects of the stakeholders. This implies a focus on observation, interpretation, principles and concepts, testing alternatives for action, networks and platforms and institutional changes. Some aspects of this new approach are illustrated in a case study in Kenya.

1. Introduction

Before the emergence of mankind, soil fertility used to be a rather static entity. It was just

[1] Contribution in the context of EU INCO-DC project 'Potentials of low-external input and sustainable agriculture to attain productive and sustainable land use in Kenya and Uganda (LEINUTS)' and NUTSEO (DLO strategic expertise development).

geological and climatic influences that altered the land surface, causing weathering and erosion, and rejuvenation through volcanic activity and sedimentation in alluvial plains. Nowadays it is a spatially and temporally highly diverse and dynamic entity. Nutrients are transported all over the world through fertiliser imports, exports of agricultural commodities, massive erosion in some places and gross volatilisation and leaching in high-input-high-output agricultural systems. In other words: a more or less balanced ecosystem (the globe) has turned into one which is still balanced at the global level, but highly unbalanced at lower spatial scales. The Netherlands, for example, is one of the 'hot spots'. Fertiliser use and imports of nutrients and organic materials through animal feed stuffs have been and still are very high. The nutrient balance, made up of the sum of inputs minus the sum of outputs (Figure 1) is highly positive. As a result, very high agricultural production is realised (OUT 1), but at the same time leaching and gaseous losses (OUT 3 and 4) have become serious threats to both human and ecosystem welfare. Since the late 1980s, the government and the European Union increasingly impose regulations, forcing farmers to use less fertiliser, apply phytase-containing animal feeds to reduce phosphate excretion, and grow catch crops during winter to reduce leaching losses.

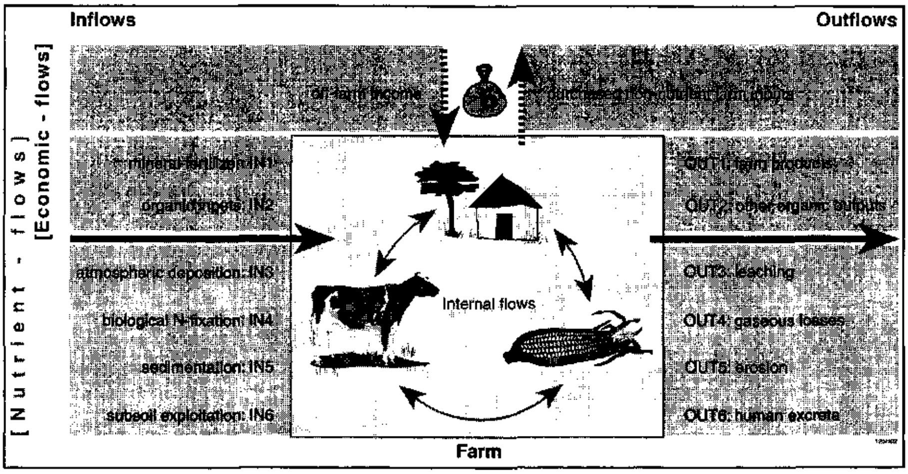

Figure 1. Nutrient and economic flows determining nutrient balance and economic performance.

In most of sub-Saharan Africa (SSA), the situation is quite different. The soils of the continent are not very rich in nutrients anyway, although the mountainous Rift Valley area in Eastern Africa is much better endowed than the West and Southern African erosion prone plains. In addition, farmers largely grow crops and keep livestock for subsistence, and have few incentives to use expensive inputs such as fertilisers. Organic inputs are available, but are largely derived from the farm itself or its immediate surroundings, and hence there is no real input into the system. The general picture of SSA is therefore: low nutrient stocks and low productivity, and on top of that nutrient balances are mostly negative, further aggravating their fragile position.

Nutrient depletion as one of the principal constraints to African food supply was brought to prominence by a report of Stoorvogel and Smaling (1990) titled 'Assessment of soil nutrient depletion in Sub-Saharan Africa'. This report introduced nutrient budgeting as a concept and estimated these budgets at country level for the continent. The results were disquieting, showing average annual depletion rates on the continent of 22 kg of N, 2.5 kg of P, and 15 kg of K for each hectare of arable land. These calculations were based on aggregate data and as such were recognised to be only approximations of the problem. The report, however, spawned a range of additional work, focused primarily on farm level estimates of nutrient flows and nutrient depletion rates (Smaling, 1998).

Table 1. Restoring soil fertility in West-Africa: technical options and their impact on nutrient flows listed in Figure 1.

Technology	Fertility effect (see Figure 1)	Adding/saving
1. Mineral fertilizers		
- increased use	Increase of IN 1	adding
- more efficient use	Reduction of OUT 3-5	saving
2. Mineral soil amendments		
- rock phosphates	Increase of IN 1 (P)	adding
- lime and dolomites	Increase of pH, IN 1 (Ca, Mg)	adding
3. Organic inputs		
- from within the farm	Reduction of OUT 2	saving
	Increased recycling FL 1,3,5	mainly saving
- from outside the farms	Increase of IN 2	adding
4. Improved land use systems		
- rotations, green manures	Increase of IN 4, reduction of OUT 2 -5	adding+saving
- fallows, woody species	Increase of IN 4,6, reduction of OUT 2-5	adding+saving
5. Soil and water conservation	Reduction of OUT 3-5	saving
6. Integrated Nutrient Management	Combination of IN 1 - OUT 5	adding+saving

Soil fertility management is an integral part of farm management with its particular spatial and temporal characteristics. This is why the term 'integrated nutrient management' (INM) more appropriately hints at the different options at hand to achieve certain soil fertility goals. INM is therefore defined here as the 'judicious' manipulation of nutrient stocks and flows, in order to arrive at a 'satisfactory' and 'sustainable' level of agricultural production. INM can be viewed from two perspectives, i.e., the hard systems approach, attempting to quantify or estimate what is meant by judicious, satisfactory and sustainable; or the soft systems approaches, focusing on inter-human and human-ecological processes. The first viewpoint uses and generates fundamental, scientific knowledge on nutrient flows (Figure 1) and INM technologies (Table 1), whereas the latter uses a combination of scientific, experiential and religious-cultural knowledge, and is tailored to a particular agro-ecological and socio-economic situation. Building bridges between these approaches calls for a new 'praxeology', i.e., a theory informing practice, which in turn feeds theory (Nas, 1997). The praxeological battlefield is multiform in that it includes theoretical aspects (systematic comparison of sectors through case studies), action aspects (intervention for innovation), and methodological aspects (using scientific results in the real-world development practice). Because, as Nas (1997) states, the real application of knowledge in society depends on factors that are outside the knowledge domain itself. As a consequence, the 'correctness' of knowledge is not always the factor that determines whether it is being used in society.

2. Integrated Nutrient Management

As stated before, several case studies on INM in SSA have been documented. A good deal of them are assembled in a Special Issue of *Agriculture, Ecosystems and Environment* (Smaling, 1998). The studies cover different spatial scales, ranging from country level to within-plot level. However, most studies were conducted at farm level, with plots and enterprises within farms as the major compartments. A number of studies use a wealth ranking to stratify farmers in studying INM, whereas others use agro-ecological zones. Data collection procedures in the field ranged from rather extractive (data collection by researchers, structured questionnaires, up-scaling of results to agro-ecological zones, etc.) to highly interactive and cyclic (Defoer et al., 1998).

Some authors attempted to calculate all nutrient flows depicted in Figure 1, whereas others just looked into those flows that can be easily measured, or those that are most meaningful to farmers. This does not mean, however, that the less visible flows are less important. Brouwer & Powell (1998), for example, show the relative importance of leaching, even of phosphorus, in sandy Sahelian soils. Brand & Pfund (1998) show the importance of burning of phytomass as a C and N loss mechanism. The (very substantial) nutrient losses through human faeces and urine (OUT 6 in Figure 1), ending up in deep pit latrines were hardly taken into account. Most authors worked on nitrogen and phosphorus. Some included potassium and secondary nutrients, whereas others also included the carbon cycle.

Going through the studies, one can clearly see that farmers in Africa tend to move nutrients from the outer fields to those fields that immediately border their homesteads. As a consequence, they still manage to realise satisfactory production levels on small pieces of land. At the same time, the 'commons' are depleted as they only receive free nutrients through IN 3 and IN 4. Increasing population pressure has led to and is still responsible for a rapid reduction and deterioration of these fallow or grazing lands, which is testified by the increasing number of conflicts between nomadic herdsmen and sedentary agriculturists (Peul, Masai, Fulani). Almost all farmers in the studies conducted, appeared to cherish certain plots at the expense of others, the banana homegardens in Uganda and Tanzania being a case in point. Communal rangelands and grasslands are exploited everywhere, and provide free lunches for farmers in terms of nutrients. As a consequence, the decreasing size of communal lands can be considered a serious threat to the sustainability of the mixed farming systems in the semi-arid zones. Cases from densely populated areas, however, show that farmers become increasingly creative in recycling organic materials.

3. Hard systems: the nutrients in INM

The various nutrient flows at farm level can be visualised (Figure 2). The farm is made up of a number of physical compartments (plots, kraals, dunghills, crops, animals) between which a traffic of nutrients takes place during an agricultural cycle. Attempts can be made to quantify all these flows for different farms, yielding information on their relative sustainability in terms of nutrients. Next, INM technologies can be studied on their potential to make the systems more sustainable. The technologies in Table 1, for example, can all be categorised as those that:

- **save** nutrients from being lost from the system, such as erosion control, restitution of residues, recycling of household waste and animal manure, and those that
- **add** nutrients to the system, such as the application of mineral fertilisers and amendments, concentrates for livestock, organic inputs from outside the farm, and N-fixation in wetland rice and by leguminous species.

The 'hard-system' conclusion from Table 1 may be that 'in order to obtain high and sustainable agricultural production in SSA, internal flows of organic materials (*FL 1-5*), and inputs that are free-of-charge (*IN 3,4,6*) should be maximised, non-useful losses (*OUT 2-6*) minimised, whereas the use of external inputs should be optimised with respect to capital and labour (*IN 1,2*). Steps in the right direction can be made by adopting one or more INM-based technologies. The scientific knowledge generated by studying these technologies is potentially very useful, but remains meaningless if not attached to a particular farming systems context. Recent reviews for West and East Africa show that much is known but little is used in this respect (Mokwunye et al., 1996; Braun et al., 1997).

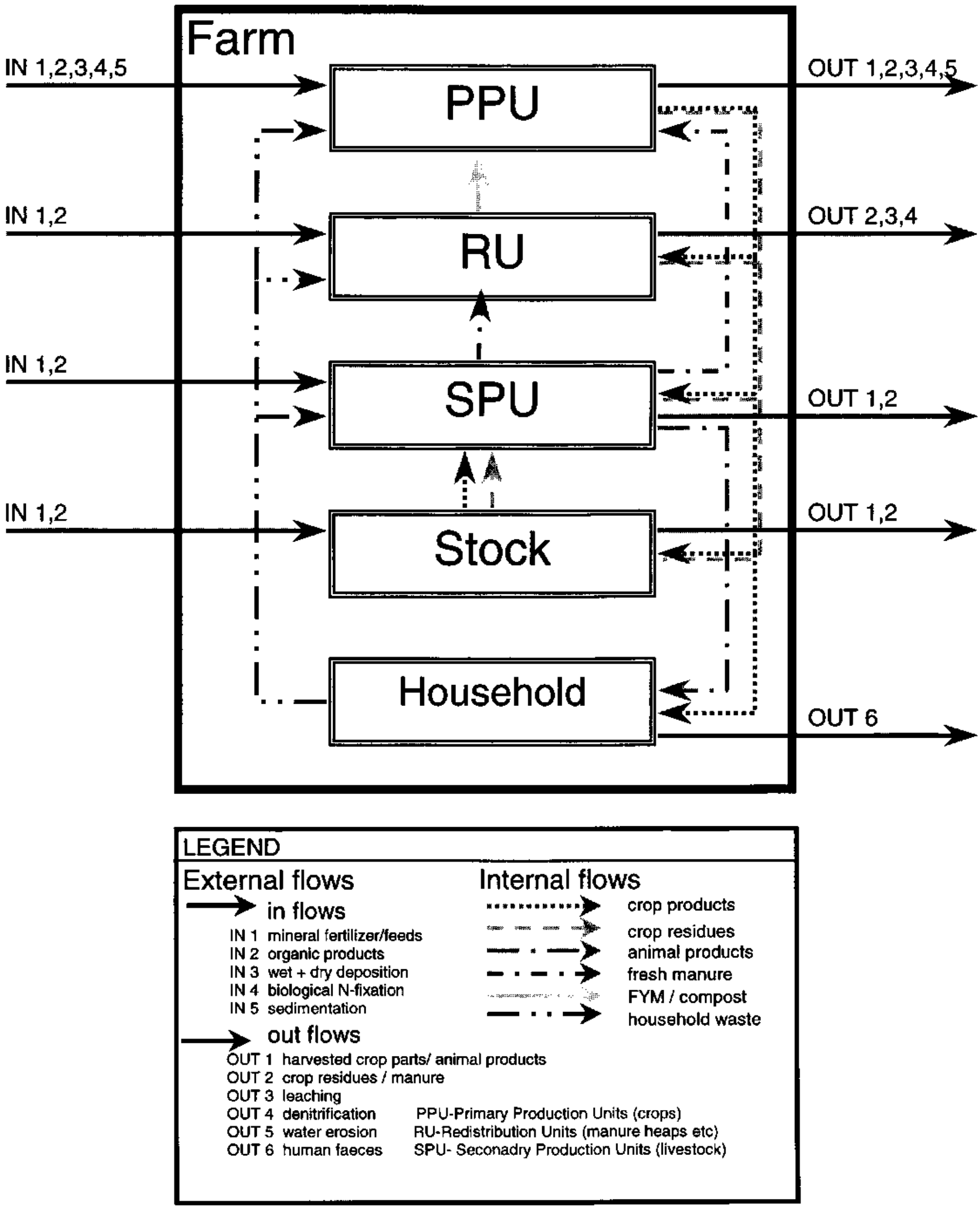

Figure 2. Nutrient flows at farm level

4. Soft systems: the human factor in INM

Behaviour of farm households with regard to implementation of soil nutrient management technologies is dependent on the perception of the soil degradation problem by the farm household, which again determines the decision, whether to implement a certain technique. A wide array of factors may in one way or another determine this perception and the resulting decision; among others household characteristics, farming system, land characteristics, asset endowment, farm orientation, technology characteristics, institutional and policy factors and market failures (Shiferaw & Holden, 1998). The economic impacts of a technology are often considered as *the* essential factor for adoption of technology at farm level. This limited view can be seen as a form of reductionism within studies of soft systems. Integrating economic aspects in the farming systems analysis and technology development process should however be considered as a first and important step to a more holistic and therefore relevant approach to addressing soil degradation problems. For example, in the recently developed nutrient monitoring concept (NUTMON), which is described in more detail later in this paper, both at the diagnostic level and during the process of technology development, agronomic and economic (cost/benefit, institutional aspects, environmental economics) aspects are integrated (De Jager et al, 1998). During the diagnostic phase of a NUTMON research project in four districts in Kenya, it appeared that the market orientation of a farm appeared to be a major discriminating factor for nutrient balances and farm management aspects. A high market orientation of a farming system was related to a capital and labour intensive production on a relatively small cultivated area and resulted in a more negative nutrient balance for N and K compared to a subsistence oriented farming system. In general, the soil fertility management on the farms studied appeared to be far from sustainable with an average 32% of the realised net farm income based upon nutrient mining. Short-term economic consideration easily outweighed the long-term possible negative impacts of this type of soil fertility management.

In reality, at farm household level a wide variety of economic aspects are of decisive importance for implementation of soil fertility management practices and implementation of specific technologies, among others the gross margins of the technology, the discount rate (time horizon) of the farm household, off-farm income opportunities, labour demands, risk, cash flow and direct cash needs. Therefore, in order to facilitate a process of a broad change in perception and behaviour in soil fertility management, integration of agronomic and economic disciplines alone is not sufficient. This requires a paradigm shift from a so-called realist-positivist epistemology to constructionism (Röling & Wagemakers, 1998).

5. INM learning processes in hard and soft systems: integrating farmers' and scientists' knowledge

So far, INM has mainly been defined in technical terms. However, it would be a mistake to ignore its crucial learning dimension. INM can only be carried out by farmers who are experts at managing their complex soils and who are able to capture the opportunities provided in the local situation to improve soil fertility. This calls for a new praxeology with respect to agricultural innovation, which some like to call the 'Doubly Green Revolution' (Conway, 1997). It is especially with respect to its learning dimension that INM can benefit from Integrated Pest Management (IPM). In fact, it is the FAO-assisted IPM Training Programme in Indonesia that has introduced a new approach to agricultural innovation and tested it under field conditions, scaling it up to a point where more than 400,000 small-scale rice growers have now been trained (Röling & Van de Fliert, 1998). It is obvious that, just as IPM is not primarily about bugs, INM is not primarily about soils. In fact, nutrients are just another entry point for this approach. The realisation dawns that agriculture cannot be developed without banking on the intelligence, creativity and competence of farmers. Instead of on *adoption*, the emphasis now is on *learning*. Farmers become experts, not by adopting science-based technologies, but by becoming better learners. Local knowledge as well as input from formal science is required to develop and modify the hard and soft system components of INM. Enabling farmers to learn entails a series of requirements, of which the emergence must be facilitated, organised or developed. They are discussed below.

Observation

This is the first step in the learning process and includes (a) routines for looking (e.g., systematic and routine looking at sampled events); (b) indicators and simple test kits for the state of affairs, i.e., for values of crucial variables, such as pH, organic matter content, moisture content, and nutrient availability, and (c) registration of processes (flows) and states (balances) in maps, records and diagrams which allow comparison across time and space. A very important observation aid is resource flow mapping, as proved by Lightfoot et al. (1994), Defoer et al. (1998), and Onduru (1998). Farmers map both soil fertility differences as they see them, as well as important nutrient flows into, among and out of the self-depicted compartments of their farms.

Interpretation and anticipation

Observation triggers mental processes, which inform effective action. Learning to draw lessons from observation requires a great deal of theoretical knowledge about variables and processes. In IPM this typically involves the life cycles of pests, the relationships between pests and natural predators ('thresholds'), and the effects of pesticides in terms of pest resurgence (the 'pesticide winter') and resistance. These tools still have to be developed for INM.

Principles and concepts

Farmers must be helped to acquire principles and concepts for nutrient management. That is, farmers are not experts on the basis of a body of memorised knowledge, which they have acquired from others. They are experts because they can apply a number of internalised principles in diverse situations and adapt what they are doing when circumstances change by changing the principles. Facilitating farmer learning of principles is difficult. It can not be done easily on the basis of words (book knowledge, lectures, etc.). Again, discovery or experiential learning has been shown to be a key avenue to impact.

Concrete alternatives for effective action

All farmers' learning about soils is to no avail if there are no concrete alternatives for effective action. Given the high diversity and variability of African smallholder environments, no blanket recommendations can be given. Again the focus would be on a higher level of abstraction, i.e., principles for solutions which farmers could apply in their locality-specific situation. The nutrient balance model, specifying INs, OUTs and flows within the farm (Table 1), could provide farmers with concrete leads to strengthen INs, limit OUTs and maximise internal flows.

Farmer networks and platforms

The essential focus is on developing farmers' capacity to identify and exploit opportunities for applying one or more of the above principles in their locality-specific situation. Developing this capacity would typically include developing local farmer networks or platforms at which such opportunities could be discussed and developed. Frequently, collective action, involving the transport of urban wastes to farms, the use of common property resources, the development of complex multi-industry enterprises adds value in the local situation.

An integrated curriculum for farmer INM training

The participatory development and testing of the ingredients mentioned in this section need to be integrated into a curriculum for farmer training which is developed and tested with farmers. Of necessity, such a curriculum should focus on non-formal farmer education. The 'Farmer Field School' as developed in Indonesia's IPM programme is one such possibility. INM training assumes the availability of trained INM trainers. IPM's success is Indonesia is largely dependent upon the great attention paid over some 6 years to developing a cadre of Indonesian IPM Trainers before the start of the actual IPM Training programme. Hence, INM-training must also start with very careful selection of a small cadre of INM trainers, which can gradually expand over the years as qualified trainers train other trainers and as trainers help develop the programme conceptually and methodologically.

Institutional support framework

The approach to INM training requires great and sophisticated attention to the institutional support framework at a sufficiently high level. Establishing such an institutional framework is likely to be fraught with tension among competencies of various stakeholders such as research institutes, extension services, foreign consultancy agencies and donors. Unless a protected niche is developed which allows INM training to establish itself and take off, it may be dissipated before it has a chance to prove itself. This point requires very careful and strategic decision-making at the highest political level. Such decision-making is considerably facilitated by the established seriousness of the threat to national and local food security (and hence political stability) posed by soil nutrient mining, and by the established unsustainability of present farmer incomes which are increasingly based on nutrient mining (De Jager et al., 1998).

The soft systems approach distinguishes itself by focussing on the interaction between the human system and ecosystems. In doing so, phenomena are regarded as dynamic, changing, and chaotic, whereby the research process itself is seen as directly influencing the process being studied (Woodhill & Röling, 1998). The latter was also experienced in the NUTMON-study where the impacts of low-external-input practises of a group of farmers were compared with a group of conventional farmers (elaborated later in this paper). After one growing season the conventional group started to adopt composting technologies of the LEIA group. This limited the possibilities for a comparison, but increased tremendously the possibilities of studying reasons for adopting and changing nutrient management practises.

6. Participatory development of INM systems

General approach

In East-Africa, INM systems are presently being developed using aspects of Participatory Rural Appraisal, Participatory Technology Development (PTD), multi-disciplinary farming systems and natural resource management analysis and Farmer Field Schools. Both in the diagnostic and the technology development phase an integrated farmer-based and science-based analysis leads to action and implementation. The learning aspect of farmers and scientists in this process constitutes an essential element of the methodology. This so-called nutrient monitoring concept (NUTMON) adds to existing methodologies (Dalsgaard & Oficial, 1997; Farrington et al. 1997) through integrating different knowledge systems (farmers' and scientists' knowledge) and disciplines (agronomy, economy, sociology) at various levels (activity, farm, catchment/district). The NUTMON concept integrates the PTD approach (see box) with a more detailed quantitative analysis. It permits, for instance, the determination and comparison a wide range of farmers' and science-based sustainability indicators in developing INM technologies. The importance and potential impact of the combining local and scientific knowledge has also been stressed by Blaikie et al.(1997).

Box 1. Participatory Technology Development (PTD)

PTD is a process of purposeful and creative interaction between local communities and outside facilitators which according to Reijntjes et al. (1992) involves:

- gaining a joint understanding of the main characteristics and changes of that particular agro-ecological system;
- defining priority problems;
- experimenting locally with a variety of options derived from indigenous knowledge and formal science;
- enhancing farmers' experimental capacities and farmer-to-farmer communication.

In NUTMON the diagnostic phase encompasses:

- participatory assessment of natural resources, resource flows and socio-economic characteristics by farmers;
- participatory quantitative monitoring of nutrient stocks and flows, economic performance and social characteristics by researchers and NGOs;
- joint evaluation workshops;
- participatory priority setting for interventions.

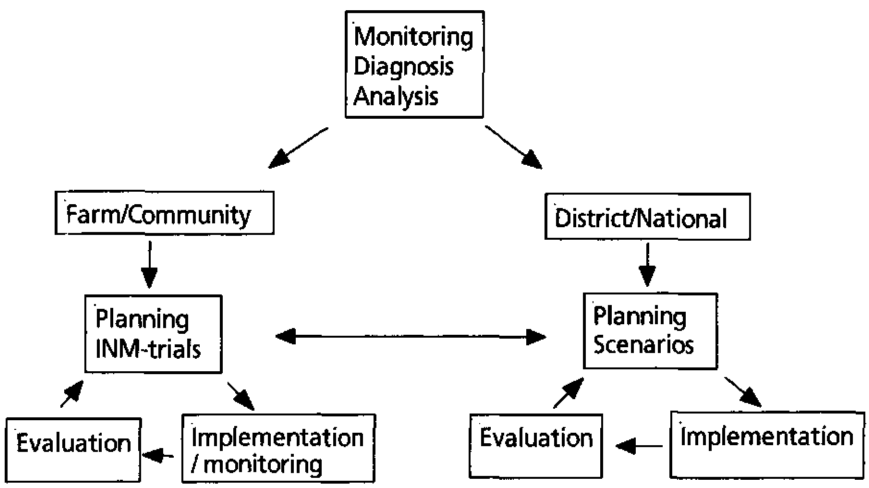

Figure 3. General overview of NUTMON approach

In the subsequent phase, relevant INM practices are tested and developed in a process of action and learning, where farmers are the main actors in the design, implementation and evaluation of the experiments. Since the socio-economic environment plays an important role in implementation of INM at farm household level, policy-makers are also involved in this participatory process, aiming at identification of policy instruments facilitating INM implementation (Figure 3).

Kenyan case study
In two districts in Kenya farmers, researchers and NGO-staff entered into a joint process of diagnosis and analysis of soil fertility problems.

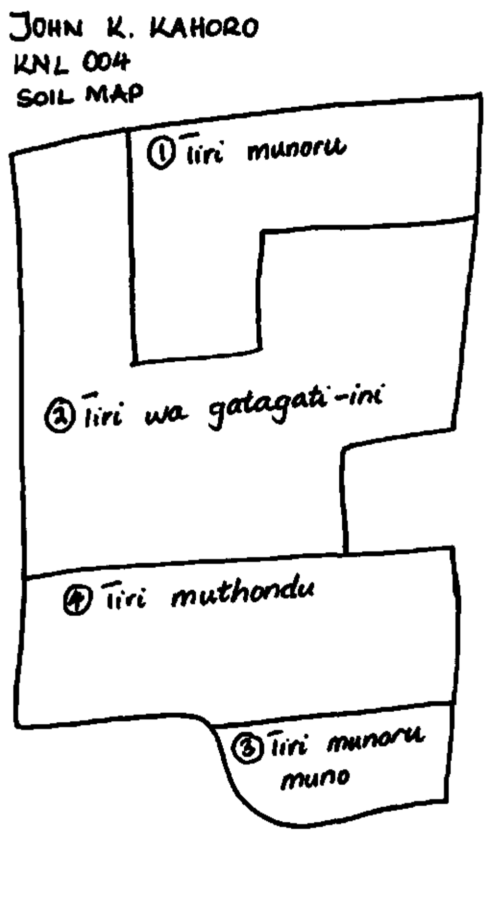

Figure 4. Farmers' soil map with local names in Machakos district, Kenya

Farmers have drawn soil maps using local names to identify soil types and their characteristics (Figure 4), assessed the performance of these soils using matrix ranking tools, visualising current natural resource management practices through resource flow diagrams (Figure 5) and visualising the economic performance of these practices and social influences (knowledge networks etc.). In addition, together with researchers a more quantified analysis has been undertaken in the form of soil sampling and analysis and quantitative monitoring of nutrient flows and economic performance at farm household and activity level (crop, livestock, compost making etc.). In a few sessions with farmers the results of both, the largely qualitative analysis using farmers' criteria and indicators, and the largely quantitative analysis of science-based indicators were compared and discussed.

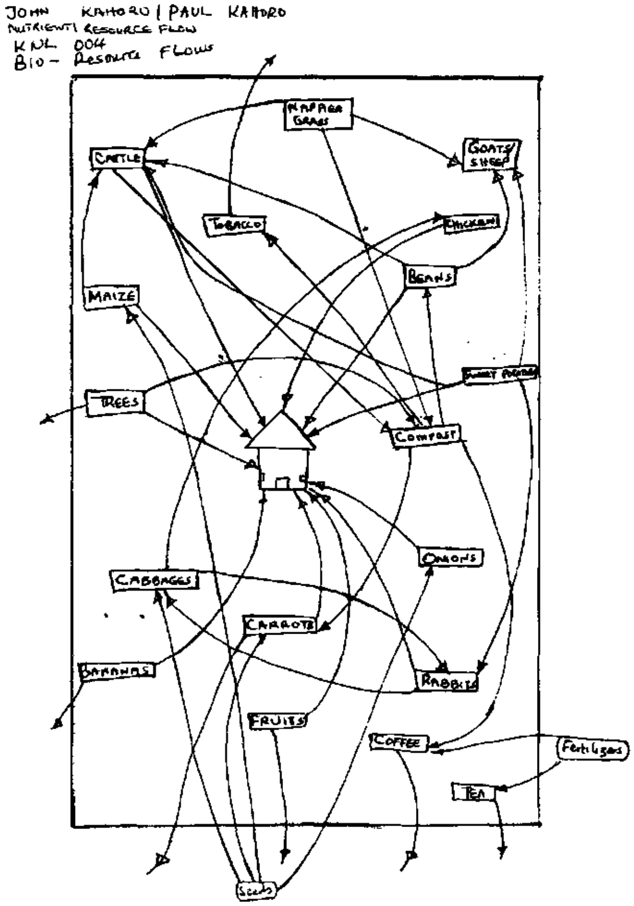

Figure 5. Farmers' nutrient flow map, Machakos district, Kenya

Both researchers and farm households assessed the soil characteristics in detail using their own criteria and indicators (Table 2). It appeared that a considerable degree of correlation between farmers' and researchers' perceptions of soil fertility characteristics existed. The soil sampling results were visualised through colouring the soil maps drawn by the farmers; science-based minimal nutrient content levels were indicated against measured levels in farmers' fields and farmers' observations of indicators such as purpling, retarded growth etc. (Onduru, 1998). The implications of these analyses for necessary changes in soil fertility management were discussed hereafter. This process showed clearly that farm households distinguish various types of soil and observe differences in nutrient status of their soils and use this knowledge to adjust nutrient management practices.

Farm households' analysis of the nutrient balance at farm level, depicted in farm nutrient flow maps, was added to the researchers' quantified analysis. In Machakos district in Kenya, conventional farm practices were compared with those of a group of farmers practising low-external-input management (LEIA). The farmers' analysis focused on the different types of flows (Table 3) and the scientists' analysis on the magnitude of the different types of nutrient flows (Table 4). A number of observations were made, showing sometimes complementing sometimes contradicting information:

- The farm households observed a higher number of different types of outflows than inflows, the scientists discovered a total higher inflow than outflow of N when excluding the 'difficult-to-quantify' flows (partial balance IN1+IN2-OUT1-OUT2).
- Between the conventional and LEIA management group, farmers observed differences in a number of internal flows, while the average quantified data of the researchers showed no differences.
- Farmers' maps showed that LEIA farms have a higher degree of diversification (more different types of outflows), which cannot easily be concluded from the aggregated quantified nutrient flows.
- The farmers of the LEIA farm management group described in their depicted nutrient flows that manure from animals was more intensively used than on the conventional farms (more SPU → RU → PPU flows), while in the quantified data no manure appears to be transferred from the redistribution unit to the crops.

The next important step in this process is to discuss the results and possible differences in perceptions with the farm households and researchers in order to enter into a learning process of better understanding of the nutrient management system and its performances.

Table 2. Example of comparison of famers' soil classification with researchers' analysis, Nyeri district, Kenya

Farm: KNL 09							
Soil type (Farmers' classification)	English translation	PH	% OM	%N-total	%P-total	%K-total	Texture class
Tiri munhinju	Poor soil	4.3	5.7	0.25	0.29	0.34	Clay
Tiri munoru	Fertile soil	4.9	6.4	0.42	0.30	0.60	Clay/silt
Tiri wa ngumba	Clay soil	4.6	5.2	0.41	0.18	0.13	Clay
Tiri wa mutaro	Deposited soil	4.8	7.1	0.58	0.30	0.20	Clay loam

Table 3. Average number of total nutrient flows per farm and per type of flow identified by farm households in conventional and LEIA farm management systems in Machakos district, Kenya (standard deviation between brackets)

Type of flow	**Conventional** (n=10)	**LEIA** (n=8)
In-flows	3.2 (2.2)	2.8 (2.0)
Out-flows	5.6 (1.7)	9.3 (1.8)
Internal flows	19.9 (3.3)	26.0 (7.2)
Specified internal flows:		
PPU -> SPU	4.5 (1.3)	4.3 (1.4)
SPU -> PPU	0.4 (1.3)	0.0 (-)
PPU -> RU	0.0 (-)	0.0 (-)
RU -> PPU	1.5 (1.2)	3.2 (1.7)
SPU -> RU	2.3 (1.1)	3.3 (0.5)
RU -> SPU	0.0 (-)	0.0 (-)
PPU -> HH	8.8 (2.7)	12.2 (4.6)
HH -> PPU	0.0 (-)	0.0 (-)
SPU -> HH	2.2 (0.6)	2.7 (0.8)
HH -> SPU	0.0 (-)	0.0 (-)
RU -> HH	0.0 (-)	0.0 (-)
HH -> RU	0.2 (0.4)	0.3 (0.5)

PPU - Primary Production Unit (crops)
SPU - Secondary Production Unit (livestock)
RU - Redistribution Unit (manure heap etc.)
HH - Household

Table 4. Matrixes of realised N-flows/ha for conventional (4a) and LEIA (4b) farm management systems, Machakos district, Kenya

(4a) Conventional farm management N-flows/ha
(Kg N/ha)

destination

	Ext	PPU	SPU	RU	HH	Stock
Ext		6 (6)	3 (4)	0 (1)		4 (7)
PPU	1 (1)	0 (0)	73 (39)	0 (0)	4 (5)	3 (2)
SPU	0 (1)	21 (11)	0 (0)	21 (9)	0 (0)	0 (0)
RU	0 (0)	2 (6)		0 (0)		
HH		0 (0)	0 (0)	14 (20)		
Stock	1 (2)	0 (0)	0 (0)	0 (0)		

source

(4b) LEIA farm management N-flows/ha
(Kg N/ha)

destination

	Ext	PPU	SPU	RU	HH	Stock
Ext		3 (4)	18 (21)	0 (0)		2 (3)
PPU	0 (1)	0 (0)	84 (64)	0 (0)	5 (4)	4 (3)
SPU	4 (5)	22 (14)	0 (0)	27 (18)	0 (0)	0 (0)
RU	0 (0)	1 (1)		0 (1)		
HH		0 (0)	0 (0)	6 (2)		
Stock	1 (1)	0 (0)	1 (3)	0 (0)		

source

PPU - Primary Production Unit (crops)
SPU - Secondary Production Unit (livestock)
RU - Redistribution Unit (manure heap etc.)
HH - Household

The quantified assessment of both farming systems in Machakos district showed high negative figures for N and K in both management systems (-55 and -10 kg/ha,yr) and the high dependency of farm households on off-farm income to obtain a sufficient income level (Table 5; De Jager et al., 1999). At this aggregate level the perception of farm households and researchers on the performance on the farming systems in Machakos match perfectly: both groups perceive the present situation as not sustainable and changes at various levels are required.

Table 5. Nutrient balances and economic performance indicators for conventional and LEIA farm management systems, Machakos district, Kenya (standard deviation between brackets)

	Conventional (n=10)		LEIA (n=8)	
N-balance (kg/ha/year)	-53	(18)	-56	(22)
P-balance (kg/ha/year)	1	(6)	-1	(3)
K-balance (kg/ha/year)	-9	(10)	-12	(12)
Net farm income (US$/year)	334	(319)	538	(523)
Market orientation (% of gross value sold)	14	(16)	13	(20)
Off-farm income (US$/year)	1022	(1483)	311	(205)
Return to labour (US$/day)	0.1	(0.5)	0.5	(1.0)

Table 6. Farmers' assessment of PTD trials in Maize on farms with conventional and LEIA farm management (10 points over 3 treatments)

Criteria	**Indicator**	**LEIA** (n=8)			**Conventional** (n=10)		
		T1	**T2**	**T3**	**T1**	**T2**	**T3**
Productivity	Yield	2.0	3.4	4.6	2.6	2.6	4.8
	Seed quality	3.3	3.7	3.0	2.9	3.6	3.6
Soil improvement	Soil fertility	2.0	3.7	4.3	1.9	3.1	5.0
	Soil structure	2.3	3.1	4.6	2.1	3.1	4.9
	Incidence of weeds	2.0	3.1	4.9	2.2	2.8	4.7
	Quality of compost	1.9	3.4	4.7	2.0	3.3	4.6
Economic benefits	Money saving	2.9	3.0	4.1	2.1	3.1	4.7
Labour	Labour input	2.0	3.1	4.9	2.6	2.7	4.7
Vigorous and strong crops	Vigour	2.0	3.4	4.6	4.2	2.4	3.6
	Leaf colour	2.0	3.0	5.0	3.6	2.3	4.1
Pest control/crop protection	Incidence of pests/diseases	4.4	2.9	2.7	3.1	3.1	3.9

T1 - LEIA 16.2 MT/ha compost manure
Conventional 17.0 MT/ha manure + 57.1 kg/ha DAP
T2 - 32.7 MT/ha compost
T3 - 32.6 MT/ha compost + 7.2 MT/ha liquid manure

Based on the results of the analysis, experimental design workshops with farmers were organised aimed at identifying soil fertility management technologies with a high potential to address the observed problems and to enter into a joint process of experimentation, observation monitoring, evaluation. In other words, starting again a learning process for farmers, NGOs and researchers. During a farmers' experimentation design workshop, the participating farmers jointly prioritised possible technologies to address soil fertility degradation. The following technologies were prioritised:

- preparation and utilisation of organic fertilisers;
- use of a combination of organic and inorganic fertilisers;
- manure and fertiliser application rates.

Through consensus the group decided on the following treatments on the test crop maize (indigenous variety) on plots of 9 by 5 meters:

- Normal practice (T1)
  For LEIA farmers: 0.5 kg tin of compost per planting hole (16.2MT/ha) + normal tillage
  For Conventional farmers: 0.5 kg of manure per planting hole (17.0MT/ha) and 57.1 kg/ha DAP
- 1 kg tin of compost per planting hole (32.7MT/ha) + normal tillage (T2)
- 1 kg tin of compost per planting hole (32.7MT/ha) + liquid manure (7.2MT/ha) + normal tillage (T3)

Table 7. Impact of tested technologies in maize on economic characteristics and nutrient balances at activity level for conventional and LEIA farm management (standard deviation between brackets)

	Conventional (n=10)			LEIA (n=8)		
	T1	**T2**	**T3**	**T1**	**T2**	**T3**
Yield grains (MT/ha)	2.4 (1.2)	3.0 (1.7)	3.3 (1.6)	2.8 (3.0)	3.1 (2.5)	3.9 (3.2)
Yield stover (MT/ha)	7.3 (4.3)	7.8 (5.2)	8.8 (4.7)	7.1 (2.3)	7.9 (2.3)	9.0 (2.0)
Labour (days/ha)	92 (27)	99 (27)	162* (55)	103 (28)	108 (45)	175* (51)
Gross margin (US$/ha)	373 (322)	420 (423)	443 (361)	452 (444)	432 (368)	508 (489)
Variable costs (US$/ha)	257* (30)	316* (49)	380* (84)	223 (42)	331* (92)	422* (91)
Gross margin (US$/day)	4.4 (3.7)	4.3 (4.0)	2.7 (2.4)	4.4 (3.4)	4.4 (3.4)	3.2 (3.2)
Partial N-balance (kg/ha)	-56	-49	-54	-74	-54	-63
Partial P-balance (kg/ha)	1	-9	-10	- 14	-9	-12

T1 - LEIA 16.2 MT/ha compost manure
Conventional 17.0 MT/ha manure + 57.1 kg/ha DAP
T2 - 32.7 MT/ha compost
T3 - 32.6 MT/ha compost + 7.2 MT/ha liquid manure
* - Significant difference (P=0.1)

According to the farmers' assessment of the first season with the above treatments (Table 6) the two tested technologies scored higher in terms of productivity, soil improvement and economic benefits, while also the labour requirements increased. The observations of the scientists however lead to less conclusive results (Table 7). The gross margin per unit area increased with increased application of compost and liquid manure: +13% for T2 over T1 and +19% for T3 over T1 at the conventional farms. On the farms with LEIA management lower increases are found: +12% for T3 over T1. But due to the also increased labour input with increased application levels, the gross margin per labour day is reduced: -34% T3 compared to T1 in the conventional and LEIA management group. None of these observed differences were statistically significant, due to the high in-between farm variation. Limited impact of the treatment on the negative N-balance is observed. The higher input levels of N result in higher yield levels and therefore have limited impact on the annual nutrient balance. In general, the farmers' assessment of the trials was more positive than the researchers' analysis. A joint evaluation of these differences in observations is the next step before any new experiments will be planned.

7. Conclusions

Hard systems and soft systems are two sides of the same coin in developing INM as a new approach to address soil fertility depletion. Scientific research in the hard systems results in 'concrete' data such as nutrient balances, quantified nutrient flows, gross margins, labour input data and statistically analysed impacts of farmers' experimentation. For a long time, this researchers' view of observation, interpretation, analysis, action and learning was considered to be the only relevant input in triggering processes of change in farm management. That in this often reductionistic process essential elements for practical implementation as well as views and perceptions of other actors could have been lost was hardly realised. The soft science, often more holistic view of reality was considered of no importance: how to draw conclusions and arrive at recommendations from studies of human behaviour? Recent experiences, however, have shown that combining hard and soft systems studies making use of both formal science and local knowledge can result in a fruitful marriage: the IPM experience and the first steps taken in developing a more or less similar approach in INM. In such an approach the most relevant actors (farmers, researchers and 'change agents') must jointly enter into a process of observation, interpretation, experimentation, learning and evaluation. For INM development, not many tools have yet been developed to facilitate such a process. The examples presented and referred to in this paper form only a start and many more efforts need to be undertaken. Special attention needs to be paid to the institutional aspects of these new approaches and to how these often-local initiatives can be implemented on a larger scale.

The stressed shift in paradigm is aimed at transforming the type of (nutrient) management at farm household level. Not the adoption and development of one or more technologies is the main target, but a change towards a management style and technology development process based upon observation, experimentation and learning. The example of the development of integrated arable farming systems in The Netherlands (Van Weperen et al., 1998) is an example of such a shift in management style. In NUTMON various tools for observation from different angles are being developed to implement a process, jointly with researchers and NGO-staff, of learning and experimentation.

So far INM has largely focused on technologies, while policies have at least an equally important impact on nutrient management at farm household level. There may be a need to develop Policy-maker Fields Schools besides the already developed Farmer Field Schools. This aspect needs ample attention in the near future and may require different tools and approaches.

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Chapter 11

Strategies for the development and introduction of sustainable farming systems

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Abstract

This paper describes a methodology and requirements for designing sustainable farming systems based on practical experience. It deals with three levels of 'prototyping' farming systems, from experimentation on a restricted number of farms to implementation by large numbers of farms. Although they have different characteristics and different applications, these levels have much in common. It is argued that designing a sustainable farming system should always lead to:

- clear and strict objectives for each farm and for all themes, with yardsticks to be used by the farmer;
- a farm plan for achieving these objectives, based on theoretical and practical insights and tailored to the individual farm and the farmer's preferences;
- a detailed analysis of results and processes to allow gradual optimisation of sustainable farming methods on the farm;
- dissemination of the strategy and results.

Moreover, designing sustainable farming systems requires intensive communication, interdisciplinary research and optimisation of farming systems in practice.

1. Introduction

This paper examines how to design sustainable farming systems in practice and is based on experience gained by the Dutch Centre for Agriculture and Environment (CLM). It focuses on the methodology of design rather than on the contents of the resulting farming systems. In the first section we describe a few characteristics of general CLM practice. In the next three sections we deal with three levels of 'prototyping' farming systems, in which the emphasis shifts from experimentation in research in the first section to implementation in practice in the third:

- designing an experimental farm, in this case the experimental environmental dairy farm 'De Marke';
- designing prototype farms, in this case a group of dairy farming pioneers formed in 1998;
- developing farm environmental plans for larger numbers of farms.

In the final section we draw on the experience gained to formulate some general requirements for the design of sustainable farming systems.

2. CLM strategy on farming practice

CLM promotes integrated agriculture: sustainable agriculture with a broader function (i.e. including energy production, water conservation, nature conservation, etc.). It is a research and advice organisation and designs sustainable farming systems, management instruments and policy proposals that make optimum use of the potentials on the farm. All its work is carried out in projects. CLM communicates intensively with both farmers and agricultural organisations and environmental, nature conservation and animal welfare organisations to keep abreast of their latest insights.

In almost every project CLM communicates with a working group of farmers. Most members are pioneers experimenting with aspects of sustainable farming on their own farms. In CLM's experience, these farmers in particular are able to discuss the farming systems that are needed in future and to develop the instruments and technologies required.

In many projects CLM experiments with certain instruments or technologies in practice. In these cases study groups of farmers are formed who are prepared to test them on their farms. The study groups are organised regionally to ease communication between farmers. For instance, the energy yardstick for livestock farming was tested by seven regional groups of farmers. Study groups magnify the value of tests by individual farmers, because communication between farmers in these groups is a powerful means of evaluating and improving the product being tested.

3. De Marke experimental environmental dairy farm

'De Marke' is an experimental dairy farm designed to meet the stringent environmental standards of the future. The aim is to develop, research and demonstrate a sustainable dairy farming system. The farm started working in 1991 after five years of preparation. How was it designed?

The first principles for 'De Marke' were developed during discussions between the CLM working group of Dutch dairy farmers and CLM researchers. In the mid eighties these dairy farmers were confronted by successive environmental problems: nitrate, ammonia, phosphate, pesticides in maize, loss of natural values, etc. In the response of research and policy these problems triggered expensive end-of-pipe measures and restrictive regulations. Farmers hated these, especially because they could not see or measure the problem on their own farms. They wanted to know what the actual problem was and how it could be solved cheaply.

We analysed nutrient cycles and nutrient balances on average Dutch dairy farms (Biewinga et al. 1987). This was an eye-opener for those dairy farmers. They had always heard that Dutch dairy farming was very efficient, but their nutrient efficiency appeared to be amazingly low: only 15% for nitrogen on individual farms, with an average surplus of 480 kg nitrogen per hectare. Losses occurred throughout the farm nutrient cycle. So the solution was hidden in the problem itself: raise nutrient efficiency at each step of the farm nutrient cycle. Many agricultural measures appeared to be available for improving nutrient efficiency. Soon the main discussion within the working group was about which were the best measures.

From this point on, our co-operation with the working group led to two developments. The first was the system of nutrient administration for individual farms. Surprised by our figures for average farms, the members of the working group wanted to know what the figures were for their own farms. So, in 1988 we developed a form that could be used by individual farmers to calculate their own nutrient balance. The members were annoyed to see that their average nitrogen surplus was nearly as high as the Dutch average. This spurred the development of a farm strategy for analysing the nutrient cycle and choosing the best measures. Within a few years the members of the working group reduced their average nitrogen surplus by more than 40%.

The second development was the design of the plans for the experimental farm. The basic principles for this farm are the same as those for nutrient management on the working group farms. These principles were developed simultaneously. An important difference was that objectives for the experimental farm were more stringent and that its farm plan could be designed with much more freedom. Farmers and researchers maintained close contact during preparations for the experimental farm 'De Marke':

- farmers: the working group and meetings with larger groups of farmers, mainly on the choice of measures that suit the farms best and are most economical;
- researchers: a project team of researchers from CLM and two other research institutes[1] and many meetings with smaller and larger groups of researchers from many institutes on the objectives, the farm plan and the research plan.

Four elements were essential in the strategy for 'De Marke':

1. *formulation of clear and strict objectives*

   The general objective for De Marke is to develop, research and demonstrate a sustainable system for dairy farming. This general objective has been further elaborated into specific objectives that concern all aspects of sustainability: ecological, agro-technical and socio-economic. Objectives contain criteria (yardsticks) and standards, quantified as far as possible. Objectives have different priorities.

[1] The Research Institute for Agrobiology and Soil Fertility (former CABO, now AB-DLO) in Wageningen and the Research Station for Cattle, Sheep and Horse Husbandry (PR) in Lelystad.

2. *design of an elaborate farm plan*
   The farm plan is based on theoretical and practical insights and favours cheap and process-integrated measures. Measures concerning nutrients aim to close the farm nutrient cycle through maximum efficiency of nutrient use in each step. As a dairy farm is a complex system, model calculations were used to assess different scenarios and to choose optimum levels for feed, crop areas and fertilisation.

3. *detailed analysis, yearly evaluation and optimisation*
   Right from the start, detailed analyses of results and processes have been carried out to understand the functioning of the system. This forms the basis on which farm management can be gradually optimised. This analytical information is collected without disturbing the system, mainly by:
   - monitoring inputs, outputs and process parameters per animal, per field and for the farm as a whole;
   - collecting specific, detailed information from some 30 measuring points to be used for process analysis and long-term evaluation of soil characteristics;
   - comparing experimental plots to define optimum fertilisation levels;
   - comparing possible large-scale optimum variants within the farm.

   All these data are used for annual evaluations and optimisations. Model calculations adapted to integrate results from De Marke and from other research play a role in the optimisation process. Evaluation also leads to questions that have to be answered by more fundamental research.

4. *broad dissemination of strategy and results*
   We disseminate not only the final research results but also the strategy followed and intermediate results obtained. De Marke is not put forward as a blueprint for Dutch dairy farms, but as a learning tool for both researchers and farmers. Results and insights are disseminated by receiving visitors (farmers, researchers, environmentalists, politicians, etc.), by giving lectures elsewhere in the Netherlands and abroad, and by publishing reports, articles and brochures.

Has 'De Marke' been successful? In many respects it has. For example, it has succeeded in reducing its nitrogen surplus to a level below the goal of 128 kg nitrogen per hectare (compared with some 400 kg nitrogen per hectare common on contemporary Dutch farms) and its phosphate surplus to the level of 0 kg phosphate aimed at. Many farmers have visited De Marke and have learned from the farm; but they have also given valuable comments that have contributed to the further development of the farm and its demonstration function.

Is 'De Marke' alone a sufficient basis for research and for the dissemination of information on sustainable dairy farming? No, it is not. 'De Marke' has two major shortcomings:

- for research: it is only one farm, which is not sufficient for testing farm models and theories;
- for demonstration: 'De Marke' is not a practical farm in an economic sense, making it less convincing to visiting farmers.

To overcome these shortcomings, the 'De Marke' project team proposed starting a similar project with a group of 'real' working farms.

4. Pioneers for sustainable dairy farming

The shortcomings of 'De Marke' van be overcome by applying and testing the strategy on a group of farms in practice, with a great diversity of soil types, farm circumstances and farm managers. In 1998 CLM and three other institutes[2] started a national project to realise this idea: within the plan period, 'Koeien & Kansen, Pioniers Duurzame Melkveehouderij' (Cows & Chances, Pioneers in Sustainable Dairy Farming). The project will take at least 12 dairy farms, develop sustainable farming practices on them and demonstrate this development. The process counts just as much as the results here: What strategies do these pioneers use? What development takes place? How do the farmers deal with disappointing results? Farmers form the backbone of the project: their inspiration, creativity, management capacity and perseverance define the possible results. They work closely together and co-operate with 'De Marke' and with a team of researchers. Each farm is also embedded in a regional study group of dairy farmers. 1998 was the first, preparatory year of the project. Crucial characteristics of the project are:

- clear environmental objectives that look forward to the year 2010 or further;
- objectives concerning all aspects of sustainability, including ecological, agrotechnical and socio-economic aspects;
- intensive support for individual farm development plans;
- binding agreements and, where necessary, financial stimuli;
- intensive research and evaluation.

An important objective is that within three years all farms will have reached the Dutch standards for nitrogen and phosphate losses for the year 2010.

Each farm development plan will be based on the objectives and an analysis of the farm concerned, written in close co-operation between farmers and researchers. The resulting plan must fit in with the farm style, capacities, ambitions and motivations of the farmer. Research results and farmers' experiences will be evaluated each year with the farmers. This may lead to annual additions and amendments to the plans in a process of gradual optimisation of sustainable farm systems.

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[2] Research Institute for Agrobiology and Soil Fertility (AB-DLO), Research Station for Cattle, Sheep and Horse Husbandry (PR) and the Agricultural Economics Research Institute (LEI-DLO).

5. Farm environmental plans

The previous two levels may be sufficient to develop a consistent set of prototypes for sustainable dairy farming. But there is still a gap between those pioneering farms and the thousands of ordinary farms. Those thousands of farms cannot simply copy one of the prototypes because their circumstances and preferences will certainly differ. A third level can help to bridge this gap: the design of an integral farm environmental plan for each individual farm interested in developing towards 'sustainability'. CLM has worked on this since 1992. First in a theoretical project, then in practice in the provinces of Noord-Holland and Zuid-Holland (1995/96) and in Gelderland (1996/97). The results of the first project are given in Buys et al. (1993), those of the latter in Bleumink et al. (1997).

In the light of these experiences, an integral farm environmental plan must comply with the following demands:

a. clear objectives for all ecological themes formulated for each individual farm;
b. yardsticks for all themes to allow the farmer to define his farm scores;
c. objectives and measures for a period of at least 10 years, in order to adjust long term development of the farm with long term objectives;
d. correspondence with the farm development desired by the farmer;
e. a package of mutually compatible measures suitable for the farm with which the objectives can be realised, when necessary divided between different phases within the plan period;
f. calculation of environmental and farm economic effects of the package of measures.

Huge numbers of farm environmental plans will eventually be needed, and so the procedure for drawing up such plans will have to be standardised to some extent. The main steps in drawing up an integrated environmental plan are the following:

1. The current situation: the current situation of the farm is described, making use of the performance indicators that will be used in step 3; the strategy of the farmer and the main features of the region are defined.
2. Opportunities and threats: an inventory of developments at the international, national and regional levels which could have consequences for the farm.
3. Objectives and priorities: objectives for the farm are formulated, based on national and regional objectives and the farmer's preferences, and an analysis is made of the differences between the current situation and the objectives (strengths and weaknesses); based on this analysis and on the relevance per theme, priorities are defined.
4. Farm development: options for the general development of the farm are discussed (size, production level, intensity, crops, etc.). This step follows a cycle of:
   - developing scenarios;
   - calculating technical, economic and environmental effects of these scenarios;
   - choosing one or more scenarios.

5. A package of measures: given the preferred farm development, measures are chosen to realise the objectives of step 3; this step follows a cycle of:
   - listing possible measures that can be applied to reach the objectives;
   - judging the effects of the proposed measures on all relevant themes;
   - selecting measures to form an integrated package;
   - calculating the technical, economic and environmental effects of this package;
   - choosing optimum levels, e.g. of fertilisation;
   - dividing measures between different phases of farm development.
6. Farm environmental plan: the results of all steps are combined to form a farm environmental plan.

CLM has applied this method on an experimental basis for some ten farms. Results are satisfying. Farmers are able to participate intensively in the process, especially when they can discuss each other's draft plans in a study group. The calculated environmental and economic results of the farm environmental plans so far produced have been good (Bleumink et al. 1997).

This type of integrated planning should become routine practice for each farm once in five to ten years. Advisory organisations will have to support farmers intensively. Certainly the first time the plan will be drawn up in co-operation between farmer and advisor.
However, for the time being there is little reason for most farmers to take this step. The group of interested farmers is rather small and the methodology is not applied routinely. This routine and the necessary auxiliary tools have to be developed gradually, making the method easier and cheaper, lowering the threshold for uptake. Regional and local authorities can encourage this development if they see integral environmental plans as a basis for an integrated environmental licence.

It is up to the farmer to carry out his plan. Each year he can monitor the results with a farm environmental monitoring system. Technical and economic results can be monitored with conventional administration systems. In future, systems for environmental, technical and economic evaluation may be integrated into one system.

6. Conclusions

- To be 'integrated', a design process should:
  - be inter-disciplinary;
  - involve intensive communication with the target group;
  - acknowledge social demands as the basis for the design;
  - refer to all relevant themes;
  - account for market and policy developments.

- Designing sustainable farming systems should comply with several requirements. There should be intensive communication on objectives (what is socially desirable in the long term) between researchers (system designers) and strategic thinkers from research, government and the agricultural sector, in interaction with groups of pioneering farmers. The process should include intensive communication between system designers, technology designers and farmers on the actual farm design, especially on the choice of cheap measures suitable for the farm. System designers should exchange intensively with specialised researchers, amongst others by aggregating specialised knowledge into computing models. Drawing-board designs and underlying models should be verified and developed further in practice, first on experimental farms and then practical farms, with intensive support, monitoring, analysis, evaluation and optimisation of each farm.

Table 1. Characteristics of the three levels of designing sustainable farming systems

	experimental farm	pioneer farms	standard farms
strict standards	++	+	0
regional and farm-specific goals	0	+	++
routine in designing methodology	-	0	+
type of manager	'ground-breakers'	front runners	front runners/ 'main-bunch'
number of farms	1	>12	many
representativeness	0	+	++
management support	++	+	0
financial support	++	+	0
farm risks	++	+	0
intensity of monitoring/evaluation	++	+	0
demonstration role	++	++	+

- The three levels of designing sustainable farming systems described in this paper have different characteristics (see Table 1) and require a different approach, but basically they have much in common. Each strategy for designing sustainable farming systems should lead to:
  - clear and strict objectives, for all themes, formulated for each farm and with yardsticks to be used by the farmer;

- a farm plan to meet these objectives, based on theoretical and practical insights and tailored to the circumstances of the farm and the farmer's preferences;
- a detailed analysis of results and processes for the gradual optimisation of the farm system;
- dissemination of strategy and results.

- All three levels of designing sustainable farming systems have important shortcomings, but they can complement each other very well. They should all be applied in parallel, but to some extent successively. Eventually each farm will need its own farm plan. Interaction between the designers of the different levels is essential.

- Designing and optimising sustainable farming systems requires a great deal of technical research. But social sciences can play an important role as well, for instance in:
  - the debate on objectives that comply with 'sustainability';
  - designing farming systems that meet the diversity of farmers' preferences;
  - evaluation of farming systems against social preferences;
  - developing ways to disseminate farm optimisation strategies;
  - looking for social and political changes that may stimulate sustainable farming systems.

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Chapter 12

Towards an interactive design methodology: guidelines for communication

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Abstract

In order to enhance technology or policy acceptance, it is important to involve stakeholders in the process of policy or technology design. Despite this general awareness, methodologies for interactive design have been slow in forthcoming. This chapter deals with some methodological aspects of communication in processes of interactive design. It is proposed that design processes can be regarded as negotiation processes, in which social learning plays an important role. On the basis of this assessment seven tasks are identified that must somehow be attended to in a design process: preparation, preliminary protocol, exploration and situation analysis, joint fact finding, getting to an agreement, communication with the constituency, and implementation of the agreement. For each task, an inventory is made of factors that may have an influence on success or failure. This results in a number of methodological suggestions which facilitators may follow in an effort to enhance interactive design processes. At the same time, however, it is argued that facilitators must be flexible and creative in applying methodological guidelines. Interactive design processes are complex and diverse, and all sorts of unanticipated developments may occur around and within such trajectories. In such circumstances it is unhelpful to treat a methodology as a rigid set of procedures, guidelines and steps.

1. Introduction

A key element within integral design is that policies, plans or technologies are developed in an *interactive* mode (see e.g. Leeuwis, chapter 1; Aarts & Van Woerkum, chapter 4). This chapter elaborates on this specific dimension of integral design. Assuming that communication is of key importance in an interactive process, we aim at generating a methodological framework for organising communication within such processes.

Various authors have pointed out that different levels of 'interactivity' can exist within design processes. For example, Hanf & Koppen (1993) make a distinction between 'consultation' (one central actor takes all the responsibility, but consults other stakeholders at different points in the design process) and 'consensus-forming' (joint decision-making on the basis of a joint negotiation process). In fact, there is a continuum that ranges from highly 'closed' to very 'open'. In relation to this Pröpper & Steenbeek (1998) introduce 7 styles of participation indicating different levels of interactivity:

1. a closed authoritarian style (no participation),
2. an open authoritarian style (participants are the target of research and/or extension campaigns);
3. a closed participatory style (participants are consulted in relation to a closed question);
4. an open participatory style (participants give advice in relation to an open question)
5. a style of delegation (certain decisions are delegated to participants)
6. a co-operative style (participants have an equal say), and
7. a facilitation style (participants are supported to take their own initiatives).

Especially beyond the level of 'consultation' (the third level of Pröpper & Steenbeek) we feel there is a lack of clarity with respect to methodology. Therefore, this chapter will concentrate on situations in which joint development of a design agreeable to all parties is sought. One important aspect of the above-mentioned methodological vacuum is that there seems to be little clarity on the question of what *kind* of process interactive design really is (see also Leeuwis, chapter 1). Some stress that design should be seen primarily as a learning process (Röling & Wagemakers, 1998; Checkland, 1981), while others emphasise its negotiative nature (Koppen, 1994) or take a middle position (Leeuwis, 1995). In addition, several authors use decision-making and problem-solving models as a basis for organising participatory processes (Van Rooy, 1997; Pretty et al. 1995; Van Veldhuizen et al., 1997). It will be clear that the choice of a metaphor ('learning', 'negotiation' or 'decision-making') has a great influence on the manner in which an interactive design process takes shape. In this chapter we take the view that the negotiation metaphor is most suited to serve as starting point for methodology development. This is because interactive design processes often take place in situations where there are more or less explicit conflicts of interest between actors involved. Any meaningful change or breakaway from the status quo is likely to cause such tensions. In conflict situations, the views of the different participants are closely linked to their interests, and the space for changes of opinion (i.e. a learning process) only comes into existence when such interests are recognised and taken seriously (Aarts, 1998). The negotiation metaphor is, it seems to us, the most suited to making conflicts of interest in design processes more explicit and manageable. This does not mean, however, that no attention should be paid to the learning and decision-making aspects of negotiation. In the following sections a negotiation model is used as starting point for methodology development. Subsequently, we will identify factors that may have an influence on success or failure of interactive design efforts.

2. Towards a negotiation model for interactive design

Aarts (1998) mentions three pre-conditions which must be satisfied if a negotiation process is to materialise at all:

(a) those involved must feel dependent on one another regarding the solution of a particular problem;
(b) possibilities must exist for communication with one another; and

(c) a conflict of interest must exist to a greater or lesser degree.

Based on these conditions we can distinguish several types of negotiation situations:

(i) A situation in which the first and/or second conditions for negotiation are not satisfied and in which the initial situation is not very conflictive. This could be a situation, for example, in which a particular party perceives a problem and feels dependent on others for a solution, while these others do not see the problem or the feeling of dependence is not mutual. Also included would be a situation in which there are no clear possibilities for communication (i.e. because certain participants are badly organised with regard to a particular problem.) Example: an environmental organisation which is of the opinion that there is a problem of excessive energy-use, while consumers do not feel the same way and buy all kinds of energy-consuming appliances.

(ii) A situation where the first and/or second conditions for negotiation are not satisfied and where there are signs of serious conflict of interests. This is a situation in which actors hold on to a power strategy for the time being in the hope of pushing through their own solutions. A good example of this is the conflict surrounding the expansion of Schiphol Airport, in which the air transport sector and environmentalists were at loggerheads for a long time.

(iii) A situation in which the first two conditions for negotiation are satisfied and where there is no serious conflict of interests to start with. Example: a group of applied scientists who, together with a number of ecological farmers, want to develop a number of practices and technologies for sustainable agriculture.

(iv) A situation where the first two conditions for negotiation are satisfied and where there is serious conflict of interests; where the relationships are disturbed and there is distrust, stereotyping, mutual reproaches etc. Example: the relationship between farmers and nature conservationists in De Peel region, a number of years ago, when the partial realisation of mutual dependence began to emerge within both parties (Aarts, 1998).

For every initial situation different demands are made on methodology for interactive design. For example, in the first and second situations a methodology must give well-founded indications as to how a negotiation situation can still be achieved (by stimulating the awareness of mutual dependence, for example). In the fourth situation a methodology will have to put more emphasis on the creation of an open debate and mutual trust than in the third situation. Nonetheless, there will also be many similarities. In the remainder we will therefore provide a general approach, and keep in mind that each specific situation will require adaptations and a different emphasis.

Facilitation tasks within integrative negotiation trajectories
Negotiation processes can be characterised in various ways. Starting from a particular situation, negotiations can take place in a 'distributive' or 'integrative' manner. With 'distributive' negotiations the different parties cling to their own perceptions and points of view and the 'gain' (or the 'pain') is divided. The gain of one party is the other party's loss. Aarts (1998) points out that such compromises are not very stable. That is why, in interactive design situations, an effort is made to arrive at an 'integrative' negotiation process. The idea behind this is that the negotiation partners go through a joint learning process on the basis of which they arrive at new (and often broader) problem definitions and perceptions. In this way space is created for the achievement of so-called 'win-win' solutions. A well-known step-by-step model for 'integrative' negotiations is *'The Consensus-building Process'* by Susskind & Cruikshank (1987). Van der Veen & Glasbergen (1992) have presented this model as follows:

Three stages in consensus building

Stage 1: Pre-negotiation stage
- start of negotiations
- selection of the right participants
- setting of agenda and laying down of rules of conduct
- joint fact-finding

Stage 2: Negotiation stage
- introduction of options for 'win-win' situations
- production of a cohesive package of measures
- production of a written document
- binding of the parties to an accord
- ratification of the document by constituency

Stage 3: Post-negotiation stage
- formalisation of the informal agreement
- monitoring
- creation of a context for re-negotiation

In our opinion, a number of issues remain under-emphasised in this model. Firstly, there is little explicit attention paid to the idea that there should be a learning process within negotiations too, allowing for the exchange of divergent points of view. Secondly, the difficult process of manoeuvring (give and take) has been made more or less invisible in this model. Finally, the distinction between pre-, post- and actual negotiation stages is unfortunate because it seems to suggest (incorrectly) that a negotiation process takes place in a linear manner according to the steps in the model. It seems to us that it would be better to approach the 'stages' as *tasks* to which the necessary attention must be paid during a negotiation process. The word 'task' also expresses better the idea that there is something that needs to be worked on. Of course, some tasks are worked on especially in the initial stages and other tasks are mainly worked on at the end. But all the tasks remain relevant at all times. The tasks are never completely finished. From these ideas and also with the inspiration of other negotiation models (especially Huguenin, 1994) we come to the following overview of tasks:

Tasks in an interactive design process

Task 1: Preparation
- analysis of inter-relations and practices in the stakeholder network;
- selection of the participants
- motivation of the participants
- clarifying links with formal policy processes (in case of interactive policy formation)

Task 2: Preliminary process protocol
- laying down of rules of conduct and interim agenda

Task 3: Exploration – Situation analysis
- formation of groups
- exchange of relevant information and expertise
- exchange of perspectives, interests and aims
- analysis of problems and their interconnections
- integration of perspectives into a new problem definition
- first identification of alternative solutions and 'win-win' situations
- identification of gaps in knowledge and insight

Task 4: Joint fact-finding
- development of plan of action in order to fill gaps in knowledge

Task 5: Reaching a consensus
- manoeuvring: taking up negotiation positions and expression of claims regarding solutions; exerting pressure in order to achieve concessions; creating and breaking impasses.
- achievement of an agreement on a cohesive package of measures and plans of action.

Task 6: Communication with constituency
- transfer of learning process
- acceptance of agreements by constituency

Task 7: Implementation
- carrying out of agreements
- monitoring of the implementation
- creation of a context for re-negotiation

In interactive design processes the parties involved are, in principle, jointly responsible for the 'implementation' and distribution of the above tasks. During the initial stages, however, special responsibility is reserved for the initiators, usually one of the parties directly involved, or a relative outsider who has an interest in promoting a joint design (a government agency, for example). Moreover, we often see specific people being drawn in and made responsible for the monitoring and facilitation of the process.

3. Factors affecting success and failure

In this section we will list a number of factors that may affect success and failure for each task in the interactive design process. This inventory is based on a literature review (Fisher & Ury, 1981; Susskind & Cruikshank, 1987; Van der Veen & Glasbergen, 1992; Mastenbroek, 1997; Vermeulen et al., 1997; amongst others). Most of these factors have implications with regard to the organisation of communication within design processes.

Preparation

The preparation includes analysis of the stakeholder network, selection of participants in the negotiation process, motivation to participate, and –in the case of policy development– integration of the negotiation process into the formal policy process.

Those who take the initiative can start by making an analysis of the network of actors involved in the conflict: who is involved, what are the practices of the different participants, how do they relate to one another, what is the background of good or bad relationships? Susskind & Cruikshank speak, in this context, about a 'conflict assessment' (1987: 103-104). Such preparatory analysis lessens the chances that relevant stakeholders will be overlooked, and increases the chances of the process starting well.

With this task conflicts can arise over who can take part in the negotiations. Susskind & Cruikshank deem it advisable not to try to avoid such conflicts of interest. They support the conscious working out of such a conflict (1987: 106) in order to prevent problems at a later stage. In relation to this, they warn against excluding certain parties in order to smoothen the process. In a similar vein, De Bruin & Ten Heuvelhof (1998) point to the positive side of involving a large diversity of stakeholders, as it widens the scope for 'package deals'. Moreover, an inclusive approach offers stakeholders an opportunity to widen their network, which makes participation more attractive. A large diversity thus leads to greater complexity, which may at times even contribute to progress reaching an agreement. On the other hand, it has been demonstrated that a large diversity of participants may also lead to 'tasteless' compromises which eventually do not satisfy any of the participants (Leeuwis, 1995). Thus, preparatory research (i.e. forms of stakeholder analysis and 'conflict assessment') can be necessary in order to make an estimate of 'optimal heterogeneity'. Thereby, it may -according to Susskind & Cruikshank (1987: 102-103)- be advisable to support structurally and financially less well organised interests. In this way the representation will be more balanced.

Participation by those who formally draw up policy calls for special attention. Vermeulen et al. (1997) call this the political formalisation dimension. They believe that a good link between the dialogue route and the relevant formal policy processes is essential. Participation by policy-makers also has a down side. These people have in many cases already had a role in the conflict and may therefore feel more strongly in favour of certain positions. It could be sensible to choose from among the policy-makers -and also from other organised interests- enough 'ad hoc' representatives who have experienced the earlier conflicts of interest in a less personal manner. These participants are better able to take others' ideas on board.

The motivation of people to participate in a negotiation process will depend on their 'Best Alternative To Negotiated Agreement' (Fisher & Ury, 1981). If people think that they can achieve more by methods other than sitting at a negotiation table, then participation in the negotiations is unattractive to them. Emphasising mutual dependence among the participants in achieving certain goals could stimulate motivation to participate. In relation to this, De Bruin & Ten Heuvelhof (1998) point to the importance that participants experience a 'sense of urgency'. Feelings of mutual inter-dependence and urgency can be stimulated, for example, by the introduction of certain external pressures (i.e. carrots, sticks and threats), deadlines and/or the (late) timing of negotiation initiatives.

Besides this, motivation to participate will depend on who takes the initiative and how this person or organisation goes about doing so. If the initiative comes from a person or organisation relatively removed from the conflict (from a non-suspect side) and if it is emphasised that participation in the first meeting is completely non-binding, there is a greater probability that the various parties will participate (Susskind & Cruikshank, 1987: 96). The image or the status of the person who takes the initiative (knowledgeable, trustworthy, reasonable) can also have an influence.

The preliminary process protocol

Before the actual negotiations take place it is important to discuss several procedural issues. Agreements on procedures must enhance trust among participants that the negotiation trajectory will be organised in a fair manner. Such agreements can relate to the agenda (what will and what will not be discussed), rules of conduct (presence of external observers, format of discussion sessions, dealing with the media, protection of participants, the mandate of representatives, etc.) and/or the role of an external process manager (mediator or facilitator).

Setting the agenda can start with an inventory of all the participants' potential agenda points by the initiators (Susskind & Cruikshank, 1987: 111). De Bruin & Ten Heuvelhof (1998) insist that the agenda for debate must be sufficiently open, and warn against too many restrictions at the process level. This in order to ensure that all stakeholders can bring forward adequately their views and interests, and influence the outcomes. Widening the agenda also increases the opportunities for making comprehensive 'package deals'.

As a way of protecting participants it may be sensible to reach agreement on the status of intermediate decisions and negotiation outcomes. Participants may be offered the right to withdraw from earlier negotiation results, in order to prevent that people feel increasingly trapped as the negotiation process enfolds.

Attention can also be paid to the mandating of the representatives: to what extent are the representatives free to operate without consultation with their constituencies. Too many restrictions placed on representatives can lead to a complicated discussion structure, which could cause an increase in the bureaucracy involved in the process.

The decision of whether or not to appoint a mediator is very important. Susskind & Cruikshank (1987: 133) formulate three preconditions for successful negotiations *without a mediator*: the number of participants and subjects involved in the conflict are relatively few, there are no barriers to communication between the parties, and the participants all have a full awareness of their mutual inter-dependence. All too frequently, these conditions are not satisfied. Thus, Koppenjan & Joldersma (1997) argue that one cannot expect interaction between participants to materialise of its own accord: "The project manager must play a stimulating role in this respect" (p. 392).

If a facilitator is appointed, some clarity as to her/his role and authority must be included in the preliminary protocol. A process manager can derive her/his 'authority' and legitimacy from jointly endorsed agreements, which is of great importance when a deadlocked design process has to be put back in motion. Especially in the case of serious conflicts of interest it seems important that the facilitator place her/himself 'above the parties' and restricts her/himself to the role of (thoroughgoing) process manager. Concerning her/himself with the content at such a moment could easily lead to a breakdown in trust with one of the parties involved.

Exploration and situation analysis

At the start of the design process there is a chance that strangeness, distrust and protectiveness of positions still play a big part. Especially in situations of conflict there is a big chance that opposing parties will stigmatise one another. The groups see things from an 'insiders-outsiders' (or 'we and them') perspective (Elias, in Aarts, 1998). The image of the entire group of outsiders ('them') is modelled on the 'worst' characteristics of the 'worst' part of that group. On the contrary, the self-image of the established group ('we') is modelled on the most exemplary part, on the minority of its 'best' members (Aarts, 1998: 33). An exploration stage is necessary in order to break through the stigmatisation and to allow mutual trust to develop so that participants become more willing to supply information on their plans, interests and pre-conditions.

In order to stimulate a constructive attitude, it may be necessary to create some space for the expression of feelings of mutual reproach regarding events in the past. Especially when the relations are very troubled by the conflict, 'letting off steam' can be a useful stage. According to Fisher & Ury (1981), one of the main principles in negotiation is the making of a distinction between the people (the relationships) and the problems (the content). They are of the opinion that before approaching the problem itself the human aspect should be isolated and dealt with separately.

In a process (rather than substance) oriented approach towards design it remains important to guarantee sufficient substantive input. Even if facts and content matters can never be considered to be purely neutral and objective -i.e. there is no 'best' solution- De Bruin & Ten Heuvelhof argue that there usually exists a certain bandwidth from which substantive positions cannot reasonably deviate (1998: 132-133). Whenever decisions are taken outside this bandwidth process has dissipated substance. In order to prevent this from happening, De Bruin & Ten Heuvelhof (1998) advocate the inclusion of process arrangements that ensure sufficient content input. Examples of such arrangements are the deliberate distribution of information and/or the involvement of external experts. Similarly, all sorts of 'learning tools' may be provided in order to help generate insight into substantive processes and/or provide feedback on the consequences of certain measures, agreements and solutions (see Vereijken, Schoubroeck & Leeuwis and De Jager et al., chapters 7, 9 and 10 respectively).

In order to stimulate learning within a negotiation process, it is necessary for the participants to relinquish their unalterable positions. Thereby it is important that participants identify the interests underlying their specific positions. The underlying thought here is that arguments and positions are not independent, but are constructed on the basis of perceived interests. Thus, it makes little sense in negotiation processes to endlessly discuss the (non-)validity of certain arguments, without considering the underlying interests. In a debate on interests and goals (rather than arguments) it becomes easier to examine the possibilities that exist of satisfying one another's interests (Fisher & Ury, 1981). Thus, participants gain insight into the differences, but also into commonalties between the various perspectives, interests and goals.

Insight into one another's points of view, interests and aims could lead to a broadening of the participants' horizons. Participants discard their old mental perspectives ('reframing') in order to be more accommodating towards the arguments of others. They are ready and able to listen and to become involved with the concerns of other parties. In other words, there could develop a readiness to 'unlearn', to no longer view their own perspective as the only possible one (Vermeulen et al., 1997: 47-48). In this way space is created for a new problem definition in which an integration of different perspectives takes place. Such a new problem definition forms the basis of a first identification of alternative solutions and possible 'win-win' situations. For this purpose an environment is necessary within which new creative ideas get a chance. In relation to this, Susskind & Cruikshank (1987: 118) are of the opinion that a process agreement that allows the generation of ideas without initial commitment ('inventing without commitment') can be stimulating.

Joint fact-finding

From the confrontation between different perspectives, interests and aims it can become evident that there is a lack of knowledge and insight regarding certain aspects. There then exists too much uncertainty to allow the formulation of certain plans. In this case consensus must be reached on a process of generating more knowledge and insight. The initiative to co-operate in filling knowledge gaps can mean, for example, that the parties set up a joint experiment or share in the cost of hiring in an expert. The setting up of such joint factual research forms a negotiation process in itself about appointments, suppositions, yardsticks etc. One side effect of such a joint activity can be the strengthening of relationships between the parties. Doing something together creates a bond.

One example of joint experimentation is to be seen in De Peel region in the Netherlands where farmers and nature conservationists have developed a joint plan for agriculture and nature. One important element of the plan is constituted by a number of experiments which are developed and implemented and which relate to the realisation of natural and environmental goals in agricultural enterprises. The aim of these experiments is finding ways of solving problems like ammonia emissions, waste-water disposal and nature in agricultural enterprises in a way acceptable to both farmers and horticulturists as well as to nature conservationists (see also Aarts & Van Woerkum, chapter 4; Aarts, 1998).

Achieving consensus

Give and take are central to this task: taking up certain negotiating positions, stating claims regarding solutions, bringing pressure to bear in order to move others towards concession, creating impasses and breaking them. These manoeuvres can lead to a consensus over a cohesive package of measures, a so-called 'package deal'. A package deal is a combination of problems and solutions that can be either accepted or rejected as a whole (see Van der Veen & Glasbergen, 1992: 231).

Whether or not the participants reach a consensus naturally depends on the preceding process: to what extent was it possible to avoid a discussion on positions, to talk about underlying interests, to arrive at an integration of perspectives, to jointly develop knowledge and to arrive at new, creative 'win-win' solutions. With reference to this, Mastenbroek (1997) suggests that -at a certain stage- actors should be encouraged to speak in terms of proposals and counter-proposals only. "Instead of defending one's own proposal through thick and thin, one simply asks under which conditions it would be acceptable to the other party or which adjustments they desire. One can also propose one's own additions. In this way a proposal is filled out until an acceptable compromise is reached" (Mastenbroek, 1997: 61). The BATNA's of the various participants also play a role. The more problematic it would be for the participants if nothing were to change, the harder they will strive towards some sort of agreement. Participants will be especially keen on a consensus if they have a great number of parallel interests besides the conflicting ones: in other words, if the mutual inter-dependence is great. Another factor that can play a role in arriving at a consensus is the measure to which participants enjoy freedom from the control of those they represent.

An agreement can be set down in writing. In this context Susskind & Cruikshank (1987: 125-126) stress that participants must build up confidence that the agreement really will be honoured ('a deal is a deal'). At any rate, clear agreements about who does what and when, are essential. Supervision of fulfilment of agreements by an outsider can help increase trust.

Communication with the constituency

One of the tasks in the design process is the transfer of the learning process and the sanctioning of the agreement by the constituencies of the various participants. This sanctioning cannot be taken for granted because there is a possibility that the direct participants in the discussions, through their direct interaction with the other participants, will experience a different learning process than the people they represent. Representatives and their constituencies can grow apart. In this context, Driessen & Vermeulen (1995) point to experiences in the Dutch province Zeeuws Vlaanderen. In the negotiations over the restructuring of the area an organisation of environmentalists had initially approved the accord that had been reached. However, this support had to be withdrawn under pressure from the people they represented, who were of the opinion that too little attention was being paid to the reduction of pollution.

Mastenbroek (1997) proposes that the relationship between representatives and their constituencies must be regarded as a negotiation process in itself. Many (naïve) negotiators are not aware of this characteristic. One could even go so far as to say that the key of successful negotiation is to be found predominantly in the willingness and ability to negotiate with the own constituency (Mastenbroek, 1997: 66).

The extent of the support of a constituency for an agreement depends on a number of factors. One of them is the extent and mode of communication between representatives and constituencies during the negotiation process. Were the negotiations taking place behind closed doors or in the open? Did the public media report on the developments in the negotiation process? Furthermore, the role perception of representatives can have an influence: are they aware that they are expected to put across the ideas and feelings of those they represent instead of their own personal opinions, and that they must communicate with their constituency throughout the process (Susskind & Cruikshank, 1987: 105)? The sources through which constituents are informed about the negotiation process may also have an impact on acceptance. In the Dutch city of Deventer, for example, representatives of various neighbourhoods developed a traffic circulation plan. The presentation of the plan was delegated to an external expert, whom the constituents considered to be a representative of the local government. Hence, the plan -which was actually developed by their own representatives- was regarded as a government plan which deserved to be 'shot in pieces' (Veldboer, 1996). Such a reflex might have been prevented if a member of a neighbourhood had presented the plan.

The sanctioning of the agreement by the constituencies of representatives from the formal policy-making bodies has a special character. It involves the formalising of an informal agreement. Democratically elected bodies can sometimes feel left out. They must accept in full a cohesive agreement that has been achieved with great difficulty. Adaptations are well nigh impossible at this stage (Van Tatenhove & Leroy, 1995).

Implementation

It is important to arrive at clear procedures for the monitoring of progress in relation to the accords: who will do it and to what criteria (Susskind & Cruikshank, 1987: 131)? If problems in implementation are identified on the basis of such monitoring, a quick response will often contribute to continued support for the agreement. It can also be necessary to create some clarity regarding the procedures for re-opening negotiations (Susskind & Cruikshank, 1987: 133). Under what circumstances (altered insights, unexpected developments or undesired side effects, for example) are new negotiations possible?

4. Conclusion

In this chapter methodological guidelines have been presented for the facilitation of interactive policy and technology design processes. The proposed guidelines are based on the idea that an interactive design process can be organised along the lines of a negotiation process, in which especial attention is paid to the facilitation of a joint learning trajectory. In many cases there will in fact be multiple parallel learning and negotiation trajectories that take place at more or less the same time. Within negotiations there are usually a number of issues at stake, and new paths can continually be added, for example by means of joint fact-finding. One can also speak about negotiations at various fronts: between the different parties, but also between representatives and their constituencies, or between the negotiation partners and third parties. The complexities involved in this imply that facilitators can play an important part in interactive design processes. Such a facilitator will have to possess the necessary insights and capabilities regarding social interactions, shaping of negotiations and organisation of learning processes. Moreover, the role of facilitator demands flexibility and creativity. The interactions within negotiation processes can have all kinds of unintended effects and can also be influenced by chance or unanticipated events and developments in the external environment. Within integrative negotiations especially, all kinds of new directions can open up, making adjustments of the chosen trajectory essential. The planning scope for interactive design processes is therefore limited. It would also be wrong to approach the proposed methodological guidelines as a 'step-by-step' plan that has to be closely adhered to in order to achieve success. Rather, we have presented a (not at all complete) collection of methodological tips relevant to tasks that are of importance within design processes. A creative, selective and purposeful application of such tips increases the chances for a productive learning and negotiation process, but still is not a guarantee for success. The course of human interactions is too capricious and unpredictable for that.

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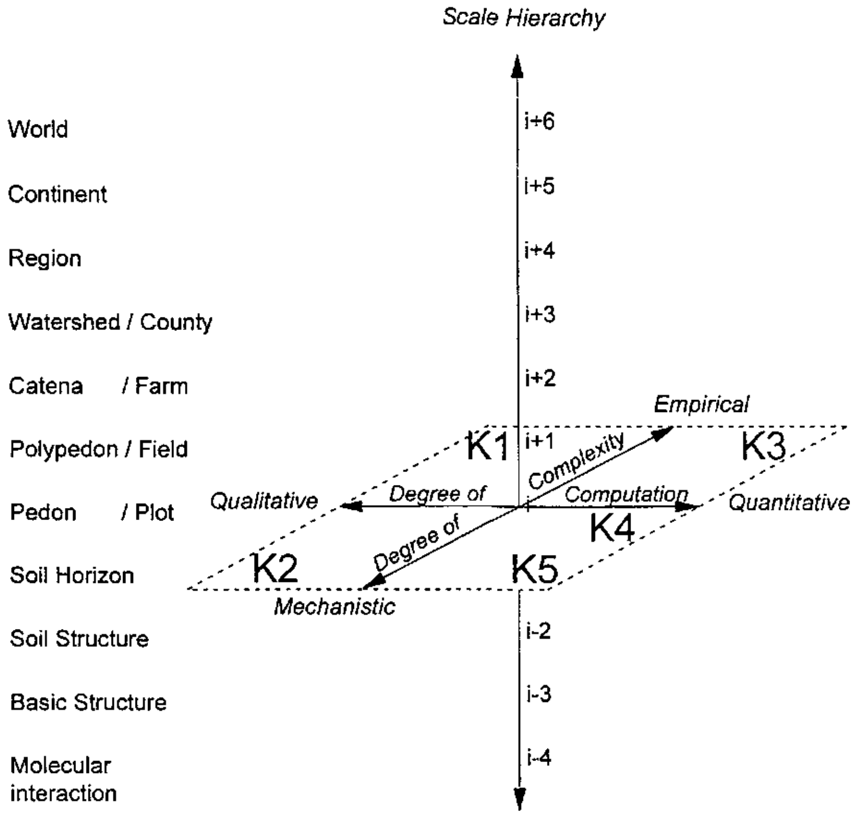

Scale Hierarchy and Knowledge Type diagram (Hoosbeek & Bryant, 1992; Bouma & Hoosbeek, 1996). Classification of models and data based on:
1) hierarchical scale level, 2) degree of computation, and 3) degree of complexity.

Knowledge types:

K1 = qualitative - empirical	User
K2 = qualitative - mechanistic	Expert
K3 = quantitative - empirical	Specialist: simple comprehensive models
K4 = quantitative - mechanistic\empirical	Specialist: complex comprehensive models
K5 = quantitative - mechanistic	Specialist: complex models of aspects

Figure 1. Five knowledge (K) types as a function of two conceptual scales ranging from empirical to mechanistic and from qualitative to quantitative. Five knowledge types can be defined as indicated for the i scale hierarchy (from Bouma & Hoosbeek, 1996).

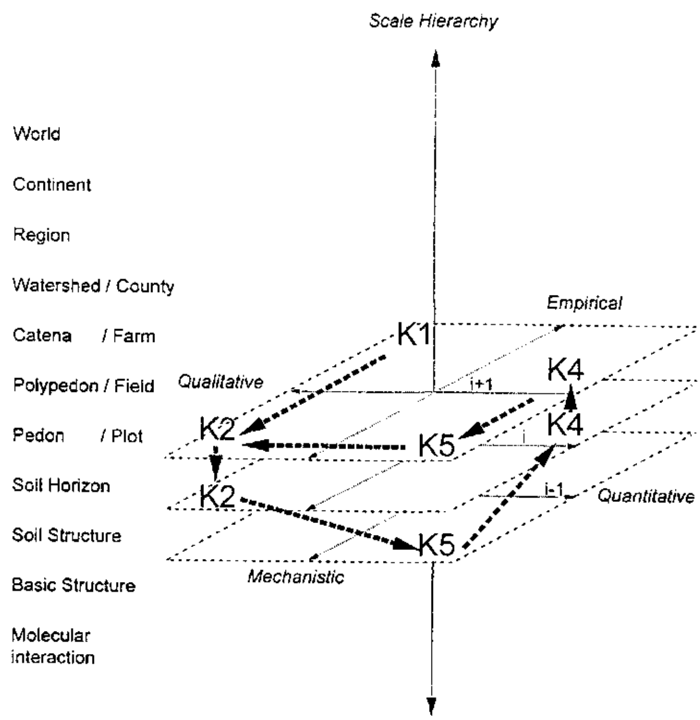

Figure 2a. Knowledge chain for a study on precision agriculture (after Bouma, 1998)

However, alternative procedures would also have been feasible:

(i) Information at the plot level could be restricted to the K2 level (Figure 2b). This assumes that experts would have adequate knowledge to characterise crop production as a function of N-input and associated leaching. This procedure is rapid and cheap, but probably unreliable.

(ii) Simpler K3 models could be used to characterise crop production and leaching. Also, the obtained soil map (K2) could be used to interpolate point data to data for the entire field, avoiding geostatistical procedures Figure 2c). Again, this would be cheaper than the 2a procedure but more complex and costly than the 2b procedure.

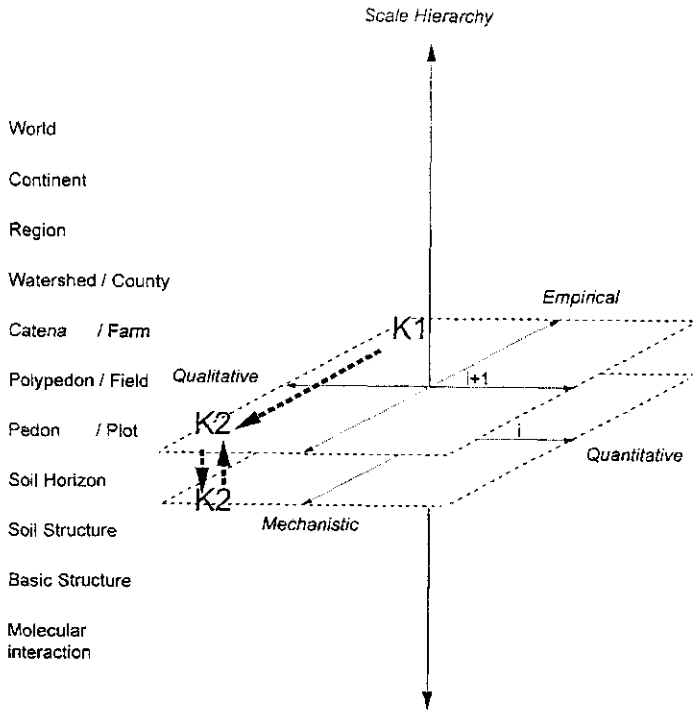

Figure 2b. As Figure 2a, but only using expert knowledge

Other possibilities would be applicable as well but the above examples adequately serve to illustrate that different procedures can be followed to answer the question for precision agriculture as to which fertilisation rates are feasible when striving for maximisation of production while minimising environmental impact. The procedures vary in cost, they require different amounts of time and they provide different accuracy and reliability. The user is offered a choice, considering the funds he or she can spend and the degree of accuracy of results that is required. This interactive process between researchers and users of research has been called: 'Research negotiation' (e.g. Bouma, 1997b). Researchers are inclined to jump into a research project, any project, using their favourite models or methods. 'Research negotiation' implies that a choice of methods is presented from which the user has to make selections. The process of interaction, which results in an ultimate choice of methodology, is quite important as it also cements the contact between researcher and user: increasingly they deal with a 'joint' problem and have a joint interest in solving it. A comparable example of research negotiation for a study on acidification of European soils has been presented by Bouma (1997b).

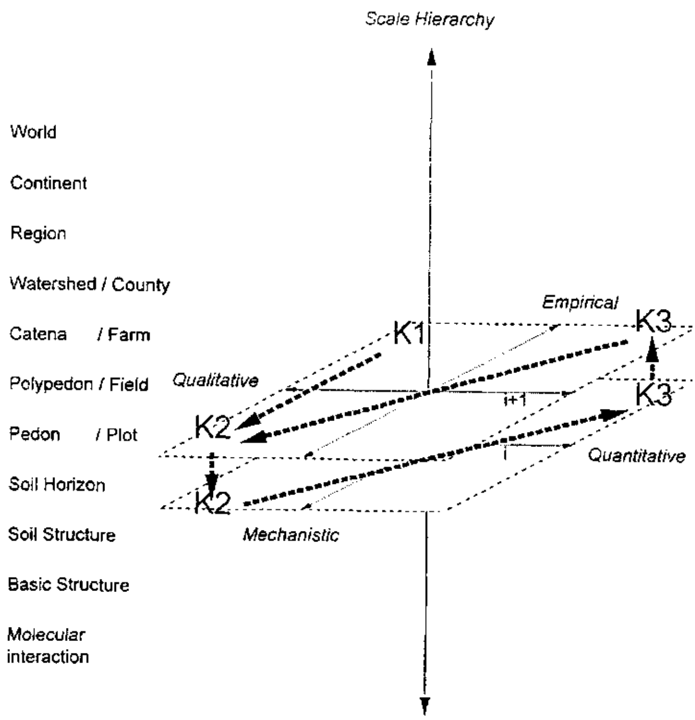

Figure 2c. As Figure 2a but using empirical/quantitative K3-type of modelling

3. Case studies

Mixed farm De Marke

An experimental mixed farm was established in the early nineties in a sandy area in the Netherlands to investigate possibilities for profitable dairy farming while meeting environmental threshold values, particularly those related to nitrate leaching to the groundwater (Aarts et al., 1993; Biewinga et al., 1996). Using expert knowledge and farmers' experience, a new management plan was developed by prototyping, which resulted within three years in a reduction of leaching of nitrates to almost acceptable levels. Prototyping implies interaction between farmers, experts and specialists with the objective of 'designing' a complex agricultural production system to the extent that adequate production is achieved while environmental threshold values are not exceeded. Growing maize, rather than buying feed for the cows, and sowing Italian ryegrass as a cover crop at the end of the maize growing season to avoid excessive leaching of nitrates in wintertime, proved to be quite effective in reducing nitrate leaching. No complicated research methodologies had to be applied to arrive at these common-sense solutions. Prototyping, in fact, resulted in different recommended management practices at different distances from the farm, which had a size of 50 ha. Closest to the farm, land was used as meadow (A) (Figure 3).

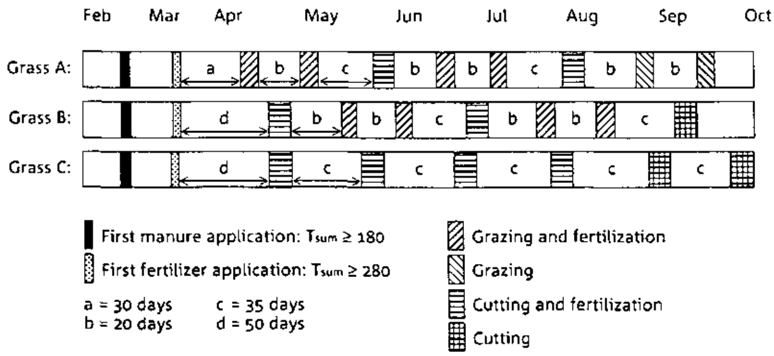

Figure 3. Schematic representation of decision rules for fertilization, cutting and mowing of grassland (A=permanent pasture close to the farm, B=rotation of three years grass and three years maize, and C=rotation of three years grass and five years maize, farthest away from the farm (from Hack ten Broeke et al., 1999).

In the second sphere, a rotation was advocated of three years grass and three years maize (B). In the third sphere, farthest away from the farm, a rotation was followed of three years grass and five years maize (C). The decision support system, represented in Figure 3 and reflecting practical experience and expert knowledge, defined times of manure and fertiliser applications and successions of grazing and fertilisation. Rates of fertiliser applications were based on recommended rates by extension services, and amounted to a total amount of 250 kg N per ha, including inorganic and organic fertiliser.

Monitoring data of groundwater quality showed a decline of nitrate concentrations in the groundwater during the first three years after introduction of the revised management scheme (Hack ten Broeke & de Groot, 1997). However, such isolated measurements are very hard to generalise because of weather variation and spatial variability problems. Hack-ten Broeke et al. (1999) proposed, therefore, a procedure in which the management scheme for the entire farm was applied to soil types occurring on the farm. By using a validated K4 simulation model, values were obtained for crop growth and nitrate leaching as a function of a wide range of fertilisation regimes, using real weather data for a 30-year period.

Results for leaching are presented in Figure 4, which shows the cumulative frequency of nitrate concentrations in the groundwater based on 30-year simulations. The threshold nitrate concentration is 11 mg /liter. For the Hn21 soil, the probability of exceedance is about 65%. Values were approximately 40% for the zEZ21 and pZg23 soils and only 15% for the zEZ21 and 0% for the Hn23x. Judgement criteria may vary, but the leaching rate for the first two soils are clearly too high, whereas values are acceptable for the latter two soils. Using these data, leaching of nitrates can be quantitatively expressed as a function of fertilisation regimes and varying weather conditions.

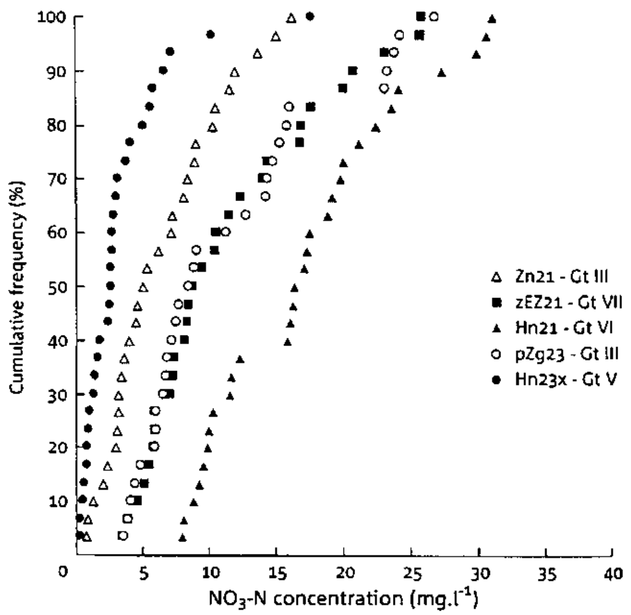

Figure 4. Cumulative frequency distribution of farm-average annual N-concentrations at 1m depth for five mapping units in sandy soils (from Hack ten Broeke et al., 1999).

Some isolated, costly measurements of nitrate concentrations in the groundwater would never yield these types of results, if only because there would not be adequate weather variation. The expression of results in terms of probabilities of exceedance allows the user to estimate risks involved when selecting a given scenario. The procedure applies the management plan that was developed by prototyping (K2) and quantifies this with a K4 simulation, thus forming an effective research chain (Figure 5).

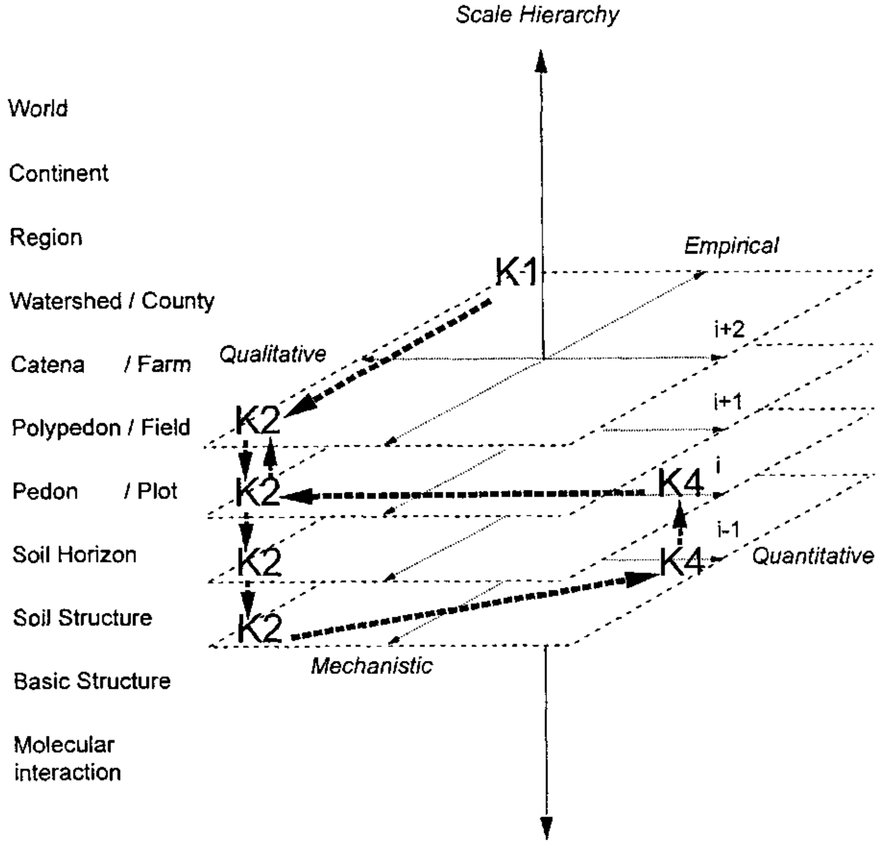

Figure 5. Research chain for reported research at the experimental farm De Marke, illustrating integrated use of expert knowledge and basic research.

Biocide application on the Vredepeel farm

To reduce losses of pesticides and nutrients while maintaining economic viability, integrated farming systems are being developed (Vereijken & Wijnands, 1990). Prototypes of integrated arable farming systems were developed on three experimental farms; in Nagele in the central clay district, in Borgerswold in the north-east sand district and in the Vredepeel in the south-east sand district. These integrated farming systems aim at a strong reduction of high inputs of pesticides and minerals while maintaining at least the same economic profitability as the conventional farming systems. We will discuss here aspects of the work on the Vredepeel farm, with a focus on pesticides.

A typical crop rotation consists of potato, sugar beet, winter wheat, scorzonera, potato, sugar beet, maize, carrot and pea/bean. Pesticides are being used in the conventional system. Table 1 lists the types of pesticides being used and quantities being applied. A problem is leaching of pesticides into the groundwater. A threshold value of 0.1 microgram per liter in the upper meter of the groundwater is used to define acceptable pollution levels. Measurements of pesticide concentrations in groundwater are difficult to make, because of the depth requirements of the threshold value, and they are very expensive.

Table 1. Pesticide use (kg ha^{-1}) for the reference pest control system for the integrated management system of experimental farm Vredepeel

Pesticide	Potato	Maize	Carrot	Pea/bean	Sugar beet	Fallow[1]
Bentazone				0.60		
Carbendazim					0.50	
Chloridazon					0.59	
Cymoxanil	0.23					
Deltamethrin	0.005					
Ethofumesate					0.40	
Fluazinam	1.90					
Iprodion			1.00			
Mancozeb	3.25					
Metamitron					1.12	
Metoxuron			1.60			
Phenmedipham					0.31	
Pirimicarb	0.03		0.03	0.13		
Quizalofop-ethyl					0.03	
Sethoxydim			0.24	0.24		
Validamycine	0.06					
Vinchlozolin				0.75		

[1] fallow and catch crop

Judgements on leaching of pesticides based on expert (K2) knowledge are impossible to make. Simulations of absorption and leaching are therefore increasingly used to assess the likelihood of groundwater pollution (Van der Veen & Boesten, 1996). The K4 PESTLA model was used to define pesticide movement in soils (Boesten & Goettesbueren, 2000). Figure 6 shows the simulated concentrations of bentazone in groundwater for crop rotations requiring bentazone applications in years 1,7, 13, 19 and 25. Clearly, concentrations are too high. Next, alternatives were checked. Among them was the pesticide metamitron, which was tested for a crop rotation with applications in the years 6, 12, 18 and 24. (Figure 7).

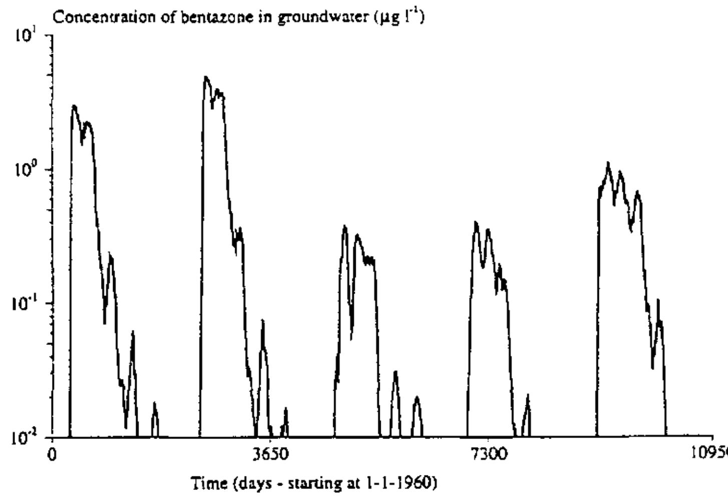

Figure 6. Simulated concentrations of benzatone in the upper meter of the groundwater for the integrated farming system Vredepeel for the crop rotation with benzatone applications in the years 1, 7, 13, 19 and 25 of the weather series (from Veen & Boesten, 1996).

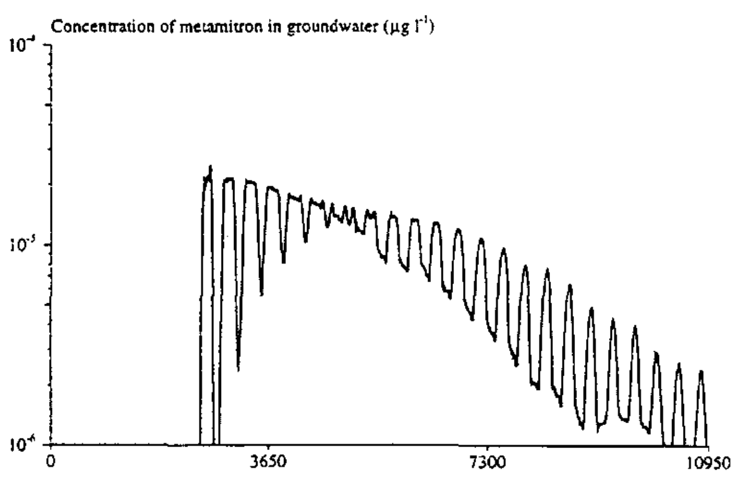

Figure 7. Simulated concentrations of metamitron in the upper meter of the groundwater for the integrated farming system Vredepeel for the crop rotation with metamitron applications in the years 6, 12, 18 and 24 of the weather series (from Veen & Boesten, 1996).

Here, concentrations in the groundwater are sufficiently low, because of higher adsorption and decomposition. By running simulations for many pesticides, that are all characterised in terms of adsorption coefficients and half-lives, a separation can be made between potentially polluting and non-polluting pesticides. Thus, a revised pest control system could be developed and proposed (Table 2) which only includes non-polluting pesticides at the given application rates.

Table 2. Pesticide use (kg ha^{-1}) for the revised pest control system for the integrated management system of experimental farm Vredepeel

Pesticide	Potato	Maize	Carrot	Pea/bean	Sugar beet	Fallow[1]
Carbendazim					0.50	
Chlorobromuron			0.50			
Chlorothalonil	2.14					
Cymoxanil	0.23					
Deltamethrin	0.005					
Ethofumesate					0.40	
Fluazinam	1.90					
Iprodion			1.00			
Lenacil[2]				0.12		
Metamitron					1.12	
Metoxuron			1.60			
Phenmedipham					0.31	
Pirimicarb	0.03		0.03	0.13		
Quizalofop-ethyl					0.03	
Validamycine	0.06					

[1] fallow and catch crop

[2] removed in second step

This information was fed back to the overall management plan, completing the research chain. Detailed work on pesticide movement in soil is coupled here to management of crop rotation, as can be visualised in a research chain (Figure 8).

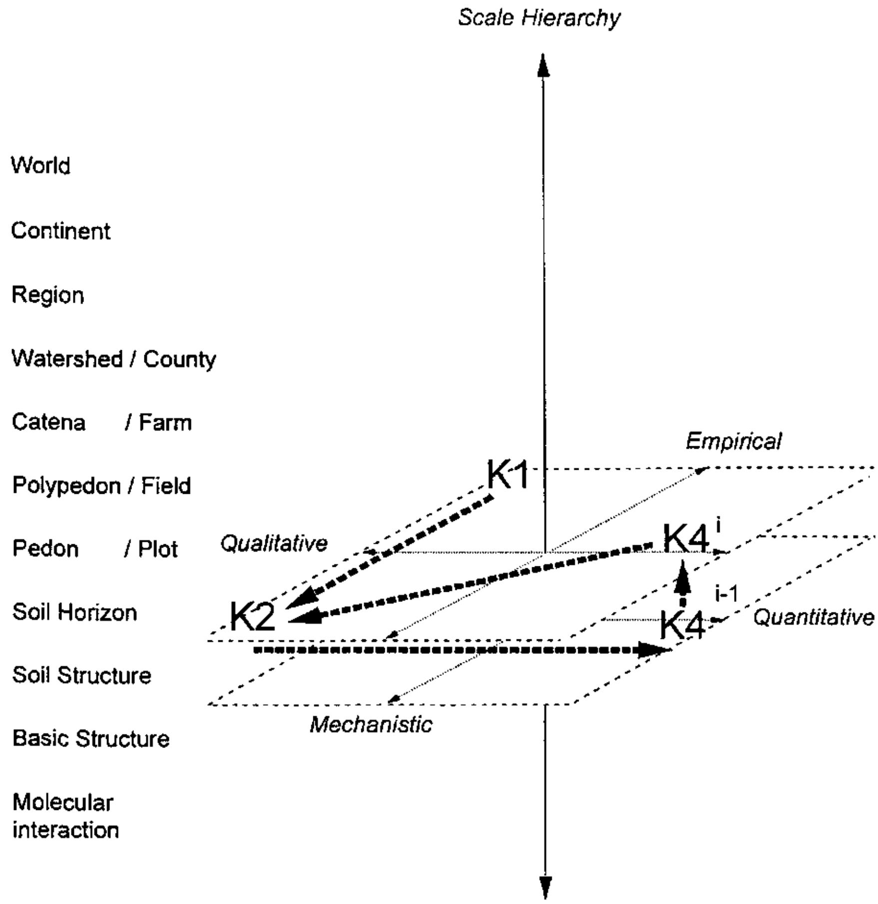

Figure 8. Research chain for reported research at the experimental farm Vredepeel, illustrating integrated use of expert knowledge and basic research.

4. Implementation of the research-chain approach

Much current agronomic research is still rather mono-disciplinary in character as reflected by the contents of international scientific journals. Relating basic research to a holistic analysis of the problem to be studied is still unusual. Conclusions that certain problems can be solved by using available stakeholder and expert knowledge, requiring no further research, are seldom reached. However, a paradigm shift is occurring as politicians and administrators realise that much traditional research is not applied while development of integrated and sustainable agricultural production systems has not proceeded as quickly as society would have liked. Complaints about the effectiveness of traditional, rigid research programmes were voiced early in Australia where the Land Care programme was started in the eighties (Campbell, 1994). In this programme, interested citizens and scientists worked together on land-use problems defining, in fact, research chains, even though emphasis was on expert and user expertise and much less on scientific research. In the nineties this type of work has also started in the Netherlands, De Marke and the Vredepeel farms being examples discussed in this paper.

How can this type of research, which deviates from the traditional separation of basic and applied research, be implemented? The best way is not by preaching about a new research paradigm but by simply showing what has been done and how it has been done and to what effect. The work on De Marke is shown to large numbers of farmers while scientists taking part in the programme publish scientific papers in leading international journals. Being part of an applied research project that is relevant for society does not necessarily imply that one is lost for science! Clearly, we have a responsibility as University educators to make this research approach part of the standard learning process of students. Another frequent question relates to the process by which choices are arrived at while designing research chains in the inter-disciplinary research team, including the stakeholders. There is no simple recipe here, but defining a general objective of the work is important. Having done so, a series of chains can be defined, starting with a holistic analysis of the entire system and disciplinary parts of the chain. By defining different alternatives, as illustrated in Figure 2, options for alternative research approaches within each discipline become visible. Also, the analysis helps to avoid the common problem that different disciplines tend to work at different spatial scales and at different K-levels. This, of course, calls for trouble. When each discipline is aware of its research options in terms of spatial i - and K-levels, there is much more common ground among the disciplines than in the old condition when each discipline had its own subculture. Still, what is most needed is a willingness to listen, to share, to communicate, and, on occasion, to admit that one's own work is not very important in a particular context. Again, this attitude - which has nothing to do with flashy software and information systems- should particularly be treasured in modern University education.

5. Conclusions

1. Questions as to whether or not environmental threshold values are exceeded in innovative management schemes developed by prototyping, cannot be answered by expert knowledge alone. Case studies on nitrate and pesticide leaching demonstrated the role of mechanistic simulation modelling in assessing the probability that unacceptable pollution of groundwater would occur. This illustrates the function of research chains linking basic research with expert knowledge that, in turn, inspires the research process.

2. Modelling studies were focused by considering the type of management practices developed by prototyping. Thus, logical knowledge chains were formed between stakeholder expertise (K1) and expert knowledge (K2) –both needed for prototyping- and modelling work at K4 or K5 level. Modelling work is bound to be more effective if it is tied to a problem formulated in the context of prototyping and when results are coupled back to the prototyping team to improve the overall design and either generate new questions for detailed research or a signal 'enough is enough'.

3. Distinction of research chains for each discipline in inter-disciplinary projects facilitates inter-disciplinary co-operation because scientists become aware that in their work they can consider different i- and K-levels when studying a given problem in a broader context and that comparable approaches in different disciplines are likely to fit better together than approaches that are based on common practices within each discipline.

4. Multi-functionality of the agricultural production systems described here relates not only to agricultural production but also to protection of groundwater quality and, by implication, to safeguarding the quality of soil and water of areas surrounding production fields. Such adjacent areas can therefore have a range of potential uses, including nature and recreation if so desired. The range of uses would be smaller if agricultural production would lead to discharge of excessive amounts of agro-chemicals.

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2. Obstacles towards integral design in a changing knowledge network

In the Netherlands (and elsewhere) the actors and dynamics in the agrarian knowledge network have changed considerably in the last decade. Important changes include the increased spreading of market mechanisms in the knowledge network, the legal privatisation of extension and research institutions, and the merger between agricultural research institutes and the agricultural university into Wageningen University and Research Centre. Although the changes have not yet fully crystallised, there seem to be a number of threats - besides the opportunities - to the capacity of the network to support experiential learning and integral design, and thereby innovation towards sustainability.

The linear dimension of the 'supply and demand' metaphor
The introduction of market mechanisms is one of the corner stones of the current agrarian knowledge policy in the Netherlands. There are a number of reasons for the increasingly popular perception of especially 'applied' (agrarian) knowledge as a private property and saleable good, for which the user must, in principle, pay (see Verkaik & Dijkveld Stol, 1989; Renkema & Leeuwis, 1998). In this context the phrase 'supply and demand' is used more and more frequently with reference to knowledge. The 'demand' side is mostly associated with *users* of knowledge while the suppliers are thought of as *developers* and *transmitters* of knowledge. The metaphor of supply and demand therefore carries with it the idea of a clear division of tasks between the three parties. In other words: innovation processes are essentially regarded as linear in nature. Clearly, this contradicts sharply with the underlying philosophy of integral design (see Leeuwis, chapter 8), from which it follows that farmers are important co-developers of innovations. Even more in general, studies on innovation have shown that in everyday practice researchers, extension agents and farmers are all occupied with the development, exchange and use of knowledge, and that it is precisely the recognition of this non-linear and non-exclusive task-sharing that can contribute greatly to the achievement of successful innovation (Engel, 1995; Röling, 1996; Leeuwis, 1995; Vijverberg, 1997; Kline & Rosenberg, 1986). Thus, strict adherence to the principle of supply and demand could form an obstacle to integral design processes that would be of benefit to sustainable agriculture. This is shown, for example, by the following observations on the co-operation between applied research and extension.

Market mechanisms and the creation of parallel knowledge networks
The privatisation of the Dutch extension service, now almost completed, has caused a split between applied research and DLV, the privatised extension service, in several sectors. Apart from the creation of spatial and cultural divisions there are tensions between these institutions over the question of who should pay whom for what, and why. Should DLV pay for the results of collectively financed research? Should applied research pay DLV for relevant questions from the field? Can the now legally independent applied researchers set up their own 'extension branch'? Are extension agents paid by their clients for the knowledge they

supply or only for the transmission of that knowledge? The tensions that have arisen seem to be leading to an effort by the applied researchers to compensate for the newly created lack of communication by setting up their own advisory channels while the private extension services take initiatives on the research market. It would seem, therefore, that there are two largely separate knowledge networks coming into being that will compete on the knowledge market. Such forms of competition might act as a stimulant to innovative research, but could also lead to research duplication and a decrease in research capacity on specific issues. It therefore remains open to question whether this development contributes to the efficient support of experiential learning and integral design towards sustainable agriculture.

The undermining of mutual knowledge exchange

The fact that farmers and horticulturists have to pay more and more often for advice and research also seems to contribute to a diminishing willingness to exchange knowledge among them. In this context, it is significant that the Association of Dutch Horticulture Study Groups (NTS) had to give up on their long-defended ideal of open mutual knowledge-exchange (Oerlemans et al., 1997). Under pressure from horticulturists it has been decided that study groups will be allowed to withhold and shield off new insights for a certain period of time from other NTS members. Likewise, there is less attention given to the support of study groups and other group activities by the privatised extension service. This is not surprising as both the support of mutual knowledge exchange and the supply of knowledge to a group can be regarded as 'spoiling' one's own market. These obstacles to the exchange of local knowledge -which is especially important in the field of making agriculture more sustainable- seem to reinforce the creation of parallel knowledge networks described earlier, to bring the same kinds of opportunities and threats. In the final analysis, there is a risk that the knowledge networks within which farmers and horticulturists operate will become more restricted, causing a further increase of the already high costs of obtaining knowledge. This does not seem to be an ideal situation for a transition to knowledge-intensive sustainable agriculture on the basis of local level experiential learning and knowledge sharing.

Is ecological knowledge a public or a private responsibility?

One complication that can arise when attention is focussed exclusively on the idea that applied knowledge is private good, is that some subjects for research and advice fall by the wayside. This risk is perhaps greatest with environmental issues because investments in sustainability usually lead to increased costs and not necessarily to greater profits. In cases of this kind farmers do not experience any personal gain while, according to the logic of the marketplace (and the principle 'the polluter pays'), they should nevertheless be carrying the costs. At the moment it can be seen that the Dutch government is investing in research and extension on such 'public' issues, but a discussion on the question whether something should be financed by the government or by the private sector arises quickly in the current climate. A phenomenon linked to this is that extension services tend to make a strict division (as regards content, methodology and time) between private (i.e. paid for by the farmer) and public (paid for by the government) extension activities. From the point of view of a market-orientated organisation this is logical enough but it will probably not lead to a coherent and integrated approach towards the support of experiential learning and integral design towards sustainable agriculture.

Shifting client-perceptions within centralised applied research

Due to considerations of efficiency and the idea that applied research should not fulfil any extension functions (in the form of 'demonstration' research), quite a number of experimental farms have been closed down over the last few years. Applied research has thus become ever more centralised. It is reasonable to assume that this has led to a decrease in routine contacts between applied researchers and farmers. At the same time other parties in the production chain can be seen to be forming an ever more important (and relatively well-resourced) customer group for applied research. Such changes seem to be at loggerheads with the intensive co-operation and communication between applied researchers and primary producers that is so desirable for the 'ecologisation' process.

Risks with regard to the readiness and pertinence of collective (applied) research

The efforts to create a knowledge market have meanwhile changed focus from extension to research. In this way applied research lost its 'lump-sum' financing from the beginning of 1998 onwards and will have to go looking for contracts on the research market. Similar changes have already taken place within the institutes for strategic agricultural research, and go along with legal independence of research organisations from the state. Although in principle the moneys necessary for 'collective' research remain available, financiers (government and product-boards) will act in future more as commissioners and will clearly indicate what types of research these moneys must be spent on ('output-financing'). It is evident that the new financing system (and also the founding of Wageningen University and Research Centre) increases the control of the financiers and thus enables them to stimulate co-operation between different research institutes. In principle, this could enhance the readiness and efficiency of research in general, and to integral design in particular, as the latter is highly dependent on co-operation between different research institutes.

However, there is a possibility that the new arrangements will be to the detriment of the applied nature of government-funded research, and thus limit the scope for integral design at local level. The government is no longer just financier of the research but also commissioner and client. The specific ecological problems and conditions known only to local farmers and horticulturists are thus likely to become less important as points of reference.

Moreover, there is a risk that a certain level of 'bureaucratisation' will occur, to the detriment of the readiness of research. More than ever now, the government -before any research can take place- will have to organise formal tendering procedures. Researchers in their turn will have to estimate whether there are funds available somewhere for a newly identified research subject, and a lot of attention will have to be paid to the writing of research proposals, of which a number will not be accepted. All this will probably cause the transaction costs of research to increase. The necessity of writing and allocating working hours to paid projects can also lead to a decrease in the 'grey area' experiments conducted informally by farmers and horticulturists in experimental farms and stations. The possibility of using the 'gut feelings' and creativity of the researchers may be limited by this too. It cannot be taken for granted that good researchers will also be good at obtaining funds, and there is a very real possibility that governmental guidance will be somewhat behindhand on the latest insights from research and practical experience. Even apart from integral design processes, the question remains whether such a 'bureaucratisation' in research would be compatible with innovation in agriculture; innovation and bureaucracy do not usually mix well (Leeuwis, 1995).

The reward structure in science

An applied-orientation clearly is a pre-condition for scientists to take part in integral design processes (even if integral design processes might open new directions for fundamental research as well, see e.g. Van Schoubroeck & Leeuwis, chapter 9 and Bouma, chapter 13). However, under the current reward system and culture within the scientific world, applicability and practice-orientation are not really important evaluation criteria. It follows that, in terms of exact questioning and/or research set-up, scientific research often integrates better with previous research than with practical problems. It makes quite a difference, for example, whether or not the question is asked how the migration behaviour of a useful insect can be modelled in an undisturbed environment, or whether it is investigated how this behaviour is influenced by the various types of interim work (spraying, manual weeding, mechanical weeding, etc.). If agricultural science is expected to make concrete contributions to integral design processes, then the current reward structure may be regarded as an obstacle.

A second problem concerns the appreciation for inter-disciplinary research. As indicated in chapter 1, integral design processes are by definition inter-disciplinary in nature. Such research is far from simple with regard to method, organisation, content and communication. Thus, 'costs' are high while the scientific recognition to be gained is dubious. It is not always easy to have inter-disciplinary articles published in leading -usually single discipline-periodicals. Other forms of reward (status, for example) are also very much dependent on disciplinary colleagues and structures.

3. Does a market for applied agricultural knowledge products make sense?

Although the above analysis is based partially in provisional impressions and does not form a complete image of the workings of the agrarian knowledge network, there seem to be plenty of reasons for anxiety, not least since similar concerns have been raised elsewhere (e.g. Marsh & Pannel, 1998). There seems a need to critically consider both the policy assumptions on which market-oriented knowledge policies are based, and the economic theories that underlie these. At this point I shall not attempt to make a full analysis, but suffice to introduce and reflect upon some basic elements of economic theory that are relevant in this respect.

According to economic theory, a market is a specific institutional arrangement for exchanging goods and/or services, next to other possible arrangements such as organisations or contracts (free from Ménard, 1995). Creating a market for a product implies that one needs to organise excludability; one must be able to exclude others from the product, otherwise it is impossible to assign it with the necessary property rights and price (Verkaik & Dijkveld Stol, 1989; Van der Hamsvoort et al., 1999). According to economic theory, it is not always possible or desirable to use markets as an exchange mechanism (Van der Hamsvoort et al., 1999). The transaction costs necessary for organising excludability may be excessively high in comparison with the benefits incurred. Also, the societal costs can be high, as particular groups may be excluded from the product, which may be deemed undesirable especially in the case that there is a public benefit for widespread provision of the product (i.e. the merit good argument). According to Van der Hamsvoort et al. (1999) the key advantages of introducing market arrangements for goods that used to be provided by the state (in their case 'nature and landscape') are typically that (a) the government can reduce costs, (b) one can expect a better connection between supply and demand, and (c) providers of goods can diversify their sources of income, and reduce risk. As risks they mention that (a) the provision of certain goods may be endangered as they will be substituted by goods that are easiest to market (substitution risk), (b) clients will obtain goods elsewhere where no market has been organised (relocation risk), (c) certain groups will be excluded (exclusion risk), and (d) providers may incur losses and go bankrupt (market risk).

Relating this brief overview to the earlier made observations several peculiarities come to mind when considering market-oriented knowledge policies. First, we can easily recognise some of the indicated risks, in particular the exclusion risk (some farmers will be excluded from relevant knowledge), the substitution risk (research and extension will focus on those issues and/or methods for which money is easily available, respectively on well-resourced clients), and possibly high transaction costs (earlier mentioned 'bureaucratisation'). Particularly the last two 'risks' may well be an obstacle towards establishing integral design processes, and may affect the readiness and pertinence of the knowledge network in general. At the same, some of the advantages are dubious. As the government is aware that it needs to keep investing in agricultural knowledge production and exchange (i.e. neutralise some of the risks), it currently keeps its role of as a key funding agency for research and extension; this time in the role of client/commissioner. Thus, it is questionable if overall costs can be reduced, especially since transaction costs may rise, and commercial rates will need to be paid. The main argument that remains, then, is the supposedly improved matching of supply and demand. This might indeed be true as far as the government and product-boards are the end-users of the knowledge products that are commissioned. However, when the purpose of knowledge production and exchange is on the ground innovation towards sustainable farming (i.e. through experiential learning and integral design), improved matching is rather unlikely. As we have seen, it only logical that the client perceptions of research and extension tend to shift towards well-resourced commissioners of contracts, and away from primary producers. Moreover, the 'supply and demand' metaphor tends to foster and/or re-introduce linear thinking, and thereby obstructs the creative and flexible co-operation that is needed for integral design. In conceptual terms, the key problem here seems to be that applied knowledge and information are considered as ready-made 'end-products'. However, it is probably more adequate to consider applied knowledge and information as 'building blocks' of local level innovations. For each innovation many such 'building blocks' -diverse in nature, and originating from various sources- are necessary, whereby they must be integrated and re-moulded time and time again in locally specific learning and design processes. Thus, each innovation requires numerous knowledge 'transactions' and exchanges. If these all need to be accompanied with payments from one party to another and vice versa (as all parties contribute relevant knowledge and information) one can wonder if such innovations and design processes will ever materialise at all.

In all, the earlier observations are in line with some conceptual doubts as to whether experiential learning and integral design can be optimally supported through a knowledge market. Perhaps other institutional arrangements than markets have a better potential in this respect.

4. Conclusion

At the very moment that farmers are in most need of optimum support in order to change over to more complex and sustainable forms of agriculture, the agrarian knowledge network is being completely reorganised. At local level, the creation of sustainable farming practices -through either experiential learning or integral design trajectories- demands creative co-operation between applied researchers, extension agents and groups of farmers. The conditions necessary for this type of co-operation seem to be deteriorating under the influence of the market mechanisms that have been introduced; hereby linear thinking, knowledge protection, internal competition and centralisation, emphasis on individual advice and changing client perceptions play a role. Also, the readiness and efficiency of research and extension could be endangered by the appearance of financial barriers, 'bureaucratisation', insufficient co-operation, and segmentation and fragmentation of research and extension capacity. There is also the threat of ever-rising costs of knowledge acquisition for farmers who wish to use sustainable production practices (see also Renkema and Leeuwis, 1998). This is because of the eventual devolution of the various payments in knowledge networks onto the shoulders of the primary producers, decreases in 'free' knowledge exchange, and the knowledge-intensive character of sustainable agriculture.

All things considered, it is rather unclear which applied researchers and extension agents would be willing and able to participate in, on the one hand, the experiential learning processes necessary for sustainable agriculture, and, on the other, the integral design trajectories geared to the development of knowledge and technology adapted to local circumstances. As yet, we cannot speak of a 'hole in the market'. Rather, we witness a knowledge market that shows a lot of gaps and shortcomings. This situation demands reflection and deeper research. If the above impressions are confirmed, there are two possible solution directions available. For a start, the government and product-boards can create a strong demand for the desired forms of support and co-operation. They can either commission this directly, or stimulate this indirectly, for example by the distribution of 'research and extension vouchers' to local farmers (Richards and Van der Zande, personal comments). At the same time, this can form a stimulus for the second option, namely the creation of a strategic alliance or fusion between Wageningen University and Research Centre and DLV, the privatised agricultural extension service. This would effectively mean a reunion of key players in the agrarian knowledge network under one institutional roof, as an alternative institutional arrangement to the market; this time without the Ministry of Agriculture at the top in the line of command.

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Chapter 15

Pitfalls in implementation of integral design approaches to innovation: The case of the Dutch Special Programme on Biotechnology

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Abstract
Integral design approaches to innovation are increasingly popular. This chapter deals with the pitfalls, which may occur during implementation of these approaches in various projects and programmes. Some of the likely pitfalls are illustrated through the analysis of a specific case -the Dutch Special Programme on Biotechnology of the Directorate General for International Co-operation. This case study shows that, if an organisation considers implementing an integral design approach in an innovation development programme, specific attention needs to be paid to the selection and training of staff, the specification of the methodology as well as the institutional setting of the programme and its activities.

1. Introduction

There is an increasing support for developing and using integral design approaches to the development of (agricultural) innovations. Such approaches would be necessary to realise certain important societal goals, such as an (agricultural) production, which is economically, environmentally as well as socially acceptable. Many suggestions have been put forward for the realisation of an integral design, as is evident from many chapters in this book. Most suggestions include the involvement of various actors and stakeholders especially end-users, the use of an inter-disciplinary research approach and a process, which is characterised by strong interactions of the different participants allowing for exchange of information, reflexivity and mutual learning. There are, however, fewer examples of how exactly these recommendations work out in practice, the constraints that may occur and how they might be dealt with.

In this chapter, we analyse a governmental programme on biotechnology of the Dutch Directorate General for International Co-operation (DGIS) in which an interactive, participatory and end-user driven approach is used. The case study describes a process of about 10 years and allows us to analyse some likely pitfalls during the implementation of integral design approaches to innovation.

We will start this chapter by describing the specific approach to integral design, which was implemented by the Dutch Special Programme on Biotechnology -the Interactive

Bottom-Up approach. This approach is developed by the Department of Biology & Society at the Vrije Universiteit Amsterdam to guide the development of biotechnological innovations for the benefit of small-scale farmers in developing countries. In the next section we analyse and discuss the achievements of the Dutch Special Programme in implementing this approach. This is followed by a discussion on the lessons learned. The chapter closes with a generalisation of the findings.

2. The Interactive Bottom-Up Approach

At the beginning of the 1980s it was concluded that technology development directed towards small-scale farmers requires that, during the design phase of a project, explicit attention is paid to the socio-cultural, political and institutional context in which farmers operate (Cernea, 1991; Dusseldorp & Box, 1990). However, a few years later evaluation studies revealed that it is not sufficient to consult farmers only during the design phase of a project. Instead, farmers need to become active participants throughout the project, continuously providing checks and balances on collected information, priorities, ideas on possible solutions, proposed sequence of action, project evaluation and so on (Cornwall et al., 1993; Scoones & Thompson, 1993). It was realised that a holistic and integrated strategy for innovation is needed. One that takes into account that farming is a highly complex and dynamic process, that sees farming in its broader social context, and develops the local capacities and socio-cultural structures necessary to sustain the change process (Bunders et al., 1996; Haverkort et al., 1991; Reijntjes et al., 1992). Based on this insight many integral design approaches were developed each with their own emphasis and field of application. The Interactive Bottom-Up (IBU) approach is one of these approaches. It is initially developed to guide the development of biotechnological innovations for small-scale agriculture (Broerse, 1998; Bunders et al., 1996)[1]. Below, we describe the principles and phases of this approach.

Principles of the IBU approach

The IBU approach is based on several principles: (1) small-scale farmers have a prominent role in decision making, (2) the innovation process is centred around a vision, (3) the development of trust relationships is facilitated, (4) mutual learning between participants is facilitated, (5) coalition building is enhanced, (6) different types of knowledge are integrated, and (7) an inter-disciplinary team guides the process.

In an IBU approach, *small-scale farmers need to have a prominent role* in decision making throughout the innovation process. It is not sufficient to 'consult' farmers only

[1] Currently the IBU approach is adapted for application in other fields than biotechnology and small-scale agriculture, e.g. for innovations in the industrial and medical sector. To signify the broader application of the approach, the name has been changed into Interactive Learning and Action (ILA) approach (e.g. Bunders et al., 1999).

during the phase of data collection. This can easily lead to misinterpretation. Active participation of farmers during the entire innovation process is probably one of the best guarantees for the actual generation of appropriate biotechnologies.

The entire innovation process needs to be centred on the *'vision'* that science-based innovations can contribute to small-scale agriculture. The IBU approach is not only procedural but also very much outcome-oriented. This commitment to a vision provides a sense of direction -which actions at what time are considered most suitable by the participants in reaching the objective of generating appropriate biotechnology for small-scale farmers. The inter-disciplinary team, which guides the IBU process, will identify people who share the vision. On the basis of commitment to the vision, participants in the process derive their willingness to collaborate, to overcome difficulties and uncertainties and to take risks. Thus the commitment to the shared vision provides the oil which lubricates the engine of change.

In the IBU process the development of *'trust relationships'* needs to be facilitated. In the interaction between members of the inter-disciplinary team and participating actors and among participating actors, a certain level of 'trust' is crucial for (1) obtaining insight into sensitive information and tacit knowledge[2] which is amongst others necessary for identifying and using the room for manoeuvring, as well as (2) enhancing mutual learning between, and risk-taking behaviour by, different actors involved in the process. At the beginning of the IBU process the level of trust is generally low. There are usually no routines, procedures or protocols on which the activities can be based -an innovative process for and with small-scale farmers is rarely present. Accomplishing innovation and change invariably threatens the status quo and thus raises uncertainty, anxiety and defensive behaviour in many actors (Pfeffer, 1992). In addition, many actors are likely to have no history of interaction and are very diverse in terms of cultural background and interests. The methodology of IBU approach, therefore, incorporates several mechanisms to create conditions, which are conducive to the development of trust relationships.

For communication and interaction to be effective -besides the facilitation of trust relationships- *'mutual learning'* between the participants needs to be facilitated. A condition for successful co-operation is respect and the willingness to listen. It is important that each person involved in the process recognises the others' expertise and potential contribution to the concerted effort and behaves accordingly. Reflexivity is a key element in this respect. Moreover, in the process of mutual learning, feedback and feed forward mechanisms need to be created to allow two important and interrelated requirements for developing appropriate technology to be met: firstly, the exchange of information, and

[2] Tacit knowledge is highly personal and hard to formalise, making it difficult to communicate or to share with others. It is deeply rooted in an individual's action, experience, ideals and values. It can be segmented into two dimensions: the technical dimension, which encompasses the kind of informal and hard-to-pin-down skills or crafts captured in the term 'know-how', and a cognitive dimension which consists of schemata, mental models, beliefs and perceptions so ingrained that we take them for granted (Nonaka & Takeuchi, 1995; p. 8).

secondly the reconstruction and verification of participants' opinions. Opinions on research priorities are likely to differ not only between, but also within the different professional communities (for example between male and female farmers or between social scientists and biologists). Moreover, because of the differences in social, cultural, educational and professional background between the different actors, prejudice and misinterpretation of ideas and objectives may easily occur. Particularly the feed forward mechanism can result in increased respect, reflexivity and willingness to listen among actors, thereby inducing a 'learning attitude'. If participants are not willing or able to have such a learning attitude their role in the process is likely to be marginal.

Also crucial for the success of the innovation process is *'coalition building'*. A 'coalition' of people from different areas serves as a check-and-balance. Coalition building ensures that sufficient and appropriate support (endorsement, backing, approval, legitimacy) and resources (e.g. knowledge, funds, materials, time) will be available to maintain the momentum of a project and guarantee its implementation. An important part of coalition building is establishing supporters from higher levels (for example peers, managers, politicians, government officials and village chiefs) who can provide advice and criticism. The members of this support group share a strong commitment to the vision[3]. Coalition building will result in the 'establishment' of a support group. Discussions between the inter-disciplinary team and members of the support group, because of the trust, which is developed, focus on opportunities and constraints in depth. Important is that tacit knowledge is made explicit and the room for manoeuvring becomes clear.

The IBU approach is, further, characterised by a high degree of *knowledge integration*. Information is collected in the following knowledge domains (see e.g. Wilber, 1995 and 1998):

- *Physical/technological domain:* This domain concerns knowledge about the visible reality, which in this case refers to the actual agricultural and technological situation. Accessing knowledge in this domain typically involves inventory studies on e.g. farming systems, and current agricultural research and innovations.
- *Institutional domain:* This domain covers issues relating to the formal structures that determine human societies, such as living conditions, economic situation, physical infrastructure, type and structure of organisations, rules and regulations.
- *Cultural/shared values domain:* This domain refers to knowledge about worldviews, common interpretative understandings, norms of behaviour, self-imposed codes of

[3] In the case of small-scale agriculture in developing countries interdependence between actors is *not* a motivation for co-operation. The differences in influence and power (e.g. those based on control and access to knowledge and information, control over resources, formal position and interaction) between relevant actors are usually very large, and the powerful and influential actors (e.g. scientists, politicians, civil servants) do not depend on the powerless (i.e. small-scale farmers) for achieving their (policy) objectives. The development of successful innovations for small-scale agriculture is rarely a formal goal of the powerful actors in developing countries.

conduct, cultural meanings, images of nature, and moral and ethical understanding of communities.

- *Personal/intentional domain:* This domain focuses on knowledge about (and of) the people (their skills, ideas, beliefs, interests, hopes and fears) in local communities as individuals instead of collectivities.

This implies that knowledge regarding more objective phenomena (physical and institutional domains) needs to be integrated with knowledge regarding more subjective notions (cultural and personal domains). While the positivist paradigm[4], is usually more appropriate for studying objective phenomena, a constructivist or hermeneutic paradigm[5] provides the best fit whenever subjective notions are being considered. Integrating data, collected in the different knowledge domains, thus involves the integration of the two main research frameworks or paradigms: the positivist and the constructivist/hermeneutic.

An *inter-disciplinary team* guides the process of communication, co-operation, learning and coalition building between the various actors. The inter-disciplinary team (1) has a mediating and facilitating role between the various actors, anticipating problems that result from differences in views, language and power, (2) collects, exchanges, links and integrates information, and (3) facilitates the change process. The members of the inter-disciplinary team thus act as boundary spanners, knowledge managers and change agents at the same time. To be able to perform these tasks successfully, a team approach is preferred over one person performing all tasks.

[4] Since the seventeenth century scientific inquiry is dominated by the positivist paradigm. This approach posits that there exists an objective single reality which operates according to immutable natural laws (Guba & Lincoln, 1989). Science seeks to discover the true nature of this reality. Objectivist epistemology asserts that it is possible (and mandatory) for an observer to exteriorise the phenomenon studied, remaining detached and distant from it (subject-object dualism), and excluding any value considerations from influencing it. An interventionist methodology strips context of its contaminating influences (variables) in order to understand nature as it really is and really works. The ultimate aim is to discover, predict and control natural phenomena.

[5] Over the past 30 years, the positivist view has been attacked, particularly when larger complex systems are studied (which are only relevant within their context) and when human values and subjective perceptions come into question; in those cases positivist premises fall short. One of the main principles of the new paradigms is that 'reality' is always open to interpretation (Pretty, 1994). Knowledge and understanding are socially constructed. Different actors may, for example, have uniquely different perspectives on what is a problem and what constitutes improvement. There is, from this point of view, no single correct understanding. 'Truth' is defined as the best informed and most sophisticated construction on which there is consensus (although there may be several constructions extant that may simultaneously meet that criterion). Subjectivist epistemology asserts that an inquirer and the inquired into are interlocked in such a way that the findings of an investigation are the literal creation of the inquiry process. A hermeneutic methodology involves a continuing dialectic of iteration, analysis, critique, reiteration, reanalysis and so on, leading to the emergence of a joint construction of a case (Guba & Lincoln, 1989).

Phases of the IBU approach
To facilitate the application of an IBU approach, the activities are structured in four phases:

- *Phase 1: Initiation and preparation:* The objectives of this phase are to establish and train an inter-disciplinary team, to become familiar with the socio-economic, agricultural and political setting and the local community, and to choose an area for on-farm research.
- *Phase 2: Collection, exchange and integration of information:* In this phase the research needs of farmers are identified. The phase begins with an appraisal of the main characteristics of the agricultural system, from the perspective of each of the actors involved. Next, the status of currently available agricultural biotechnologies is assessed. In undertaking this activity, the team can generate awareness of the IBU process on the part of relevant individuals and institutions, enlisting their support for later activities. This phase allows all those involved to obtain a basic understanding of the relevant issues and of the points of view of the various participants. The team collects data, organises recurrent dialogues with key informants, and analyses and integrates information and knowledge.
- *Phase 3: Public priority setting and planning:* Although farmers or others may decide that they wish to test relevant options at any stage of the process, it is advisable at some time to organise and hold a priority setting and planning workshop that brings together all the actors involved. The objectives of such a workshop are: (1) to allow review and criticism of the team's findings by a wide audience, (2) to legitimise the findings, (3) to allow room for new contributions, (4) to enhance the visibility of the needs of small-scale farmers, and (5) to establish a plan of action. Discussions at the workshop should lead to consensus on the most important topics for research at farm and laboratory level, and on any other relevant matters (links between research at different levels, changes in policy, etc.). After the workshop, the results of the information analysis and integration exercise can be published, together with (or separately from) the workshop proceedings. The mechanisms used to give feedback should be adapted to the different actors addressed.
- *Phase 4: Project formulation and implementation:* The plan of action which resulted from the previous phase forms the input to the fourth phase, in which specific projects are formulated and implemented. These projects are, or should be, a direct response to the needs expressed by farmers. Activities could include:
  - Experiments at farm level
  - Institution-based R&D
  - Changes to the policy environment
  - Training in IBU approach at institutional level
  - Improvements to the approach followed

  Project formulation and implementation can be undertaken at any level and may focus either directly on the farming community or on research institutions or policy-making bodies, or any combination of these. As in the previous phases, it is essential that formulation and implementation should be interactive, exploring the options in close collaboration with all concerned.

These four phases can be broadly distinguished on the basis of their chronology, the outcome of the previous phase being the input for the next. Yet the phases overlap, as each consists of activities which may be undertaken several times in a different order throughout the process. In this way an interactive, iterative, spiral (instead of a linear) process evolves. The time required for the first three phases is likely to take at least three months. The entire process will probably last several years.

3. Dutch Special Programme on Biotechnology

In this section we present a case study on the Dutch Special Programme on Biotechnology which provides interesting learning experiences regarding the pitfalls which may occur during implementation of the IBU approach in a governmental donor organisation, the Directorate General for International Co-operation (DGIS). The Special Programme was officially established in 1992 and ran for a period of five years. We analysed the way the IBU approach was interpreted and implemented within the Special Programme, the achievements of the programme as well as the difficulties encountered from the first initiatives in 1987 until the termination of the Programme in 1997.

We start with a description of the historical background of the Special Programme. Next the content and activities of the programme are described, followed by a description of some of the findings of the Review Team, which evaluated the Programme during 1996, as well as of our own (participant) observations[6].

Background of the programme

The subject of biotechnology and developing countries appeared on the Dutch political agenda in November 1987. The topic was extensively discussed during the parliamentary budget debate on development co-operation[7]. The starting point of the parliamentary discussion was the dual character of biotechnology. Biotechnological developments can increase the gap between rich and poor, yet biotechnology also has a great potential for overcoming the constraints that developing countries face. Parliament reached a consensus

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[6] The first author worked at the Office of Research and Technology of DGIS from 1988 till 1990, while the second author was a member of Advisory Committee on Biotechnology and Development Co-operation from 1989 till 1991, and its predecessor, the Advisory Committee Biotechnology, from 1992 till 1994.

[7] Report on the 25th and 26th parliamentary budget debate on development co-operation, 24-25 November 1987.

on two policy issues. Firstly, it was felt that the government should take a more active role in steering developments in biotechnology to the direct benefit of the Third World. Secondly, it was recommended that an inventory be made of current activities in the Netherlands.

In response, the then Minister for Development Co-operation, Piet Bukman, promised Parliament to make an inventory of current activities in the field of biotechnology within his own department and at (inter)national level. The Minister commissioned his Office of Research and Technology to take up this challenge (Broerse & Wessels, 1989). During the next two years, three inventory studies were conducted (Office of Research and Technology, 1988; Directorate for Agricultural Research, 1988; Office of Research and Technology, 1989a). In addition to these inventory studies, the Minister asked the National Development Co-operation Advisory Council (NAR)[8] for advice on how biotechnological developments could be integrated within existing Dutch policy on development co-operation (NAR, 1988).

Based on the results of these activities, DGIS drew up a policy paper in which it disclosed its intention to establish a special programme of, in principle, five years (Office of Research and Technology, 1989b). After inter-ministerial discussion, the paper was presented to both houses of Parliament in May 1989. A follow-up document would deal specifically with the operationalisation of the special programme. An Advisory Committee on Biotechnology and Development Co-operation was appointed to guide the process. The follow-up document was submitted to the Cabinet in May 1991 and shortly afterwards approved by Parliament.

No reference was made to implementing an integral design approach to biotechnology development until April 1991, when the then Minister for Development Co-operation, Jan Pronk, stated in a speech at the opening of the public debate 'Biotechnology and Farmers' Rights' that (Pronk, 1992: 15-16):

> "... modern technology is only used in large-scale, commercial agriculture. The challenge now is to apply biotechnology to solve problems in small-scale agriculture. ... The position of small-scale farmers requires biotechnology applications, which are adapted to their environmental and socio-economic conditions. The involvement of the target groups is vital in problem identification. ... The interactive bottom-up approach developed by the Free University provides a model for this. ... I know of no better assessment methodology in this field. ... I intend to test this model under practical conditions."

Subsequently, the Minister approved the Special Programme on the one condition that it would use the interactive, bottom-up approach to biotechnology development in the South.

[8] NAR, whose members are drawn from a wide social spectrum, advises the Minister for Development Co-operation and the government on issues concerning the Third World.

Analysis of the programme

The Special Programme officially started in January 1992, initially for a period of 5 years with a total budget of US$ 30 million. The programme focused on three issues: (1) integration of the development dimension in the Dutch national biotechnology policy; (2) technical co-operation with developing countries; and (3) international co-ordination and co-operation (DGIS, 1992). The biotechnological research activities were directed towards three sectors: agriculture, human health care and environmental management with special focus on women and small-scale farmers. In addition, attention was paid to building local biotechnological research capability, policies, and regulations, and to conducting technology assessment studies and risk analyses. A special team (of four members) with a 'status aparte' was established within DGIS. Three outside experts (a biotechnologist, molecular biologist and sociologist) were brought in. The team was to disburse funds and to implement the Special Programme. A Dutch advisory group -Advisory Committee Biotechnology (ACB)- was installed to consider the allocation of resources to different sectors as well as the development relevance of the Programme. On the basis of advisory papers of the Netherlands' Organisation for Technology Assessment (NOTA; Bunders & Broerse, 1992) and the National Council for Scientific Research for Development (RAWOO, 1991), both discussed in Parliament, a checklist for project appraisal was developed (DST/SO-Biotech, 1994). The list of criteria used by the Special Programme to assess project proposals is provided in Box 1.

Box 1. Criteria for the Priority Assessment of Project Proposals

Relevance of research and technology development

- The proposal states the important issues (technological, social, economic or political) to be addressed in the project.
- The proposal indicates how the beneficiaries have been assessed. It includes a gender specific analysis of the socio-economic conditions of the target group.
- The proposal indicates how the beneficiaries have been and will be involved in formulation, implementation and evaluation and how access to and control over the projects products will be secured.
- The proposal includes an assessment of the expected impact of the project on the position of women and an assessment of the participation of women in the project.
- The proposal includes an assessment of the expected impact of the project on the environment and its contribution to sustainable development.
- The proposed project contributes to building local capacity and describes mechanisms for transferring knowledge.
- The proposal describes -if applicable- how intellectual property issues are dealt with.
- The proposal describes the risks associated with the research and its results. Biosafety issues are specifically being addressed.
- The proposal indicates how the project contributes to the country's biotechnology and development policy.

- The proposal indicates the institutional and physical infrastructure and the mechanisms required for dissemination of research results and adoption of new technologies by the target group.
- The proposed activity has the support of researchers, policy makers, beneficiaries and other stakeholders.

Scientific aspects
- The research problem, goals and objectives are clearly stated in the proposal.
- The biotechnological approach has a comparative advantage over conventional approaches.
- The proposed methodology is sound and takes into consideration the current state-of-the-art.
- The proposal indicates the scientific qualifications of the individuals and organisations involved. Opportunities for national and international co-operation have been evaluated.

Operational and management aspects
- The proposal describes how the research project or programme will be managed.
- The proposal describes how the continuity of the project will be ensured. It includes a realistic time schedule for project implementation.
- The proposal indicates how progress will be monitored and evaluated.
- The proposal clearly lists resource requirements for effective project implementation (funds, scientific and support staff, buildings and equipment) and potential follow-up activities.

Source: DST/SO-Biotech, 1994 (pp.14-15)

The IBU approach was used as a guiding methodology in the programme. The activities of the programme were to be identified through a participatory process, starting with a local need assessment and agenda setting in which end users, researchers, policy makers and non-governmental organisations (NGOs) would participate. Four countries, Zimbabwe, Kenya, Colombia and India, were selected on the basis of their interest shown in establishing a biotechnology policy, the existence of local research capacity, the co-operative relationship with DGIS, and the regional role of the country (DST/SO-Biotech, 1994).

In each country a four-phase process was initiated. During the first phase, an inventory mission took place and discussions were held with representatives of relevant ministries, universities, local research institutes, extension services, international institutes, farmers' and women's organisations and NGOs in each country. In the second phase, a local partner organisation was identified. The local partner initiated a consultation process with small-scale producers, researchers and policy makers, and executed several inventory studies (agronomic, socio-economic, marketing, etc.). This phase resulted in a selection of research topics and areas for intervention. In the third phase, a national workshop with representatives of different groups was organised to review and finalise agenda setting. A Steering Committee -consisting of about 10 members drawn from the policy, research, farming and NGO communities- was established in each country. The task of the Steering Committee was to enhance integration of biotechnology in national research institutes and to monitor and advise on the relevance of project activities executed within the framework of the Special Programme. To perform these tasks adequately, the programme allocated funds to set up a small secretariat. During the fourth phase a workplan was drafted and discussed with end users at local workshops (DST/SO-Biotech, 1994). Subsequently, project proposals were formulated, appraised and executed on research topics in line with the outcome of the different workshops.

Although the way the Special Programme implemented the IBU approach may, at first glance, seem quite successful, the findings of a review study, which took place during 1996, are rather sobering. The members of the Review Team -selected for their perceived ability to assess the impact of scientific activities from a development perspective oriented to poverty alleviation and participation- concluded in their report that (Röling et al., 1996: 19,21):

> "...the specific way the SP [special programme] has been implemented represents in fact a modification of a conventional ... control-oriented approach to research and development projects, rather than the more radical ... interactive, participatory approach that the policy objectives had required. ... In a review of many of the research projects coming out of the biotechnology model, we found little evidence that research would be playing an interactive role with clients or other actors during the process of conducting 'their' research projects. ... The SP has simply added a phase of priority setting on the basis of needs assessment with farmers to [conventional] procedures."

Nevertheless the Review Team also found many strong points, such as the creation of multi-stakeholder Steering Committees, the dedication and enthusiasm of most members of the committees, the contribution of the programme to the capacity building of biotechnology research, the selection of 'target areas' which made the identified priorities locality-specific, and the contribution of the programme to greater respect for farmer knowledge and concern for biosafety issues in the programme countries (Röling et al., 1996). For the purpose of this chapter, we will however focus in more detail on the observed difficulties in the implementation of the IBU approach.

First of all, the members of the special team (particularly the ones present at the start of the programme) felt highly uncomfortable with interactive and participatory methodologies. The team members had been selected on the basis of their agricultural, biotechnological or social sciences background, not on the basis of their prior experience and affinity with these methodologies. They found it difficult to understand the principles of the approach, and were totally in the dark as to how to facilitate its implementation. The decision of the Minister for Development Co-operation to make the IBU approach the philosophy of the programme was seen by the team members as a top-down decision forced upon them.

The lack of background of the team members in interactive and participatory methodologies did not lead to the provision of additional training. Learning was completely left to the personal initiative of the team members. As it turned out, this hardly happened (Röling et al., 1996). The team members were not well acquainted with the literature concerning interactive research and processes, and did not seek contact with practitioners of participatory and interactive methodologies. If they had done this, it would have enabled the programme to build on new insights in the field. The advice of the IBU expert in the Advisory Committee Biotechnology (ACB) was also rarely sought. When advice was given, it was usually received with resentment. As a consequence, the IBU expert resigned from the ACB in 1994. Bereft of its IBU expertise, the ACB could hardly redirect the Special Programme towards a more integral design approach (Röling et al., 1996).

The self-imposed isolation of the Special Programme from the expertise with integral design approaches led the team members to develop their own so-called 'Biotech model' (Röling et al., 1996). This model was based on their interpretation of the IBU approach. This resulted in a more positivist version of the approach; the phases and activities of the IBU approach were adopted while excluding several of the principles.

The restricted view regarding interactive and participatory methodologies was especially observed at the level of the country programmes. The Dutch team members initiated a kind of standardisation process across the programme countries. This did not enhance the creation of a learning environment, but rather led people in country programmes to take "an attitude of waiting for the next set of instructions that they will be expected to follow" (Röling et al., 1996: 21). Through the programme, training courses were provided in the four countries. However, these courses only focused on technical training in biotechnology; none of the courses provided training in interactive and participatory methodologies. The Review Team stated that needs assessment was the only interactive achievement of the Special Programme, but that this was done only once in the process by special consultants and/or NGOs. Once a biotechnology R&D agenda had been set at the end of a public debate, this agenda was seen as a final statement for at least the next five years. As a result, the approach lost its iterative and flexible nature.

In addition, the Biotech model did not include the establishment of a coalition of committed people. Coalition building is an essential element of the IBU approach. It ensures that sufficient and appropriate support will be available to maintain the momentum of the innovation process and guarantee its implementation. Coalition building activities result in the establishment of a support group. In the Biotech model, the informal character of the support group was replaced by a funded, formal Steering Committee. A steering committee is a common donor strategy to improve project and programme management in a developing country. The members of the Committee were selected on the basis of being a representative of a specific group of actors, their knowledgeability and prestige, not on the basis of their commitment to a shared vision and trusting relationships. The Special Programme allocated considerable decision-making power to the Steering Committee regarding the approval of project proposals. The Committee thus became an institution with considerable power, and consequently the issues of power relations and conflict were brought in. Due to this very formal character of the Steering Committee, its members are unlikely to be able to properly fulfil some of the 'tasks' of the support group, such as the provision of access to sensitive information and tacit knowledge. Access to such information is necessary in order to be able to understand how the social system works and how much room for manoeuvring is available -in other words to provide the groundwork for a change process.

Finally, the structure established in the programme countries and the embedding of the Programme within DGIS were not sufficiently conducive to the implementation of an IBU approach. The programme was not commissioned to an external organisation to ensure linkages with aid administrators and diplomats in the Dutch government, both in The Hague and in the South. Although the programme was kept within DGIS, the Special Programme was given a special status in order to improve the flexibility of the programme; the normal approval and fund disbursement procedures were considered too rigid. However, the special status aroused considerable jealousy and rivalry between departments and individuals, which resulted in slowing down activities whenever the programme was dependent on others within the Ministry. In addition, the uniform structure established in the programme countries without linkages to local institutions increased the dependency of the Steering Committees on the donor (Röling et al., 1996). The Committees had no official representation and recognition and totally depended on donor funding in order to execute their activities. This set up considerably reduced the sustainability of the entire undertaking.

Disappointed with the direction the Special Programme took, the Minister felt obliged to intervene a few times in ACB meetings (in 1993 and 1994). However, he was not able to enforce the required internal and external change. In February 1997, he decided -based on the findings of the Review Team- that the Special Programme was not to be extended, and that the programme's activities were to be integrated within the regular activities of the research and technology department of DGIS. The special team was dissolved; only two of its members -who had the most experience and affinity with interactive and participatory methodologies- were transferred to the research and technology department. The implementation of an integral design approach to the biotechnology development process remained the official focus of the activities.

Based on the findings of the Review Team, changes have taken place in the programme countries. However, we have no clear insight in the current achievements in the different countries. Whether the changes have resulted in the successful implementation of an interactive and participatory approach throughout the innovation process would require additional research.

4. Lessons learned

It can be concluded that -despite the good intentions, dedication and enthusiasm of many people- the implementation of an integral design approach by the Special Programme of DGIS was not very successful. Implementing such an approach to innovation is clearly not an easy and straightforward process. We would like to highlight some lessons in three areas: methodology, institutional setting, and training and learning.

The case shows that it is difficult to apply interactive and participatory methods throughout the entire innovation process. Interaction with many actors (including farmers) was mainly restricted to needs assessment and agenda setting. When specific biotechnology R&D projects were designed and implemented, it was mainly scientists who were involved and made the decisions. It was implicitly assumed that once priorities have been set after an interactive process involving many relevant actors, different organisations such as NGOs, research institutes and universities can easily follow up on the ideas and the approach -lack of interest of researchers or lack of funds being the only constraints. This assumption has proven to underestimate the difficulties scientists face in implementing farmer participatory methods. Inter-disciplinary research and the co-operation between scientists and non-scientists are difficult. This is not surprising. The skills which scientists acquire at universities are often not directed at effective inter-disciplinary and intercultural collaborative research and interaction. Particularly researchers in formal institutions are used to the application of more conventional approaches to R&D. When they follow up on the research ideas identified through an integral design approach, the activities easily loose their interactive and inter-disciplinary nature -particularly since higher level support for application of such an approach is often lacking. Needs assessment and agenda setting then become an additional activity prior to conventional technology development. There is, therefore, a need to pay explicit attention to the active involvement of actors (particularly the end users) during the design and implementation of specific R&D projects.

The case also shows that the institutional embedding of the programme and the approach was not sufficiently effective. The embedding was particularly poor in the developing countries. The Steering Committees were the main initiators, supervisors and co-ordinators of the activities in the countries. Their members, however, did not receive training in integral design approaches or interactive and participatory methods, and the committees were not linked to any local institution. In addition, the needs assessment and agenda setting activities were not executed by a specifically trained inter-disciplinary team, located at some institution to guarantee sustainability, but its members were temporarily contracted consultants. Such an organisational set up does not enhance a sustainable implementation of an integral design approach. To achieve sustainable implementation of such approaches specific attention should be paid to an appropriate institutional embedding. What is appropriate may differ in each context. It may be advisable to establish a 'permanent' inter-disciplinary team within a local NGO, a university or a research institute, depending on whether the top management of the organisation is willing to commit itself to an integral design approach to innovation. We are not in favour of a powerful steering committee. However, a less formal committee consisting of representatives of many relevant actor groups will be extremely helpful, provided its members are selected on the basis of commitment, shared vision and trusting relationships. This will enable the committee to function as a support group, which can provide appropriate feedback and advice to the inter-disciplinary team.

It is equally important to provide appropriate training and to create a learning environment. Since integral design approaches to innovation are relatively new, most people have no prior experience with these approaches. On the contrary, most scientists have only been trained in the positivist research paradigm while application of the IBU approach requires that team members are also able to conduct research within the constructivist or hermeneutic. Most of the members of the special team as well as the people involved within the programme countries had difficulty in understanding the IBU approach. The members of the special team had not been able to acquaint themselves with the IBU approach as described in the NOTA advisory paper (Bunders & Broerse, 1992). The written information was obviously not sufficient to generate vicarious learning (also because it was not intended as a training manual). In addition to training in the basic principles and phases of the approach, it is important to develop a learning environment. A learning environment focuses on problem solving and is interactive and field based. Error and failure are seen as a learning process. In such an environment, participatory behaviour and attitudes -such as openness, willingness to listen and learn and power sharing- are encouraged. Absence of a learning environment leads to a static situation; the approach as initially applied becomes a blueprint. The case clearly shows that the IBU approach is too complex to be understood and applied without extensive interactive training and subsequent learning.

5. Generalising the findings

The experiences and lessons of the DGIS case concern a programme on biotechnology and small-scale farmers in developing countries in which a specific type of integral design approach to innovation is applied -the Interactive Bottom-Up approach- by a governmental donor organisation. Integral design approaches are also used in programmes on e.g. natural resource management or land use planning in the Netherlands, of other organisations such as NGOs and the private sector. Can we expect the same problems, as described in the case study, to arise in these programmes?

In answering this question, it is important to recognise that although there are currently different types of integral design approaches to innovation -such as participatory technology development (PTD; e.g. Haverkort et al., 1991; Reijntjes et al., 1992), rapid appraisal of agricultural knowledge systems (RAAKS; e.g. Engel, 1997) participatory learning and action (PLA; e.g. Pretty et al., 1995) and constructive technology assessment (CTA; e.g. Schot & Rip, 1997)- these approaches have several basic aspects in common. All integral design approaches take into account the multi-functionality and multi-dimensionality of (rural) areas, are inter-disciplinary, and are interactive with regards to relevant actors in society (see Van Woerkum, chapter 2). Integral design approaches consist of roughly three elements: (a) the definition of the problem(s) and its causes, (b) the possible technological options, and (c) the analysis of the way to move from the current societal situation towards one in which the problem is effectively dealt with (see Van

Woerkum, chapter 2). These approaches enhance learning processes between the various actors involved in the innovation trajectory. To this end, reflexivity of the actors is considered crucial in order to avoid falling back into old positions and preconceived opinions, and to recognise the different roles of actors in the innovation process. Furthermore, relatively new codes of conduct usually are established, since there are very few appropriate routines and procedures to fall back on. In addition, the outcome of the process (what the innovation will look like) can usually not be predicted beforehand, which adds to the uncertainty, which characterises many aspects of these approaches. Integral design approaches are, further, characterised by a high degree of knowledge integration. Knowledge regarding more objective phenomena[9] needs to be integrated with knowledge regarding more subjective notions[10]. As mentioned in the second section of this chapter, this requires the integration of the two main research frameworks or paradigms: the positivist and the constructivist/hermeneutic.

The wide variety of actors that need to participate actively, the learning processes and reflexivity that need to be induced, the new codes of conduct that need to be established, and the high degree of outcome uncertainty and knowledge integration make the implementation of all integral design approaches currently far from easy and straightforward. A high demand is put on the people applying these approaches as well as on the organisations adopting them. Particularly the unfamiliarity with these approaches combined with the rather mono-disciplinary training of many people currently complicate their use.

Therefore, the implementation of integral design approaches in general is highly likely to run into similar problems as were experienced in the DGIS case. Should we then discard these approaches as being unpractical? This would, in our opinion, be a case of throwing out the baby with the bathing water. There are clear situations in which the use of an integral design approach to innovation is the most effective way to 'solve' a certain 'problem' (Broerse, 1998; Brouwer & Tompot, 1995; Dusseldorp & Box, 1990; Scoones & Thompson, 1993). This refers to a problem context in which:

- various actors with different interests have a stake in the way the problem is solved;
- a solution (in the form of an innovation) of the problem at hand is considered feasible by relevant actors and has not yet materialised, while several design options are possible and consensus is feasible;
- much tacit knowledge is available which is relevant and necessary for successful innovation development;
- the problem at hand is not highly acute; and

[9] Such as knowledge on production systems and current research and innovations, living conditions, techno-economic situation, physical infrastructure, type and structure of organisations, policies, rules and regulations.

[10] Such as knowledge on cultural meanings, norms and ethics, and codes of conduct, as well as personal ideas, beliefs, interests, hopes and fears.

- a 'sufficient' number of actors are willing to co-operate and support the endeavour.

Application of integral design approaches is only problematic if one underestimates their novelty For example, implementing these approaches with a conventional frame of mind is bound to lead to failure.

Another conclusion, which some readers may be inclined to draw from the case study, is that DGIS, a bureaucratic and public organisation, is not suitable for implementing an integral design approach to innovation. Much literature on institutionalisation of integral design approaches to innovation points out that bureaucratic organisations -characterised by hierarchical authority (pyramid shape), top-down management, specialised disciplinary departments, standardised procedures, and rather uniform outputs- provide the least appropriate setting (Blackburn & Holland, 1998; Leurs, 1996; Pretty & Chambers, 1994).

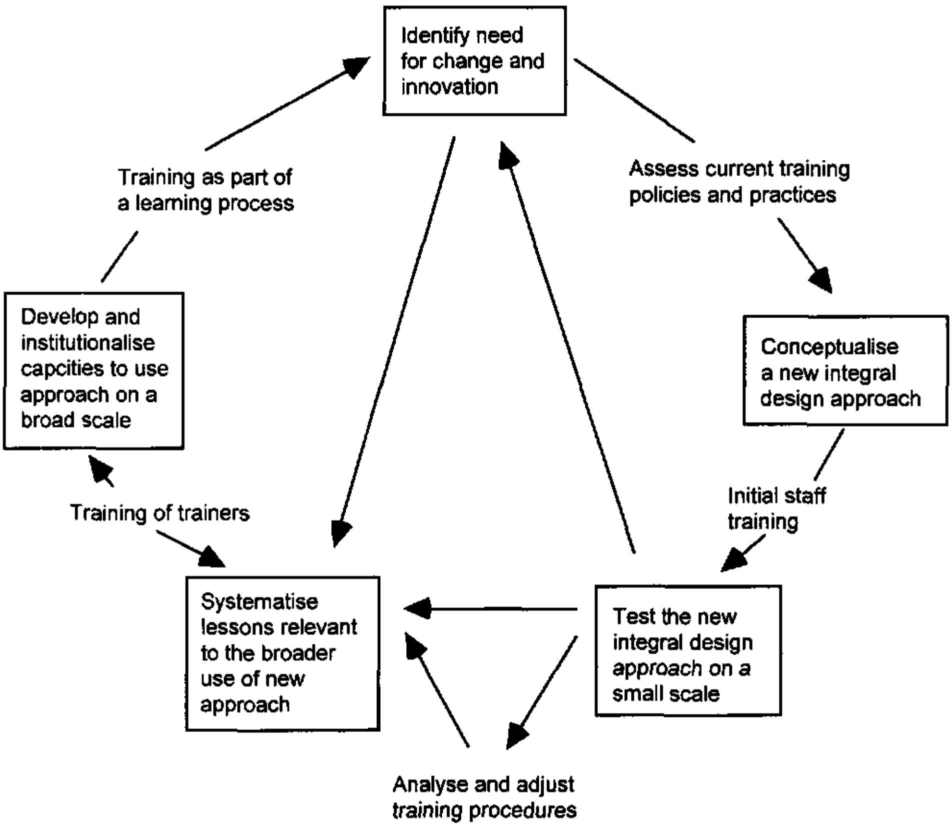

Figure 1. Institutional learning process and training cycle (Thompson, 1995).

In contrast, organisations which are characterised by decentralised authority (flat and horizontal shape), bottom-up management, open and flexible teams and heterogeneous outputs responding to demand-pull from clients- would be most appropriate (Farrington & Bebbington, 1994; Pretty & Chambers, 1994). Indeed, most 'success stories' about institutionalisation of integral design approaches concern small and flexible NGOs (Blackburn & Holland, 1998; Kaimowitz, 1993).

However, we feel this is a misconception. There are several examples which show that, although it may be less easy and quick for centralised, bureaucratic organisations to implement integral design approaches, it is very well possible provided certain requirements are met (Hagmann et al., 1998; Paul, 1998; Pretty & Chambers, 1994; Shepherd, 1995; Thompson, 1995). A first requirement is that top management commits itself to the use of an integral design approach to innovation. Secondly, a specific structure will have to be established (e.g. a small inter-disciplinary team or working group of innovative and committed staff) which allows for flexibility and a learning environment. Thirdly, careful attention should be paid to the selection of the people who will apply the approach and these people should receive thorough training. In addition, top management should provide resources and support (amongst others through establishment of an appropriate reward system) on a long-term basis. And appropriate links should be established with other organisations and individuals. Last but not least, the experiences and lessons need to be documented thoroughly for improving practice and building an institutional memory. The institutionalisation process within these organisations should be gradual and iterative, based on reflexivity and further experimentation and innovation. Eventually a learning cycle evolves (Figure 1). The pitfalls come from demanding too much, in a top-down mode, too fast, without a good understanding of integral design approaches and their implications.

Although small and flexible organisations may face less constraints for the initial adoption process of integral design approaches to innovation, more top-down managed organisations have a comparative advantage in scaling up the process and in large-scale dissemination of outputs. Institutionalisation in more bureaucratic organisations is, therefore, not only possible but also very rewarding. We have seen this in our own work in Bangladesh (Bunders et al., 1999). But there are many more examples of successful institutionalisation of these approaches in public institutions in developing countries (Blackburn & Holland, 1998; Korten & Siy, 1988; Pretty & Chambers, 1994; Thompson, 1994) and in Japanese companies (Nonaka & Takeuchi, 1995).

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Chapter 16

Epilogue: Accommodating dynamics and diversity in integral design

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In the introductory chapter to this volume, a number of practical and conceptual issues were raised in relation to the notion of integral -i.e. multi-functional, inter-disciplinary and interactive- design. At this point, it is pertinent to revisit these on the basis of the experiences and contributions presented (section 1), and draw some overall conclusions with respect to the facilitation of integral design (section 2).

1. Unresolved issues revisited

In returning to the questions raised in chapter 1, we have brought together some closely related 'unresolved issues' under joint headers. However, the order in which the different issues are discussed remains largely the same as in chapter 1.

Looking at 'design' as a learning and negotiation process

Serious questions were raised in chapter 1 with respect to the appropriateness of the term 'design' in 'integral design'. Why maintain a term that has so many connotations of control if it is evident that relatively few socio-technical practices in agriculture and resource management are a direct reflection of a deliberately designed package? Explicitly or implicitly, most authors in this book emphasise that -when talking about 'design'- we must think primarily about *activities* and *processes* rather than about '*products*'. The verb is more significant than the noun. Thereby, the dominant processes seem to be joint experiential learning (Röling, Vereijken, Leeuwis, Van Schoubroeck & Leeuwis, De Jager et al., Biewinga, Broerse & Bunders, chapters 6, 7, 8, 9, 10, 11 and 15 respectively) and negotiation (Aarts & Van Woerkum, Leeuwis, Van Meegeren & Leeuwis, Bouma, chapters 4, 8, 12 and 13 respectively). The idea is that no meaningful change or innovation in 'hard' and 'soft' systems can be brought about without some degree of effective co-ordination between inter-dependent social actors. In one way or another, such co-ordination requires a degree of shared understanding (on the basis of joint learning) and negotiated agreement in relation to tensions that are bound to emerge whenever significant changes are proposed to the status quo. Hereby, learning is required not only on technical, ecological, economic and/or social-organisational processes, but must also extend into the perspectives, interests, values and concerns of the different stakeholders, and include critical self-reflection within stakeholder groups (Van Woerkum, chapter 2; Broerse & Bunders, chapter 15). In other words: learning must include 'social learning'.

Typically, joint experiential learning and negotiation are emergent and -in a way- never ending processes, that are characterised by (a) unexpected dynamics, and (b) outcomes which are inherently unpredictable, temporary and diverse[1]. The complex interactions between adapted (social and technical) practices, context, cognitions and stakeholders result an ongoing chain of intermediate and temporary action patterns (see e.g. Vereijken, chapter 7; Van Schoubroeck & Leeuwis, chapter 9). Remmers (1999) speaks of (a network of) 'performances': a state in which the design process temporarily crystallises, and which is always 'hybrid' by nature. Effective design, then, means that multiple actors craft new and relatively stable 'joint performances' (or 'social cognitions', see Van Schoubroeck & Leeuwis, chapter 9) in and between the technical and the social domain. Such joint performances, then, can be conceived of as new 'modes of ordering' (Law, 1994) between and within 'hard' and 'soft' systems. If we (re)conceptualise 'design' in this manner, it may indeed be legitimate to maintain the term. Admittedly, pragmatic considerations play a role here. Many scholars and practitioners identify with the term 'design', and engage in active attempts to 're-order' hard and soft systems. In communicative terms it is probably easier and more effective to redefine the notion than it is to replace it altogether by a new term (e.g. 'integral re-ordering') that is equally non-self-explanatory.

'Designing' the design process

It was already established in chapter 1 that 'design' is a multi-layered concept. Effective design processes result in relevant problem definitions, new biotic and a-biotic artefacts, and novel social arrangements. Each of these layers requires 'design': i.e. learning and negotiation. During design processes, these different dimensions must be carefully interwoven in order to become -gradually- a coherent and viable innovation or 'joint performance'. In other words: they must be subject to effective 'alignment' (Rip, 1995). The outcomes of such a multi-dimensional process of social interaction cannot be reliably predicted or pre-specified in detail, so that the central question becomes how -through what 'procedures'- to maximise the chance that meaningful outcomes emerge. In other words: how to organise ('design') the design (learning and negotiation) process?

In general terms, we would argue that there is a need to 'optimise' both joint learning (including 'reconnaissance', see Hidding, chapter 3) and negotiation. Hereby, the hypothesis is that the two processes pre-suppose each other: effective social learning is unlikely to happen if it is not embedded in a well-'managed' negotiation process, while

[1] Thus, learning and negotiation are quite incompatible with models of rational planning and decision-making that tend to underlie conventional design approaches (Long & Van der Ploeg, 1989; Leeuwis, 1995).

effective negotiation is impossible without a properly facilitated learning process. Given the great diversity in socio-technical problem contexts and the capricious nature of social interaction, no rigid following of methodological recipes and packages is likely to be helpful in relation to the facilitation of either learning or negotiation (Leeuwis, chapter 1). Nevertheless, several contributions in this book suggest that it is important to be aware of certain tasks, principles and guidelines at process level (Aarts & Van Woerkum, Van Meegeren & Leeuwis, Broerse & Bunders, chapters 4, 12 and 15 respectively). Thus, it is suggested that design processes require continuous monitoring of the dynamics and progress within the learning and negotiation processes, so that sensible decisions can be made about its further continuation (Aarts & Van Woerkum, Vereijken, Van Schoubroeck & Leeuwis, chapters 5, 7 and 9 respectively). Especially in potentially conflictive contexts, this need justifies the presence of a skilled and respected facilitator whose task is primarily to guide and monitor the process (Koppenjan & Joldersma, 1997; Van Meegeren & Leeuwis, chapter 12). For a timely recognition of the constraints and opportunities created by unanticipated developments outside the immediate environment of the stakeholders, provisions for monitoring the 'external' environment are important as well. In addition, various authors emphasise the need to have access to transparent tools for learning within integral design processes, ranging from simple measurement tools for e.g. soil fertility or pest infestation (De Jager et al., chapter 10; Van Schoubroeck & Leeuwis, chapter 9), to complex 'hard' and 'soft' simulation models (Rossing et al., chapter 5; Röling, chapter 6). Moreover, the participatory methodologies mentioned in chapter 1 too may provide useful tools (e.g. visual communication aids) for joint learning especially, as they tend to fall short if it comes to the facilitation of negotiation and conflict resolution (see Leeuwis, 2000 for a more elaborate discussion).

It is with the help of such monitoring, principles, guidelines and tools that design processes can be flexibly shaped and moulded (not controlled!) towards the development of well-aligned problem definitions, artefacts and social arrangements. In doing so, all sorts of more 'traditional' engineering skills and forms of expertise may need to be mobilised in order to contribute to the development of artefacts and social arrangements (see below).

The need for modesty and conducive conditions in science

It is clear that integral design requires new modes of operation, not only from the side of scientists (Van Woerkum, chapter 2), but also from the side of societal stakeholders and (non-) governmental institutions (Hidding, chapter 3). Focussing on the role of scientists, it can be observed that many of the cases reported upon mark a considerable breakaway from conventional practice in agrarian science. These discontinuities include, for example, intensive co-operation between strategic research and stakeholders at local level (Vereijken, chapter 7; Biewinga, chapter 11), holistic rather that reductionist forms of on-farm experimentation (Vereijken, De Jager et al., Biewinga, chapters 7, 10 and 11 respectively), the increased involvement of research staff in 'extension' activities along with decreasing importance and/or a re-orientation of laboratory research (Van Schoubroeck & Leeuwis, De Jager et al., Biewinga, chapters 9, 10 and 11 respectively; Leeuwis et al., 1998), and innovative ways of managing inter-disciplinary 'research chains' (Bouma, chapter 13). Others propose additional changes, such as a further hand-over of 'ownership' from science to stakeholders, and a more effective utilisation of social science expertise in design processes (Röling, chapter 6; Leeuwis, chapter 8).

Engaging in integral design processes, however, does not imply a devaluation of scientific endeavour (see e.g. Bouma, chapter 13). It may require changes in the type of research questions asked, their origin, and/or the objects of research, and thus it poses new conceptual, methodological and epistemological challenges. In our view, agrarian scientists must not go out of the way of such challenges, and should be willing to adapt their role perception and views on what is 'science' and what is not. Some authors in this book have successfully contributed to such a re-conceptualisation in theory *and* practice (e.g. Vereijken, chapter 7). At the same time, more traditional forms of scientific investigation can be very helpful during certain episodes in the integral design process (see e.g. Van Schoubroeck & Leeuwis, chapter 9).

A key conclusion to be drawn here, however, is that 'integral design' is not primarily about 'doing research'. For many 'doing research' bears as a connotation that 'facts' found in the past can be 'plugged' into the future without much difficulty, as if they would have an undisputed meaning. The point is precisely that science is rather strong at *analysing* what happened in the past, but weak in composing, or *synthesising*, the future (Remmers, 1998:321ff). Even if science is carried out with a focus on portraying people's strategies, patterns and historical trends (as is e.g. the case with farming styles analysis; e.g. Van der Ploeg, 1990), there is no guarantee that these can be projected into the future. They can only be inserted in a learning and negotiation process from which a new synthesis may emerge. The following image captures the differences between analysis and synthesis:

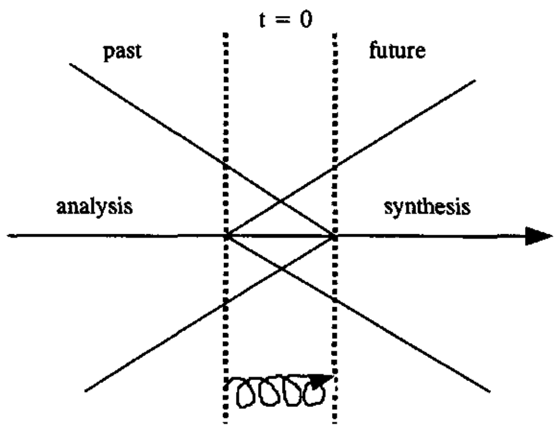

Figure 1. Analysis and synthesis in time perspective (derived from Remmers, 1998:323)

Design is essentially *synthesis*, research is essentially *analysis*, but doing research and gathering data can include interactions between researchers and stakeholders that imply learning moments for both. Thus, scientific insight and investigation can play an important role in joint learning processes and joint fact-finding within a context of negotiation (Van Meegeren & Leeuwis, chapter 12). But integral design is not likely to be a success if it is a scientist owned and/or initiated process (Leeuwis, chapter 8; Broerse & Bunders, chapter 15). In a learning and negotiation process, knowledge generated in various locations (e.g. research stations and farmers' fields), by different stakeholders (e.g. researchers and farmers), for dissimilar purposes (e.g. assessing the 'truth' and promoting stakeholder interests) and through different procedures of validation (e.g. scientific method and farmer experience) must be creatively articulated and integrated.

It must be noted that the indicated changes in the way scientists operate are still rather marginal in quantitative terms. In fact, several authors have expressed the concern that academic reward structures and current trends in the management and financing of research and extension may not favour scientists' participation in integral design processes (Van Schoubroeck & Leeuwis, Bouma, Leeuwis, Broerse & Bunders, chapters 9, 13, 14 and 15). There seems to be a serious need to empirically evaluate the consequences of market-oriented knowledge policies, new institutional arrangements for knowledge exchange and co-operation, and changing procedures for agenda-setting and budget-allocation in research.

'Traditional' science, architectural innovations and integral design

Some authors seem concerned that an integral design approach may be incompatible with developing visionary innovations and a radical break-away from existing practice, even if the circumstances may call for this (Vereijken, personal comment). Involvement of stakeholders in research would reduce the bandwidth in which alternatives are sought, and lead to risk-avoiding solutions. In conceptual terms: it is feared that interactive approaches lead to 'regular innovations' within the rule set provided by the dominant 'technological regime' (Kemp et al., 1999), and not to 'architectural innovations' (Abernathy & Clark, 1985) that require a fundamental re-organisation of existing relationships and rules. At the level of learning, then, it is implied that an interactive approach fosters 'single loop learning' (i.e. learning without challenging the underlying assumptions) rather than 'double loop learning' (Argyris & Schön, 1996). In view of such concerns, it is proposed that scientists may need to remain 'in charge' of design processes. In relation to this debate, it is important to recall that research can play three basic roles during learning and negotiation processes:

(a) Research can play a role in *joint fact-finding* geared towards answering shared questions. The purpose of this type of –natural and/or social science- research is not only to provide answers, but also to build confidence, trust and shared perspectives among stakeholders by working together on an issue in the first place (Van Meegeren & Leeuwis, chapter 12). Depending on the questions addressed such research may involve on-farm research, laboratory research by scientists, computer simulations etc., as long as it remains part of a commonly agreed upon -and preferably iterative (see Vereijken, chapter 7)- procedure. In the context of such research, scientists also need 'free space' to follow their own intuitions (see Van Schoubroeck & Leeuwis, chapter 9).

(b) Results from research can serve as -more less confrontational- *feedback* in order to induce learning, i.e. through the creation of new problem definitions. Such *feedback* from natural and/or social scientists may be provided by research data on the existing situation, but may also arise from comparison with totally different situations (including laboratories) or computer-based projections about the future (Rossing et al., chapter 4; Röling, chapter 5). This can also include comparison with radically new technological and organisational solutions.

(c) Research can play a role in *monitoring the social dynamics* of the learning and negotiation process itself, in order to inform its organisation and further facilitation. How are relations between stakeholders developing? Which new developments, questions, wishes and problems emerge? How do these affect progress, and what can be done about it?

From the above it is clear that visionary and revolutionary solutions can play a legitimate role in learning processes towards viable innovations. It would, however, be a mistake to conclude that interaction with stakeholders would be less useful for the development of such visionary horizons and architectural innovations. In order to induce a learning process radically different solutions must somehow be appealing and speak to the imagination. Thinking along totally new lines (e.g. for the development of a radically new system for pig farming in the Netherlands) a number of options will emerge, and numerous decisions will have to be taken in order to operationalise the ideas. For arriving at a credible package that speaks to the imagination, it is important to involve stakeholders in this creative process. This is not to say that one should bring in all the diverging interests; rather it is important to involve (a coalition of inter-dependent) actors who show an interest and are willing and able to think along particular lines. Moreover, the development of a credible revolutionary package too requires iteration between 'thinking' and 'doing' (i.e. experiential learning) in order to stimulate the design process. This iterative application and adaptation of radically new solutions requires -at least temporarily- a *safe space for experimentation*; i.e. what Kemp et al. (1999) label a 'protected space'. Almost by definition, the risks involved are high, and these must be neutralised. Without proper safeguards stakeholders will indeed be more inclined to experiment only with less radical alternatives within the boundaries of the existing technological regime. From Rossing et al. (chapter 5) it has become clear that forms of virtual experimentation can in some cases play a role in reducing and/or postponing risks. In many cases, other forms of protection will be necessary as well until the innovation is mature enough to do without, or until it is clear that it will never become viable (Kemp et al., 1999).

In all, we can conclude that there is no inherent tension between radical thinking and an interactive approach, as long as (a) a safe space for experimentation is provided, and (b) sufficient attention is paid to the selection of an appropriate coalition of stakeholders (see Van Meegeren & Leeuwis, chapter 12). To put it more strongly: an architectural innovation still requires an interactive design process in order to become credible, appealing and thought-provoking. Finally, it is important to recall that -within the context of an integral design process- radically new concepts and solutions cannot serve productively as blueprints for the future, but should rather be treated as triggers for learning.

Supporting reframing and inter-cultural communication

It has been argued in chapter 1 and by Aarts & Van Woerkum (chapter 4) that integral design requires actors to gain in-depth insight in other actors' perspectives and discourses (Hidding, chapter 3), and a willingness to 'reframe' their own. Apart from skilled facilitation, such an inter-cultural process requires first and foremost that actors feel interdependent, see no other option than to work together (Aarts & van Woerkum, chapter 4), and are ready to see each other as a 'relevant context' (Remmers, 1999). If such interdependent feelings are absent and cannot be induced (e.g. with the help of a 'stick behind the door', by selecting only a sub-set of stakeholders, or by the creation of reward structures for collaboration), thorough inter-cultural communication is not likely to emerge. But even if a genuine willingness is available, numerous problems of language and communication remain.

While none of the chapters in this book specifically addresses the solving of inter-cultural problems among (networks of) stakeholders and/or within inter-disciplinary teams, some chapters provide partial solutions. Here, one may think of the general communication guidelines in a context of negotiation (Van Meegeren & Leeuwis, chapter 12). Apart from such 'process-oriented' solutions, Hidding (chapter 3) proposes to encourage the construction of 'planconcepts' as bridges between different networks and discourses. Furthermore, Rossing et al (chapter 5) have shown that computer modelling is a tool which allows natural scientists from different disciplines to work together, and integrate knowledge from various disciplines and at different aggregation levels in a common framework (see also Rossing et al., 1999). More in general 'systems thinking' has been promoted as a common language among scientists. However, the 'systems language' seems far less appealing to social scientists and stakeholders (Rossing et al., chapter 5). Nevertheless, there seems to be scope for a much more creative, reflexive, transparent and interactive use of computer models within integral design processes, as an imperfect but thought provoking discussion aid (Rossing et al., chapter 5; Röling, chapter 6). Having said that, computer models and systems languages are certainly not a miracle solution to inter-cultural communication problems in integral design processes; in fact they may well foster new communication barriers between for example scientists and local stakeholders. We must conclude that the issue of inter-cultural communication remains a blind spot which requires additional literature exploration and empirical research.

2. Concluding reflection

Within the learning and negotiation processes that constitute integral design, facilitators have a complex task, which can be summarised as 'dealing with dynamics and diversity'. Here 'dynamics' relates to at least five dimensions (adapted from Mastenbroek, 1997): (i) matters of content (i.e. learning on social and technical design issues); (ii) social relationships between different stakeholders; (iii) 'trading' between different stakeholders (striking deals); (iv) relationships between representatives and those represented; (v) the wider social and natural environment. Each dimension of change requires deliberate attention, active monitoring and possibly action and intervention, whereby the interrelations between these areas must be carefully considered.

Dealing with these dynamics also requires attention for various forms of diversity. Most importantly, the diversity in stakeholders' contexts, interests, perspectives, inter-dependencies and problem perceptions must be of continuous concern during learning and negotiation processes. In doing do, one must also anticipate a possibly unequal distribution of skills and resources across the stakeholders to articulate views, and make them count in a design process. Similarly, it seems pertinent to take account of relevant diversity *within* a particular category of stakeholders. That is: it is important to identify dimensions on which e.g. farmers differ to such an extent that they require differential solutions to similar problems (see e.g. Van der Ploeg, 1990; Leeuwis, 1993). Finally, there is of course the huge diversity in relevant academic and non-academic expertise at various levels of aggregation (see Bouma, chapter 13) that must somehow be accommodated in design processes. Here it is important to note that the search for diversity should not be conceived of as an extra burden on top of all the other activities one engages in. It simply requires a completely different outlook on problem solving. 'Taking into account diversity' is not something to be 'added on' to what is already there. It is the reverse: diversity of stakeholders is the premise and starting point for design. It provides richness, promising initiatives, and is a challenge. This then does not mean that the facilitation of integral design processes is easy. Indeed, it is a daunting task.

In relation to this, one of the issues that deserves further study and reflection is where to place the 'boundaries' of design processes in terms of diversity in stakeholders, spatial locations, time horizon, academic disciplines and issues involved (see Leeuwis, 1995). How multi-functional, inter-disciplinary and interactive need (or can) one be? When becomes what type of diversity redundant? How to deal with the tension between opening up design options (divergence), and working towards a solution (convergence)? Probably, such boundaries need to be shaped during the process, and be based on clearly experienced inter-dependencies as well as stakeholder initiatives (which often carry the seeds of eventual innovations). Surely, they should not be determined on the basis of artificial dogmas such as the idea that we should always be as holistic as possible, and/or should involve all the relevant stakeholders we can think of. Here it is perhaps indicative that none of the case studies reported upon in this volume are 'exhaustively' interactive, multi-functional and inter-disciplinary. Rather, they tend to focus mainly on either the interactive or the multi-functional dimension of integral design, and tend to be restricted to a fairly limited issue, region and/or set of interests. Apparently, there are practical limitations to integral design, which need to be further explored.

It may, in relation to the above, be a comforting thought that -provided that one succeeds in creating an open flexible environment for learning and negotiation- there is no need to do 'everything right' at once. In a learning environment, 'mistakes' are the seed -and in fact a pre-condition- for future 'success' (Senge, 1993; Garvin, 1993; Holling, 1985)[2]. For the moment, the possibility to create such open and flexible environments is probably the most serious bottleneck towards integral design. Obstacles exist not only in current knowledge policies and the organisation of science (Leeuwis, chapter 14), but also in the wider policy environment (Hidding, chapter 3; Broerse & Bunders, chapter 15). Government bureaucracies are perhaps too segmented in order to allow for an integral approach, while politicians are extremely hesitant to delegate responsibilities to stakeholder networks (Frissen, 1996). Moreover, policy makers are still indecisive towards the 'steering on eventual goals' (rather than 'steering by concrete means') that is needed to both anticipate diversity and provide learning and negotiation space in design processes (Aarts, 1998). This expresses that that diversity is more often regarded as problem ('we need simple, concrete and uniform rules and regulations') than as a resource. Finally, despite all the critiques (Long & Van der Ploeg, 1989; Crehan & Von Oppen, 1988; Leeuwis, 1995), prevailing management styles still adhere to the idea of discrete and rationally organised 'projects' with clearly defined material outputs and objectives as the most appropriate way to enhance change. This is hardly an environment in which the type of process-management needed for integral design can thrive. At the same time, it provides a good mirror for the progress we can make.

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[2] More in general, it can be argued that mistakes, lost opportunities, leftovers, marginalised actors, in other words, things we usually consider to be 'waste' (Grabher, 1994), can be a vital input and source of inspiration within integral design processes. Thus, they need to be actively explored and cared for.

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