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THE RATIONAL ORGANISATION OF DISSENT

Boundary concepts, boundary objects and boundary settings in the interdisciplinary study of natural resources management

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Contents

Keywords

interdisciplinarity, boundary work, natural resources management, transdisciplinarity

1. Introduction

"*Interdisciplinary studies* may be defined as a process of answering a question, solving a problem, or addressing a topic that is too broad or complex to be dealt with adequately by a single discipline or profession." (Klein and Newell, 1996:393)[1] This general definition of interdisciplinarity expresses the following practical reasoning:

1) science as we know it is organised in disciplines;
2) the knowledge domain that a discipline covers is limited;
3) however, some problems, questions and topics require the input of more than one discipline;
4) for this category of broad and complex problems, questions and topics we (therefore) need an interdisciplinary approach that is able to integrate the different types of disciplinary knowledge in some way or the other.

Many of our societal problems are such complex problems, having several components and dimensions influencing each other. Natural resources management (NRM) problems are a prime example.[2] NRM as a scientific object of enquiry is complex because it needs combined understanding of ecological (natural resources) and human (management) systems. Both of these two fields are inhabited by a series of scientific disciplines. NRM is also complex in a second manner. It is not just a field of academic enquiry, but also a highly contested domain of development intervention. In NRM situations a variety of interest groups pursues different kinds of objectives, which are contested, and sometimes aligned. Normative concepts like equity, productivity, sustainability and democracy play a prominent role in NRM policy debates, research and intervention. The stakes tend to be high in NRM. This makes NRM a complex issue in both in an intellectual and a practical sense.

An important property of much interdisciplinary research is that it often has a very practical starting point in solving or addressing real and complex societal problems.[3] It aims to mobilise different disciplinary knowledges to address the challenge of complexity, which, as suggested, is both an intellectual and a practical challenge. In contemporary interdisciplinary research the driver is often the urgency of the societal problem, that is societal and policy push to 'do something about it'. This is very clear, for instance, in the global support for interdisciplinary research to address the issue of climate change. Another example is the large amount of funding for interdisciplinary research that the European Commission makes available to enhance the implementation of its integrated water resources management policy.

A reflective question that might logically be asked at the start of a discussion on interdisciplinarity is why we have disciplines in the first place, particularly when the questions and problems that society has to answer and address are increasingly complex. This is not the place to venture into the history of academic science, its relation with societal problems, and its disciplinary organisation in any detail. The emergence of a seemingly ever-increasing number of disciplines is the product of the professionalization of scientific practice since about 1800.[4] There are major advantages to a division of labour and specialisation in science, as the advances made in the past two hundred years testify. At the start of a

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[1] I thank Anjali Bhat, Bettina Bock, Jos Mooij and Jan Sendzimir for their full reading of and constructive comments on the 2006 version of this text. I also greatly thank the 2004 to 2008 batches of participants of the yearly ZEF Interdisciplinary PhD course, for which earlier versions of this paper were the background text, for helping me to develop the framework presented below. Their confusion and feedback has been invaluable. Colleagues who lectured in the course and external guest lecturers contributed many insights. Remaining flaws and lack of clarity are obviously mine.

[2] It may be, and has been, argued that *any* form of comprehensive understanding of processes in which people are involved needs to simultaneously look at the material and social dimensions of such processes, and that the distinction between the two is largely artificial (Latour, 2002). Renewed interest in the sociology of the body is one of many examples of this (Malcrida and Low, 2008). Given that ZEF as a research centre strongly focuses on natural resources management, this wider discussion is not entered into in this paper.

[3] For a discussion of interdisciplinarity and complexity, see Klein (2004).

[4] Journals like, for instance, *History of Science, Social Studies of Science and Technology, Issues in Integrative Studies*, and journals focussing on the history of particular disciplines are sources for accounts of this development.

treatment of interdisciplinarity it is important to note that it is not particularly helpful to cast that treatment in a 'for or against' mode. This happens very regularly, however, and sometimes in quite dogmatic ways. On such way is to mobilise the advances made by disciplinary science as evidence of the superiority of disciplinary over interdisciplinary science. Many perceive arguments in support of interdisciplinary approaches as arguments against disciplinary approaches (and *vice versa*) – as if we are forced to make a choice between the two.

The disciplinarity/interdisciplinarity dichotomy is a false dichotomy for several reasons. The terms disciplinary and interdisciplinary are much less singular in meaning than a dichotomous scheme suggests. Problems in distinguishing the two are discussed below. Moreover, what counts as an (inter)discipline changes over time; science is much more complex than a dichotomous schema allows, and is ever reinventing itself. It may be argued, for instance, that in recent decades there is a general development towards 'problem-oriented' research, in the context of which disciplinary science is also increasingly practised – and perhaps becoming less disciplinary in the process.

Institutionally the dichotomy is also a false dichotomy. It is probably the case that the institutional space for interdisciplinary approaches is increasing somewhat (though many interdisciplinary scientists would argue that the increase of that space meets a lot of resistance, and moves at a snail's pace). Nevertheless, by far most science would still be labelled as 'disciplinary science' by most people. This is very likely to remain the case, because of the already mentioned advantages of specialisation, but also for reasons like the incentive structure in academia: most academic prestige is still linked to disciplinary, specialised achievement.

The disciplinarity-interdisciplinarity opposition is often, in this author's experience, a proxy for a different issue: that of paradigmatic differences in view of and approach to science in general.[5] Such paradigmatic differences have little to do with disciplines as such, that is, all fields and disciplines have 'paradigms'. However, in certain disciplinary fields particular paradigms are dominant (say, neo-positivism in many natural sciences and critical realism in many sociologies and anthropologies[6]). These paradigms involve different approaches to complexity, integration, reductionism, and other basic questions. Debates on the meaning and relevance of interdisciplinary knowledge can thus easily become battlefields with contesting disciplinary armies.

To overcome the false dichotomy between disciplinarity and interdisciplinarity, the basic question to ask in choosing a research approach is: what is the nature of the research object/problem and what is the purpose of the investigation? Object and purpose (should) define what approach is suitable to address a particular problem, not a preconceived notion of 'good science'. The answer to this question is not always obvious, and easy to agree on. Sometimes it is even impossible to agree on it. However, at least it directs attention away from the idiosyncracies of researchers to the nature of the issue and the reasons to research it. The latter are the prime concerns of a 'problem oriented' science like that of natural resources management studies.

This paper mainly discusses interdisciplinarity in natural resources management studies as an academic pursuit: how to do interdisciplinary research on NRM? It gives an introduction to the literature on interdisciplinarity, with a focus on natural resources management studies.[7] However, in the course of the exposé it will become clear that the context in which such research is done, the standpoint from which it is approached, and the objectives it pursues, are relevant to its design. There is a politics to interdisciplinary research, as there is to any research.[8]

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[5] The classical text on the existence of different 'paradigms' in science and their succession is Kuhn (1962). More discussion can be found below when presenting Burawoy's 'division of labour' table in section 2.2.

[6] See Sayer (1984) for detailed discussion of this philosophy of science problematic.

[7] The author's own expertise lies in the field of irrigation/water resources management, and therefore many examples are drawn from that context.

[8] Some take the view that when disciplines emerge from the ongoing division of labour in industrial society and consolidate paradigmatically and organisationally, "interdisciplinarity becomes impossible as soon as it becomes necessary." (Eisel, 1992:247) In Eisel's perspective interdisciplinarity is basically about "rational organization of dissent at [a] reflective level. (...) [P]roblems which require interdisciplinarity for their solution are in one way or another oriented towards application and planning, as is their institutionalization in universities as

After this introduction, section 2 gives a first approach to the topic by discussing classifications of interdisciplinarity: their type, their level of ambition and their orientation. Section 3 presents an overview of problems associated with doing interdisciplinary research. Three types of problems are distinguished: syntactic, semantic and pragmatic. Section 4 discusses what the requirements are for moving towards effective interdisciplinary research on natural resources management. It develops a framework consisting of three components, boundary concepts, boundary objects and boundary settings, with the help of which the issues involved can be systematically addressed. In section 5 I present some concluding remarks.

2. Classifying Interdisciplinarity

2.1 Interdisciplinarity: Levels and Degrees[9]

As mentioned above, the notion of interdisciplinarity assumes the pre-existence of a set of disciplines. Though the sub-division of science into disciplinary units evolves over time, influenced by both intellectual and social factors, and also varies across locations, the system of disciplines is relatively stable for a given time period. The division in natural sciences, social sciences and arts & humanities has been a historically constant principle of division and organisation, despite the fact that not all existing disciplines neatly fit the scheme[10], and that the scheme itself is regularly questioned. Relatively unquestioned are also the main subdivisions of these categories in main disciplines like biology, chemistry, sociology, economics, linguistics and art history. Such subdivisions create the possibility of interdisciplinarity within each of the three main groups. Going further down the structure of specialisation these possibilities multiply, and interdisciplinary fields like astrophysics and economic anthropology emerge. Mooij (2003:14) suggests that interdisciplinarity can occur at at least four levels.

1) Between the three main groups;
2) Between the main disciplines in these three groups;
3) Between specialisations within a main discipline;
4) Between subsequent specialisations, and so forth.

Interdisciplinarity at the first, basic level, into which much interdisciplinary work on natural resources management falls, is likely to be the most ambitious and difficult, with facility increasing while moving down. However, this may not always be so, because even within a single discipline there may be almost insurmountable differences between different schools of thought (paradigms) in terms of epistemology and ontology. More mundane concerns of institutional and societal interests may also create a logic for boundary guarding rather than boundary crossing, maybe particularly in cases of 'adjacent' disciplines that are potential competitors for research funds or peer group recognition for instance.

For understanding the occurrence of interdisciplinary endeavours the 'where' question (the location of the discipline in the system of disciplines) is less instructive than the 'how and why' question. Mooij (2003:15-26) suggests that the 'how and why' of interdisciplinary research can be captured in four categories: *synopsis*, *interaction*, *symbiosis* and *unification*, signifying different degrees of interdisciplinarity, or levels of ambition of the interdisciplinary exercise.

Synopsis means the creation of an overview of the different dimensions of a problem, topic or question by collecting together the different disciplinary perspectives relevant to it, without influencing the

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interdisciplinarity courses. They produce for themselves, as a result of the contradiction between their fitness for practice and the necessity to become sciences, a training dilemma which is practically insoluble. (...) Above all it is essential that the contradictions in the situation are made clear – at a meta-level – and that there is no emotional and ideological infighting between interdisciplinarity and disciplinarity." (ibid.:248, 249 fn.3, 253) The context of Eisel's discussion is the evolution of landscape planning training and education in Germany. The title of this document was taken from his article—notwithstanding his ominous statement on interdisciplinary training, about which the present author is much more optimistic.

[9] The first part of section two is a selective summary of Mooij (2003), with some additions by the present author.

[10] Examples are medical science, law and mathematics

disciplines themselves. This is often called multi-disciplinarity rather than interdisciplinarity. Mooij mentions the study of time as an example, to which many disciplines have contributed, with physics, psychology and sociology addressing foundational questions. He notes, "as of yet, connecting the subjective time experience of present, past and future with the objective, physical science understanding of time has not been possible." (ibid.:16; my translation) The concerned disciplines have not influenced each other and therefore synopsis is what can be achieved.[11] Also in interdisciplinary teaching programmes synoptic approaches are common.

Interaction refers to the situation where different disciplines do influence each other. There are two main types of interaction: one focused on concept formation, a second focused on problem solving. An example of the first is the use of concepts like behaviour, information, evolution, system, sign, structure and text. The trajectory of the concept of evolution (borrowed by Darwin from political economy, applied to the development of species, and later employed in a wide range of disciplines) is an example that a key-concept and the theoretical perspective associated with it, can have influence well outside the domain in which it was articulated.[12] Other examples would be the concepts of 'resource', 'culture' and 'capital'. The 'borrowing' may be so substantial that it leads to a new incarnation of the discipline[13], or sometimes annexation of the discipline.

The second type of interaction emerges when a problem can only be solved through the collaboration of different disciplines. Theoretical coherence and consistency is not the prime concern here, but the solution of the problem at hand. Large infrastructure works like land reclamation and flood protection are an example. In such projects civil engineers, economists, agronomists, land use planners, geographers, sociologists and archaeologists may work together.[14]

Interactive interdisciplinarity through teamwork is almost a logical consequence of increasing specialisation. Environmental studies are one of the fields where this approach has been attempted. In such collaborative teams the question arises whether the relationship between the disciplines is horizontal or hierarchical. One discipline may be guiding the research programme and others may supply information and insight relevant to that, or the relationship may be more balanced. Zandvoort (1995) argues for environmental science that this domain will remain a case of balanced interactive interdisciplinarity, as there is little indication that one discipline will take the lead[15], or that a single overarching framework for a 'discipline' of environmental science will appear. In each individual research activity there may be hierarchy, but not in the field as a whole. Mooij also notes, more generally, that hierarchy can have strong ideological overtones, referring to physicalism, that is, the idea of a unified science modelled on physics (ibid.:23-24).

In the third and fourth categories of interdisciplinarity, *symbiosis* and *unification*, the main point is that of joint problem definition. In symbiosis the problem definition and research question are shaped by the interdisciplinary collaboration – and not provided by one of the partners, as often is the case in the interactive mode. Mooij mentions the example of the cognitive and information sciences, and some period studies and regional (or area) studies. Also parts of environmental sciences come under this

[11] However, in the study of the philosophy of time, influences of other disciplines can be traced, and *vice versa* (Mooij, 2003:17). This is an example of the second category, interaction.

[12] Whether the use of borrowed concepts is mainly metaphorical, or constitutes a substantive addition to the conceptual apparatus, and what its ideological effects are (particularly pertinent for a concept like evolution), is a subsequent question.

[13] The history of the Irrigation and Water Engineering group at Wageningen University, the Netherlands, where the present author worked most of his academic career, is an example of this type of interdisciplinarity. A 'normal' irrigation-engineering department, with civil engineering and agronomy as its main constituent disciplines, since 1980 slowly evolved into a department that looks at irrigation from a developmental perspective, and now has an interdisciplinary and social science research programme on irrigation and water resources management. The transformation was internally generated and involved extensive borrowing from development sociology, rural development studies, the political economy of agriculture, legal anthropology, communication and innovation studies, gender studies and political science.

[14] How effective communication can take place in such 'applied' contexts is a research topic by itself, which has been explored, among other approaches, through the notion of boundary objects (see below).

[15] Zandvoort discusses ecology and the public choice perspective on public policy as candidates for such leadership, but decides that 'integration' will remain elusive.

category. When symbiosis leads to a new discipline (which, as already suggested, is as much a social and institutional process as it is an intellectual one) it becomes unification. Examples of the latter are physical chemistry, information science and political science, which have become ‘real’ disciplines, with a defined object, problem definition and methodology. In many other cases the matter is ‘under discussion’.

Lastly, Mooij discusses the phenomenon of what he calls intra-interdisciplinarity (ibid.:26-30). This is not strictly a form of interdisciplinarity, but refers to the phenomenon that some disciplines are inherently multi-faceted, for example because they harbour different, even contradictory approaches to the same object. An example would be the dualism of structural and historical approaches to explanation, which can be found both in the natural and in the social sciences. Such disciplines sometimes fall apart in sub-disciplines, or in terms of institutional location, but more interesting from the perspective of interdisciplinarity is when they stay together under one roof and interact. In economics separation seems more common; in sociology co-habitation is perhaps more frequently encountered.[16] The way physical and social geography are connected in geography departments would also make an interesting case. In many cases the two wings of the discipline seem to operate separately, but where not they are interesting abodes of interdisciplinarity relevant to the study of NRM and other issues.[17]

2.2 Instrumental and Critical Interdisciplinarity

Klein (1996) presents a different way of classifying interdisciplinarity. According to her, interdisciplinary claims can be theorised on a spectrum of argument ranging between *instrumentalism* at one end, positing interdisciplinarity as an empirical problem, while at the other end *epistemology* posits interdisciplinarity as a theoretical problem.

> “Solving social and technological problems and borrowing tools and methods exemplify instrumentalism. The search for unified knowledge and critique exemplify the other end of the spectrum. The difference is embodied in two metaphors (...): bridge building and restructuring. (...) Bridge builders do not tend to engage in critical reflection on problem choice, the epistemology of the disciplines being used, or the logic of disciplinary structure. In contrast, restructuring changes parts of disciplines. It often embodies, as well, a critique of the state of the disciplines being restructured and, either implicitly or explicitly, the prevailing structure of knowledge.” (Klein, 1996:10, 11)

An example of an instrumentalist perspective on interdisciplinarity is the OECD’s 1982 report *The University and the Community: The Problems of Changing Relationships.* In an instrumentalist perspective “[i]nterdisciplinarity serves the political economy of national needs and marketable trends.” (Klein, 1996:14) Examples of critical interdisciplinarities are the fields of women’s studies, development studies, environmental studies and cultural studies.[18] These were established and grew on waves of public concern for specific societal problems, and were sometimes the ‘academic arm’ of social movements (like in the case of women’s studies and environmental studies).[19]

[16] The intra-interdisciplinarity idea can probably be generalised to most disciplines as most have a history of competing paradigms. These may be sequential (the new fully having overtaken the old), but one would also encounter situations where one is dominant and other(s) marginal, or cases of more equal competition of schools of thought. Some of these differences may be more ‘fundamental’ than others; the structure/history dualism is certainly one that has great persistence and widespread presence.

[17] One wonderful example of interdisciplinary work within the geography discipline is Cosgrove and Petts (1990).

[18] For summary accounts of the evolution of (USA) environmental studies, of women’s studies and of cultural studies, see Klein (1996:96-101; 115-123; 123-132). For the evolution of development studies see for example Kitching (1982), Schuurman (1993) and Törnquist (1999).

[19] The institutional trajectories of these four examples are different, and the fields have internally differentiated also, and developed more instrumentalist variants (cf. environmental studies and development studies). Nevertheless, the element of critique, both as societal critique and as critique of ontological and epistemological premises, remains prominently present in these fields. Also see for example d’Andrade (1995) on the use of ‘moral models’ in anthropology.

Klein's distinction into instrumental and critical interdisciplinarity can be regarded as a specific case of a more general 'division of labour' in scientific endeavour. Burawoy has proposed the following table to describe the 'division of labour' in sociology.

TABLE 1: THE DIVISION OF SOCIOLOGICAL LABOUR

	ACADEMIC AUDIENCE	EXTRA-ACADEMIC AUDIENCE
INSTRUMENTAL KNOWLEDGE	*Professional Sociology*	*Policy Sociology*
- Knowledge	Theoretical/empirical	Concrete
- Truth	Correspondence	Pragmatic
- Legitimacy	Scientific Norms	Effectiveness
- Accountability	Peers	Clients/Patrons
- Pathology	Self-Referentiality	Servility
- Politics	Professional Self-interest	Policy Intervention
REFLEXIVE KNOWLEDGE	*Critical Sociology*	*Public Sociology*
- Knowledge	Foundational	Communicative
- Truth	Normative	Consensus
- Legitimacy	Moral Vision	Relevance
- Accountability	Critical intellectuals	Designated Publics
- Pathology	Dogmatism	Faddishness
- Politics	Internal Debate	Public Dialogue

Source: Burawoy (2005a:16); also in Burawoy (2005b:4)

Burawoy sets up a classification of four approaches along two axes. The first axis is whether the approach aims at instrumental or reflexive knowledge, the second axis what its audience is: academic or extra-academic. This produces the matrix of table 1, the boxes of which he describes as follows.

> "*Policy knowledge* is knowledge in the service of problems defined by clients. This is first and foremost an instrumental relation in which expertise is rendered in exchange for material or symbolic rewards. It depends upon pre-existing scientific knowledge. This *professional knowledge* involves the expansion of research programs that are based on certain assumptions, questions, methodologies and theories that advance through solving external anomalies or resolving internal contradictions. It is instrumental knowledge because puzzle-solving takes for granted the defining parameters of the research program. *Critical knowledge* is precisely the examination of the assumptions, often the value assumptions, of research programs, opening them up for discussion and debate within the community of scholars. This is reflexive knowledge in that it involves dialogue about the value relevance of the scientific projects we pursue. Finally, *public knowledge* is also reflexive – dialogue between the scientist or scholar and publics beyond the academy, dialogue around questions of societal goals but also, as a subsidiary moment, the means for achieving those goals." (Burawoy, 2006:5)

For 'sociology' any discipline can be filled in, while different kinds of interdisciplinarity can also be understood in this manner. The top half of the table would then refer to Klein's instrumental interdisciplinarity, while the bottom half refers to critical (or reflexive) interdisciplinarity. Referring to Kann (1979) Klein summarises the political dimensions of this as follows.

> "Conservative elites want a specific kind of explanation that enables them to solve problems and devise practical answers, divorcing questions of politics from questions of knowledge. A liberal explanation emerges among those caught between older positivisms and newer, radical perspectives. Locating themselves in the middle ground of harmonious interaction, they too are bridge builders. Radical dissidents, in contrast, demand that interdisciplinary explanation be useful to oppressed groups seeking greater socio-political equality. They are restructuralists." (Klein, 1996:15)

Klein thus illustrates that associated with different ways of doing (interdisciplinary) science are different 'politics'.

The two-by-two matrix allows the clarification of a further distinction, and that is that between interdisciplinarity and transdisciplinarity. Burawoy's table distinguishes between the different audiences that different ways of conducting science serve. The main division is that between science being internally oriented (science as the audience for science), and science being externally oriented (society as the audience for science). Society may not just be a passively listening audience, but may shape the research for example by making the funding of it conditional on certain criteria. When interdisciplinary research is organised in a manner that includes different interest groups associated with a complex societal problem in the research process from the very beginning, we speak of transdisciplinarity. This is discussed in more detail in the following sub-section.[20]

Burawoy's matrix is a useful grid for mapping the 'underlying' differences between different scientific approaches, including different approaches to interdisciplinarity. At this stage the general point is that interdisciplinarity itself is a contested category, with the axes of instrumentrality *vs.* reflexiveness and science driven & oriented *vs.* society driven & oriented as two important contested characteristics. The disputes over appropriate terminology express this. Describing interdisciplinary endeavours differentially as "subdisciplinary exchange, a multidisciplinary affiliation, an interdisciplinary solution, and integrative approach, a collaborative project, a transdisciplinary paradigm, or cross-disciplinary critique" (ibid.:10) imply different knowledge claims and different objectives.[21] The discussion on the place of interdisciplinarity in the academy revolves around the issues of problem solving, pluralism, and critique. However, the resurgence of interest in interdisciplinary studies in the 1990s, after a first wave in the 1960s and 1970s of 'euphoric' interdisciplinarity, seems to be mostly pragmatic in orientation. "In a fragmented world, the integrative skills needed for problem solving and dealing with complexity are stronger warrants for interdisciplinarity than is unity of knowledge." (ibid.:34), something I have implicitly suggested already in the first section of this paper.[22]

2.3 Interdisciplinarity and Transdisciplinarity

Notwithstanding the implicitly suggested generic use of 'interdisciplinarity', as a contested concept with multiple meanings, it is worth commenting specifically on the concept of 'transdisciplinarity'.[23] The journal *Futures* has recently devoted a special issue to transdisciplinarity, a word *à la mode* as stated in the introduction to the volume (Lawrence and Després, 2004:397). That same introduction goes on to state that "Like interdisciplinarity, there seems to be no consensus on [transdisciplinarity's] meaning." (*ibid.*:399). Nevertheless, the following characteristics as proposed by different authors are listed (*ibid.*:399).

[20] Klein distinguishes a third category of interdisciplinarity that she calls transdisciplinary integration around an overarching concept or theory. Examples of such attempts are general systems theory, structuralism and Marxism. A risk of this 'unity of science' perspective is that it can make interdisciplinarity into an ideology, as it may be associated with a monistic concept of the world, in which reduction of all phenomena to the metaphor of a system or a structure takes place as part of a master narrative (cf. Mooij's warning against 'physicalism' mentioned above). For different meanings of 'transdisciplinarity' see below. Also see for example Pohl (2005). In these perspectives Klein's examples of transdisciplinarity would not qualify as such, as they focus on 'theoretical integration' only.

[21] Annex 1 and 2 of Pohl and Hirsch-Hadorn (2007) are a 26 pages overview of definitions of inter- and transdisciplinarity.

[22] One (among many, but still striking) example of the practical orientation of not just interdisciplinary research, but of systems analysis in general in the domain of water management can be found in the Preface of a publication of the International Association of Hydrological Sciences on 'Closing the Gap between Theory and Practice' (Loucks and Shamir, 1989). It plainly states "systems analysis is aimed at helping practitioners make better decisions (...) Eventual implementation [of a model or program], after all, is the ultimate test of the value of the products by those involved in systems research." (ibid.:v-vi)

[23] In its new strategy document, ZEF states that it will undertake 'transdisciplinary research for sustainable human development'.

1) It tackles complexity and heterogeneity in/of science, problems and organisations; knowledge production is characterised by hybridity, non-linearity and reflexivity, transcending any academic disciplinary structure – hence the name.
2) It accepts local contexts and uncertainty; it is context specific negotiation of knowledge.
3) It implies intercommunicative action and is inter-subjective. Transdisciplinary research and practice require close and continuous collaboration during all phases of a research project.
4) It is often action-oriented; in addition to making linkages across disciplinary boundaries it may also entail linkages between theoretical development and professional practice. “Transdisciplinary contributions frequently deal with real-world topics and generate knowledge that not only address societal problems but also contribute to their solution.”[24] It aims “to bridge the gap between knowledge derived from research and decision-making processes in society.”

Some of this is hardly distinguishable from common descriptions of what constitutes interdisciplinary research, particularly interdisciplinarity with a transformative agenda. One way to read this terminological proliferation is that, apparently, the difficulties in ‘doing interdisciplinarity’ (see below) made a new term necessary to state the necessary characteristics more firmly.

However, significant differences between the two concepts may be constructed. Interdisciplinarity may be understood to remain caught within the structure of academic disciplines – the existence of these is the starting point, and the struggle is one of combination and integration. In this reading transdisciplinarity would more radically start from the problem/issue at hand, and all the knowledge dimensions and claims associated with it, be they scientific, lay, professional, or otherwise, and consider the different claimants as (at least cognitively) equal partners in the research *cum* action. Transdisciplinarity in this reading takes a stronger view than interdisciplinarity on the democratisation of scientific practice (and thus puts the existing knowledge *system* into question, rather than just the knowledge as such), and more strongly emphasises the context-specificity of knowledge than interdisciplinarity or multidisciplinarity would do (see particularly characteristic 2 above, the *negotiated* nature of knowledge).[25] In the context of development studies, ideas and approaches developed in work on participatory research, action research, social learning, co-management, local knowledge, research-policy interfaces, and other fields would be relevant for elaborating a concept of ‘transdisciplinary development research’.

Transdisciplinary research may also be considered as the type of research that effectively addresses the challenges of boundary concepts, boundary objects and boundary settings as discussed in chapter 4 of this paper. For the moment, however, we return to the issues involved in doing interdisciplinary research.

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[24] For instance, the website of the Institute for Environmental and Sustainability Communication (INFU) at Lüneburg University, Germany, writes that “Transdisciplinarity implies the co-operation with partners outside university. These are involved right from the beginning into the scientific operating process, and they considerably contribute to the problem solution.” (http://www.uni-lueneburg.de/infu/chair/aboutus/missionstatement.htm accessed 11 September 2006).

[25] The most elaborate discussion of transdisciplinarity is Pohl and Hirsch-Hadorn (2007) already referred to above. It consolidates experience with inter- and transdisciplinary research in the Swiss context. For further reference, see for example the websites of the network for transdisciplinarity in sciences and humanities of the Swiss Academy of Sciences at www.transdisciplinarity.ch and of the *Centre International de Recherches et Études Transdisciplinaires* (CIRET), Paris (http://nicol.club.fr/ciret/index.htm) (accessed 11 September 2006).

3. Problems in Doing Interdisciplinary Research

This section discusses some of the problems associated with doing interdisciplinary research. These will be classified into syntactic, semantic and pragmatic problems, but before this is explained and discussed I summarise three articles that vividly illustrate some of the problems that interdisciplinarity tends to encounter.

3.1 Interdisciplinary Communication: A Conference

In an entertaining paper Kann (1979) (re)constructs the proceedings of a three-day conference that sets out to discuss and develop a basis for interdisciplinary consensus on the relationship between culture and explanation. The participants are from the natural sciences, humanities and social sciences, and the conference is scheduled to conclude with a public presentation on the third day. I quote and summarise at some length.

> The biographical introductions of the participants at the start of conference make that all participants are impressed with the diversity of the group. These introductions also raise substantive questions. "For example, a biologist might have suggested that language may soon be an anachronistic mode of communication. A literary critic attuned to linguistic structuralism may find this suggestion incomprehensible and ask for further elucidation. But further elucidation is difficult if not impossible because the two scholars have no common theories or concepts with which to communicate. Seeing this discussion going nowhere, a third participant might redirect discussion to the importance of language in his discipline or research. (...) Indecision may inform the discussion for quite a while, but eventually everyone will become dissatisfied. Noting this, the convener may try to summarize the discussion and then ask one participant to expand on earlier comments. One scholar discusses his 'historicist' perspective on the topic, but another may find his usage of the term to be unintelligible, unconventional or unacceptable from his particular perspective. Yet another participant uses the word *pluralism* to indicate a multifaceted view of explanation, but someone else takes the word to mean survival of the fittest in group competition." (ibid.:191-192) According to Kann three political strategies are likely to emerge at this junction.
>
> 1) Participants quiet so far assert themselves and call for discussion on 'serious' matters, for example by providing a summary of the preceding discussion in an effort to overwhelm and redirect.
> 2) Some will feel offended and will challenge what is 'serious', leading to confrontation in the discussion in which words like silly, ludicrous or inane may be used. As people are from different disciplines there is no common authority to check this uncivil behaviour.
> 3) In response it may be suggested that everyone should remain calm and reasonable, the liberal-professional ethos should be observed by everyone, and argument proceed by reason and tolerance of disagreement.
>
> However, some may reject the latter as consensus is the objective and not tolerance. If all these three strategies emerge, conflict is likely to escalate, which puts the convener in a difficult position. The best way forward is to recess the discussions and ask participants to prepare a statement with their perspective on the topic, which would be presented. Three positions on the issue of culture and explanation emerge.
>
> 1) Culture influences explanation, but this can be checked or minimised by appropriate methods – something every scholar should strive for. Natural scientists and other neopositivist disciplinary scientists are likely to support this position.

2) "Cultural pressures and scholarly explanation are inextricably entwined." (ibid.:193) All explanations are contingent on historical and cultural forces, which also blend in unique ways in individuals' lives. Support is likely to come from disciplines that emphasise the unique, like history or literature.
3) The intermediate position: the actual relation is somewhere between the first and the second position, and the issue itself can be discussed and explained. This is likely to be supported by disciplines that emphasise analytical criticism and creativity.[26]

The problem is that these substantive positions are associated with the political strategies. Strategy and position one will try to dominate the floor or keep quiet having decided that they are far above this nonsense. Strategy and position two are congruent because intellectual conflict is seen as the playing out of cultural conflict, and only through conflict new possibilities emerge. Tolerance and reasonable compromise unite strategy and position three, to enhance precision and creativity. The first group are benign conservatives, the second radical egalitarians, and the third conventional liberals.[27] "[I]t is only a matter of time before the turbulence of preceding discussion is reawakened, now with greater forcefulness." (ibid.:195) If the convener now calls for reason and tolerance he is immediately associated with position three – he[28] will get worried about how to achieve a civil discussion for the public presentations on day three. To avoid direct confrontation he organises the public presentations in such a way that participants cannot respond to each other, and only the audience can ask questions. "Surprisingly, the presentations and discussion are civil and reasonable." (ibid.:195) Presenters take care not to misrepresent others' viewpoints while presenting their own. Opportunities to regenerate turbulence in the question-answer part are ignored. A consensus starts to emerge, not on interdisciplinary explanation, but on the barriers to that. This turn in the style and tone of the discourse is possible for three reasons. 1) The first two days functioned to explore ways to communicate similarities and differences. A concept like embeddedness (of explanation in culture), though understood differently across participants, was used by many and helped to articulate the problem. 2) On the second day all disciplines were able to find allies for their position in at least one other discipline – suggesting that interdisciplinary alliances are possible even when they may express consensus in a narrower sense than anticipated. 3) The public nature of the third-day forum brought back the liberal-professional ethos, the authority of both the university and the discipline. At least a few members of the own discipline would be likely to attend the public presentation. "The public presentation consequently went off peacefully, respectfully, and even harmoniously." (ibid.:196)

Kann is rather pessimistic about the possibilities for further developing interdisciplinary consensus based on this, in what would be an in most people's perspective, successful conference. The reason is that in his view the three different strategies/positions are associated with and supported by different interest groups in society. Simply put, the first is associated with the powers that be, the second with civil society opposition, and the third is caught in between with too high expectations of what self-reflectiveness can achieve.

The general point that can be drawn from this is that interdisciplinary communication and the problems that are part of it, should be understood not only at the level of the individual, the discipline and the university, but in a broader context of social relations and interest groups. In the view of Kann different modes of interdisciplinary explanation are likely to emerge, reflecting different societal positions. From a more optimistic angle it might be asked whether society's increasing need for more 'integrated' approaches and solutions will force or enable more constructive forms of interdisciplinary communication.

[26] Kann mentions English as an example. I would suggest the social (constructivist) studies of science and technology, which has become a well-established 'discipline' since Kann's paper was published. An instructive paper on this issue is Jasanoff (2003).

[27] Kann doesn't make the link, but there would be an interesting case here to discuss positions on interdisciplinarity from a cultural theory perspective.

[28] There are only he's in Kann's conference.

A more mundane inference from Kann's paper might be that conferences are perhaps not the most appropriate locations for achieving interdisciplinary communication. More intense and prolonged interaction may be necessary—for example in a research project.

3.2 Interdisciplinary Collaboration: A Research Project

In this section I discuss a paper that reflects on the constraints of anthropology's contribution to interdisciplinary policy studies (Simon and Goode, 1989). The case study describes research conducted on the efforts of newly laid-off employees and their union leaders to save their jobs in the supermarket industry in Philadelphia, USA in the early 1980s. The paper discusses how the research project on job saving strategies evolved, from pre-funding to fund-seeking to funded—with a book as the final output. The focus of the analysis of the problems associated with interdisciplinarity is how to combine quantitative and qualitative methods. Again I summarise and quote at some length.

> The research project started off from an initiative of 600 workers of a total number of laid-off supermarket employees to take over the closed supermarket outlets and start worker-owned stores. Two worker-owned stores were set up in the Philadelphia region. This provided a local university with an excellent opportunity to study worker ownership from its inception, a topic of interest to a public policy studies group at the time. In the initial survey two anthropologists, two social psychologists from a business school and an educational psychologist participated. The first two were qualitatively oriented; the latter three quantitatively. The team jointly discussed the design of the interview protocol for the survey, a semi-structured interview. The protocol became lengthy and complicated because all members' interests were accommodated. The initial survey suggested there might be scope for a larger research project as the worker stores set up offered some elements of a controlled experiment (ibid.:224). Fund-seeking started.
>
> After meeting the potential funder, who had a particular policy focus and approach, a research project was designed. The funder would also publish the book that would be the outcome. The natural experiment situation was particularly attractive for the researchers interested in hypothesis testing. One team member provided the model that the study would use, with inputs, organisational process and outcomes as the basic elements. "The 'inputs' included features of the workers, the environment, and the store models. 'Organisational processes' within the stores consisted of features such as participativeness of workers in decision-making, how the stores functioned, and the 'labour strategy', or how the labourers were deployed to get the job done. Finally the model specified that we would determine economic outcomes for both the workers and the stores." (ibid.:225) The team member who provided the model was given a leading role as it was believed that his approach would increase chances of funding. Thus the research became strongly linked to the worker ownership literature. However, other interests like job satisfaction and organisational development were also incorporated to some extent in the organisational processes and outcomes components. The anthropologists saw some or their interests reflected in the inputs component, notably workers' characteristics.
>
> The way the funder was courted implied several constraints on the interests and approaches that could be pursued in the funded stage. The funder defined its audience as "economist or business types in the academic world and business consultants and decision-makers in the practical world." (ibid.:226) There was a preference for 'unequivocal and straightforward answers'. The funder's economic orientation meant that it was primarily interested in the economic outcomes component, particularly store economic success (rather than worker economic outcomes). A labour economist was put on the team on the suggestion of the funder, which introduced a new set of theoretical notions related to productivity etc. The research traditions of worker ownership and economics came to dominate the language and arguments of the project. The influence on method was that qualitative methods were 'unfathomable' for the funder (ibid.:227), and the funder also assumed that anthropology could only produce findings on worker attitudes—which was not of the funder's interest.

> The participation of anthropologists in the research was questioned. Contributions already made to the research by anthropologists, such as the importance of pre-existing social networks, were not recognised. The concept of 'social networks' did not fit the research tradition with which the funder was familiar. The team members, though recognising the value of anthropological research had no incentive to make it a central element. A structured questionnaire was conducted in three store types, with sufficient numbers to achieve statistical representativeness. Some additional in-depth interviews were also done (additional to those of the initial survey in the pre-funding stage). The qualitative and quantitative data was processed simultaneously.
>
> The paper shows that the two different types of research provided different explanations of the issue at hand. "It seemed to the anthropologists that much of what happened in terms of productivity, worker satisfaction, participation in decisions as worker owners or in QWL [Quality of Worklife, a management strategy—PM] was related to these [informal] processes of store formation as much or more than to the formal innovation mechanically imposed by technical assistance agents. However, the model which the overall study was testing assumed that the inputs (e.g. worker characteristics) and organisational processes would be uniform or if they differed it would be along the lines defined by the constructs, variables and scales commonly used in the human resources literature." (ibid.:231)
>
> In the final book the division of labour between disciplines was reflected through the different chapters that the team members wrote. The member who had contributed the framing approach of the project wrote the introduction. There were two anthropological chapters written in a narrative form "not as integrated with each other or with the whole study as they might have been. (...) [that are] treated as background or mere description and do not frame the analysis and conclusions of the study." (ibid.:231-2)
>
> Draft chapters were exchanged but mainly commented upon in terms of writing style, comprehensibility and format. There was a "failure to see the epistemological value of each other's work." (ibid.:232) In the book, the first of the two anthropological chapters was "treated as one of the scene setting chapters (...) In spite of the fact that understanding the developmental cycle of the industry and the series of management strategies was critical in understanding worker's responses, this material was not incorporated into the analysis, conclusions and policy recommendations. While the [second anthropological] qualitative analysis chapter was called a 'findings' chapter in the introduction, it was not summarised in the conclusions as the other data chapters were. This was partly because its non-quantitative form of presentation did not lend itself to 'proving hypotheses' and 'testing the model'. More important was the fact that the ethnographic findings, in dealing with diachronic social processes and in dealing with the worker's sense of meaning and interpretation of the events, created a whole new set of significant categories that did not fit the a priori model."" (ibid.:233-4)

Simon and Goode identify four models of interdisciplinary research, with a different potential for anthropology to contribute to interdisciplinary study.[29]

1) The anthropological component provides background or context information. In this model anthropologists work on their own, may write a background chapter and/or provide 'human interest' case studies.
2) Anthropology elaborates on or explains the surprises in the findings from the quantitative component. Also in this second model anthropology is added rather than integrated. Typically, anthropological explanation would be used in the concluding chapter "as elaboration or flesh on the bones of the statistical findings." (ibid.:221)
3) Researchers use anthropology's ethnography to define important variables or categories to be explored in the quantitative study. The anthropological research takes part at the start of the study in this model, before the research design is finalised. Through its influence on the design

[29] The paper focuses on anthropology, but much of it is relevant to other qualitatively oriented social science disciplines too.

of the study anthropology will shape the findings, but it may or may not be integrated in the interpretation of the quantitative analysis.

4) Ethnographic and multivariate approaches are creatively combined in research, analysis, and interpretation. In this – rare – model, the distinction between quantitative and qualitative parts of the research study would largely disappear. Ethnography would be used to design questions as well as to test hypotheses, and in the analysis both types of data would be used. The assumption is that both types of data are mutually illuminating.

It is clear that in the case discussed in the paper the research does not achieve the level of interaction and integration of the fourth model. Anthropology was mainly used in the first and second sense, and to some extent in the third sense. Actually the paper is a story of the marginalization of the qualitative, anthropological input. The interesting question for a general discussion on interdisciplinarity is whether general lessons can be learnt on the 'why' of this process. Some points for consideration are the following.

1) The study shows how external, funder influence can shape focus, theory and methodology of a study. This 1980s study supports Kann's suggestion that such influence is likely to go into the direction of the 'dominant' societal (and academic) voice. This highlights the importance of the choice of partners and collaborators in research projects, and the modes of collaboration and engagement among them. Relations with external actors may also affect the relationships within the research team.
2) There seems to be a difference in orientation between disciplines in terms of, using Simon and Goode's phrasing, 'process oriented evaluation' (the qualitatively oriented anthropologists) and 'model testing' (the economists and other quantitatively oriented researchers). The latter could not be convinced "that contextualised, diachronic studies in themselves ultimately yield better understandings of how systems work." (ibid.:236).[30] There seem to be two issues.

   a) Bringing a priori models or theories to a situation to be tested vs. starting from a locally specific situation and building a model of it based on empirical investigation.[31]
   b) Generalisation *vs.* an emphasis on history and process, or put differently, a structural vs. a historical approach to explanation.[32]

3) Simon and Goode suggest that the anthropologists could and should have been more assertive in arguing their position and influencing the research design and outcomes. Apart from social factors they identify epistemological issues as the main cause for explaining the subordinate role of the anthropologists in the project. "The notion that the purpose of the scientific research is to produce generalisable conclusions arises from the myth of science as objective. (...) Generalisable studies which are aimed at national or broad based policy afford decision makers assured, straightforward answers to questions about what works. However, they leave out the very local contingencies and circumstances which can be so important in illuminating the underlying conditions for success or failure." (ibid.:238) The point they make is that there is a structurally different appreciation of different scientific (and policy) approaches, which is difficult to overcome even with the best of individual intentions. And, that difference works both and the level of science and at the level of policy.

[30] The authors provide ample evidence that the anthropological findings when taken seriously would indeed lead to a different modelling of the system.

[31] One interesting observation the authors make in this context is that "The [labour process] innovators as well as the majority of researchers assumed that the elements of the change would be understood by the workers in the same way as they were discussed in the labour relations literature." (Simon and Goode, 1989:237)

[32] See McAllister (2002) on structural vs. historical approaches to scientific explanation. Simon and Goode primarily phrase the problem in terms of quantitative vs. qualitative approaches. I believe that is slightly misleading, and somewhat of a red herring. The mode of explanation, or one's view of causality, is the more basic issue. Their distinction between 'process orientation' and 'model testing' is more to the point. Quantitative and qualitative methods can be used on either side of the fence. For a discussion of realist *versus* interpretative approaches to explanation, see Mahoney and Rueschemeyer (2003), and the other papers in that volume. The issues they raise for the field of comparative historical analysis are common to much of social science, and, in some perspectives, the natural sciences, *mutatis mutandis*.

Like Kann, Simon and Goode end on a pessimistic note. Again, hope may lie in the increasing societal demand (as observed by Klein (1996) and others) for 'true' interdisciplinary research – a demand generated by the policy making sphere particularly for NRM research. In terms of interdisciplinary collaboration, the subject of this section, a conclusion is that explicit consideration of the epistemological and ontological premises underlying a research project and the approaches of the participants is a requirement. It may not be possible to reconcile the different premises, but without recognising and respecting them collaboration seems to be very difficult. Whether some differences are insurmountable is an open question.

3.3 The Culture of Disciplines

Disciplines can be thought of in purely cognitive terms: as ensembles of theory and methodology related to a particular knowledge object. However, they are also institutions, and more generally, cultures. Following Becher and Trowler (1989), Huber suggests that disciplines can also be seen as academic 'tribes', that

> "have their traditions and taboos, their territories and boundaries, their fields of competition and their pecking orders within and between them, their tacit knowledge and hidden assumptions, and their specific patters of communication, publication, division of labour, hierarchies and careers." (Huber, 1990:242).

Huber lists the following categories of differences between disciplines as academic 'tribes'.[33]

a) Disciplinary communities differ in their *attitudes to political and social issues*. He refers to a list of research papers that "show that [academic's or university teachers'] stance is more liberal or to the Left than that of the average citizen, but within academia they tend to reproduce the same rank order from Left to Right, 'progressive' or 'liberal' to 'conservative': people in the social sciences are farthest to the Left, followed by those in most of the humanities (less so in modern languages and sometimes history); natural sciences fall in the middle (physics more to the Left than chemistry); medicine and particularly engineering tend to the Right. This appears to be true over time and across national borders (...)."(ibid.:243)
b) Disciplinary communities differ in *cultural practices and preferences in their members' private lives*. Huber gives several examples, but an amusing one is that "physicists were inclined towards an interest in the theatre, art and music, whereas the engineers' typical leisure activities included aviation, deep-sea diving and 'messing about in boats'."(ibid.:243, quoting Becher, 1989:106)[34] Whether these patterns are modes of demarcation or 'come with the territory' would need to be investigated.
c) Disciplinary communities differ in the *social background of their membership*. "In general, of course, the professoriate is mainly middle class. However, judged by the socio-economic status or the educational attainment of their parents, professors of medicine, closely followed by those in law (or *vice versa*), have always been and still are the most upper class; humanities are a mixture; parts of the natural sciences, followed by the social sciences, recruit more from lower social classes; engineering is definitely at the low end (...)." (Huber, 1990:244) These differences are very slow to disappear and Huber shows that they are still, at least till the late 1980s, reproduced in a country like West Germany.

What is the relevance of this anthropology and sociology of disciplinary culture? In the context of this paper the primary significance is that interdisciplinary encounters are not only an encounter of different theories and methodologies, that can be objectively compared and tested for explanatory power, but are also the interaction of groups of people with (sometimes very) different cultural styles and preferences. Because cultural behaviour is unconscious to an important extent (cf. Bourdieu's (1989) concepts of

[33] It may be noted that Kann's paper discussed above analyses interdisciplinarity as a political culture.
[34] Implicitly the issue of the masculinity of/in certain disciplines and professions is raised.

habitus and disposition) this may lead to serious communication problems, and even conflict— for instance when implicitly disciplinary hierarchies are projected.[35]

3.4 A Classification of Problems in Interdisciplinary Research

On the basis of this and other literature a classification of the hurdles for disciplinary boundary crossing can be attempted. Carlile (2002) divides these hurdles into syntactic, pragmatic and semantic ones—a terminology taken from information processing science. I use his terminology with some liberty here.

Syntactic problems or, language and communication problems

Syntactic problems refer to 'using the same language' in the literal sense. Despite globalisation, scientific communities are still segregated along language lines to an important extent. This is probably less the case in disciplines where mathematical language is important, and more prevalent in disciplines where text and narrative are more central. For example, within the sociology of water management literature the English, French and Spanish literatures are quite segmented. The Chinese and Russian literature on the subject is largely inaccessible to scholars who do not master these languages. This is not just a language problem. The literatures also are about different geographical regions, and therefore lack of interaction easily reproduces. The dominance of the English language implies dominance of that body of literature, if only by its sheer volume.[36] A common problem is that certain concepts are language/culture specific and cannot be translated satisfactorily into other languages. An example from the land and water management domain is that the term *Cultuurtechniek/Kulturtechnik* as it exists in Dutch/German has no proper translation into English or French for instance. In policy studies it is interesting to note that some languages use different words for 'policy' and 'politics' (obviously English, but also Dutch) but that many other languages use the same word, like German, French, Spanish, Italian and several others. This makes that the phrase 'politics of policy', which is the description of a certain approach to policy analysis in the English language literature, can be translated to other languages with great difficulty only. Though perhaps thought trivial by some, language is a critical issue in both disciplinary and interdisciplinary communication.

Another aspect is the difference in language and presentation style that exists across disciplines. In the engineering sciences for example diagrams, graphs and other pictorial representations are highly valued. In the ethnographic and literary sciences text is the preferred medium. The latter scientists tend to find graphical representation too crude to convey the subtlety of meaning they are after in their research, while the engineer may find twenty pages of 'grey text only' impossible to get through. These differences are partly related to the subject matter of the discourse, but also linked to differences in scientific approach, and have a cultural-historical element. The styles are part of the culture of the disciplines.[37]

'Discursive strategies' or 'rhetorical styles' that are used in different disciplines are yet another element of the culture of disciplines. Rhetoric and style can be used strategically to enrol and convince, or to

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[35] Huber (1990:247) operationalises this further, following Bourdieu, by discussing the different forms and amounts of 'capital' that academics bring to such interactions: economic capital, social capital, cultural capital and symbolic capital. The appreciation of these different forms also varies across disciplines.

[36] For instance, as a Dutch national I have no incentive to publish on irrigation water management in my own language. I have been estranged from my own language to the extent that I can professionally express myself better in English than in Dutch.

[37] There is a larger issue of non-textual presentation and problem solving, as in design-oriented sciences. For landscape planning Eisel (1992) argues that "it is somehow possible to acquire through learning the special kind of spiritual concentration and practical facility characteristic of the creative mode, namely the interplay of craftsmanship (as learned skills) with artistic talent and political know-how and a feel for planning." (p.252) This capacity cannot be fully 'textualised', as anyone who has ever designed something, be it an irrigation canal, a piece of furniture, or a piece of software, can testify, but it is crucial in practical problem solving activities. In recent analyses of the activity of modelling in scientific practice a similar argument has been put forward on the irreducible elements of tacit knowledge, skills and judgement that are part of what defines a 'good modeller' (see Morrison and Morgan, 1999). The implication is that all scientific practice exhibits this feature, though the degree and importance may differ.

distance and oppose. (Berkenkotter, 1995) This is not really a syntactic problem perhaps, but comes very close to the second type of problems, that of interpretation.[38]

Semantic problems or, differences in approaches and paradigms

Semantic problems are problems of interpretation—attributing different meanings to the same word, sentence, text or concept. At a mundane level this is the issue of being aware of what other people, disciplines or schools of thought intend to mean when they use particular words or concepts. Such clarification is a necessary, though far from sufficient, condition for interdisciplinary interaction. Concepts may, of course, also have a contested status within a single scientific group.

At a more fundamental level semantic problems are about the epistemological and ontological premises on which scientific approaches are based. These imply different understandings of causality, the objectivity status of knowledge, the meaning of generalisation, reductionism, and many other issues. For example, one important bone of contention in the social sciences is the concept of human agency that the different disciplines employ.[39] There are thus, in Kuhn's phrase, different scientific paradigms, or put in a less grand manner, different scientific approaches that have qualitative differences at the level of basic premises. It is not difficult to imagine that this may cause serious problems in interdisciplinary collaboration and communication—even with the best of individual intentions there may be incompatibility of frameworks.

How does one deal with this problem in practical situations? As already mentioned above, practising interdisciplinarity requires a degree of self-reflectiveness, to at least recognise and respect that there may be differences and problems at this level, and to be able to articulate one's own premises with some precision. Given the history of science it is unlikely that there will be some grand convergence.[40] Muddling through theoretical and methodological divergence seems to be the more likely prospect.[41] Rather than reconciliation or integration at a highly abstract level, detailed engagement in analysis at the concrete level with concepts and methods that span disciplines seems to be a more promising, and realistic route. In section four below I discuss the notion of 'boundary concepts' that may be useful for this effort.

Pragmatic problems or, problems related to incentives and institutions

The third category of problems, labelled pragmatic problems, refers to the institutional disincentives that exist for interdisciplinary research work. A lot has been written on this (see for example Klein (1990, 1996) for overviews; also see Berge and Powell (1997) and McNeill, García-Godos and Gjerdaker (2001)). The general point is that the funding structure, the career structure, the publication and peer review structure, and other institutional elements of academia are largely organised along disciplinary lines. The disciplines individually and collectively have an interest in maintaining this structure, and therefore change towards interdisciplinarity tends to be difficult and slow. Acquiring and maintaining space for it often is a struggle. The discussion above has shown that such intra-academic interests are linked to broader societal interests and interest groups. Kann goes to the extent of stating that only "the relatively few academic superstars (...) can afford to ignore narrow disciplinary norms in the name of general knowledge." (1979:186). This is probably no longer true, and perhaps wasn't when he wrote it.

[38] Style and rhetorical capacity are also strategic resources in the context of the pragmatic problems associated with interdisciplinarity.

[39] For a general theoretical treatment of of human agency, see Archer (2003). For a discussion of the concept of human agency in the context of irrigation management see Mollinga (2001).

[40] Though some people take a different view. See for example Abell (2001) on the prospects of a unified social science.

[41] My own favourite approach at the level of the philosophy of science is the school of thought called 'critical realism' (see Bhaskar (1989); Sayer (1984) is a very accessible summary and introduction). I believe that this school of thought takes a position that makes many of these foundational problems workable in concrete research, but others would undoubtedly disagree. An exploration of the questions of social structure, structuration and agency from a critical realist perspective, attempting to improve upon Giddens' and Bourdieu's approaches for social analysis are Archer (1995) and Kontopoulos (1993).

Nevertheless, the point that there are significant institutional hurdles for practising interdisciplinary research and that it requires a lot of personal stamina, commitment and willingness to take risk is often true. In organisational terms interdisciplinarity seems to works best in dedicated centres, schools or groups that have sufficient financial independence, sufficient status, committed and creative leadership, and intensive interaction among group members. To prosper, interdisciplinarity requires favourable, enabling organisational and institutional arrangements.[42] A second lesson from the literature on interdisciplinarity seems to be that it works best when research is focussed on concrete, circumscribed issues, that is concrete problem-solving, be these knowledge or practical problems, where the problem is jointly defined at the outset. (For more detailed discussion on the organisational dimensions of interdisciplinary research see particularly Klein (1996).)

Knowledge: localised, embedded, and invested in practice[43]

When embarking on the trajectory of interdisciplinarity, we need to realise that we do not only have cognitive problems at hand. Knowledge is generated and used in 'communities of practice', which have purposes, cultures, interests, worldviews and organisational forms. To use Haraway's phrase, knowledge is 'situated' (Haraway, 1991), as are the persons who produce and carry the knowledge.

This is not meant to suggest that the problems in doing interdisciplinary research are insurmountable. Quite the contrary—the institutional momentum seems to be towards strengthening interdisciplinarity given the complexity of societal problems that need to be addressed. In different domains there has been substantial progress in developing more comprehensive and integrated approaches, even when crossing the boundar(y/ies) between the natural and social sciences remains a very big challenge.

In a recent paper, Pohl discusses the practice of interdisciplinary/transdisciplinary collaboration, based on interviews of researchers active in Swiss and Swedish problem-driven environmental research projects. One interesting point in the paper is Pohl's suggestion that it makes more sense to distinguish between 'Detached Specialists' and 'Engaged Problem Solvers' in explaining the problems of interdisciplinary collaboration , rather than between natural and social scientists or quantitatively and qualitatively oriented scientists (Pohl, 2005). 'Detached specialists' want to provide expertise to decision makers or others dealing with the problem; 'Engaged problem solvers' want to solve problems *themselves*. Natural and social scientists can be found in both groups – the difference lies in the purpose and orientation of research. The detached specialists tend towards 'additive collaboration', not influencing each other's science, while engaged problem solvers tend towards 'interrelating collaboration', which can lead to development of new, joint concepts and methodologies. Pohl suggests that it is not so much differences in fields of expertise/discipline or in methodology that generate the most difficult problems of interdisciplinarity in practice, but the issues of the purpose of research and how to embed it in societal processes of transformation. This is confirmed by this author's own experience. For a development research institute like ZEF, this would imply an articulated view on the meaning of 'development' that conceptually and strategically informs research design and practice, and, perhaps more importantly, an active process of reflectively engaging with the meanings of development that are encountered and pursued in research projects.

Lele and Norgaard (2005) make a related point. They suggest that the problem in interdisciplinarity is not so much about disciplines but about commonality in approach across disciplines. There is diversity in approach within disciplines, and definitions and boundaries of disciplines change. What matters are scientific communities across disciplines adopting a similar approach.

> "There is both a great deal in common across disciplines and much variety within them. In the social sciences, market economic models are used in economics, anthropology, history, sociology, political science, public policy, and even psychology; those from different disciplines who use these models may have more in common with each other than with those from the same departments who use Marxist perspectives. The biological sciences

[42] My own experience at Wageningen University, the Netherlands suggests that it also requires educating and training a cohort or generation of interdisciplinary scholars after the initial step of putting a group of committed faculty together, most of whom are likely to be socialised in a disciplinary manner.

[43] This heading is literally taken from Carlile (2002:445)

> have reorganized over the past quarter-century, dropping the historic disciplinary distinctions, for example, between the plant and animal world and organizing more on levels of analysis from the gene to the organism to the ecosystem. Yet evolutionary biology cuts across all levels of analysis, and ecologists use genetic techniques to understand ecological systems and processes. Thus the structure of scientific knowledge and the differences in epistemologies, theories, and methods among scientists have little to do with what have historically been called disciplines. So, when approaching collaborative work between scientists, forget disciplines; think scientific communities. (Lele and Norgaard, 2005:972)

In Lele and Norgaard's perspective, scientific communities share among their members a similar perspective that has the following elements:

a) a subject focus;
b) underlying assumptions of the factors they study (for example the nature of human agency);
c) assumptions about the larger world they do not study (for example assumptions about predictability);
d) the type of models they use;
e) the type of methods they use;
f) the audience they strive to inform through research (ibid.:972).

Scientific communities thus exhibit similarity in some basic, paradigmatic characteristics. The suggestion is that that is an important condition or enabling factor for successful interdisciplinary collaboration, and that the discipline a researcher belongs to is less relevant.

How to move forward to overcome the problems in interdisciplinary research that have been outlined above? In procedural terms, and as far as the university context is concerned, there seems to be little alternative than to adopt the conventional liberal attitude discussed by Kann: reason, tolerance and self-reflection to further intellectual development, while being aware of the inherent politics of disciplinary and interdisciplinary academic practice. This awareness must be translated into organised communication around interdisciplinary research questions—a rational organisation of dissent.

4. Towards Effective Interdisciplinarity: Boundary Concepts, Boundary Objects and Boundary Settings

This chapter uses the metaphor of 'boundary crossing' as the *Leitmotiv* for exploring what it takes to achieve effective interdisciplinary research.[44] Metaphorically speaking, the question is what kind of gates, bridges, and other cross-over devices and procedures should exist at the boundaries to make efforts at interdisciplinary research more effective. The framework presented suggests that three things are required: suitable boundary concepts, adequate boundary objects, and conducive boundary settings. In all likelihood we need all three simultaneously. In some more detail, the basic argument is that effective interdisciplinary analysis and action poses the following three requirements.

1) The development of *boundary concepts* that allow us to think, that is conceptually communicate about, the multidimensionality of the issues we study and address.
2) The configuration of *boundary objects* as devices and methods that allow us to act in situations of incomplete knowledge, non-linearity, and divergent interests – characteristics of most concrete natural resource management situations.
3) The shaping of *boundary settings* in which these concepts, devices and methods can be fruitfully developed and effectively put to work.

The chapter thus hopes to present a framework with the aid of which the relevant issues in designing and practising interdisciplinary research can be thought through systematically. Practical solutions to concrete problems in research projects are not found here – these, of course, have to be articulated in each specific, that is, localised and embedded, problem setting. The framework's main value is that it can help to 'rationalise dissent', that is to help disentangle the often confused, and heated, debate regarding the problems of interdisciplinarity.[45]

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[44] The assumption is that those involved in interdisciplinary research are genuinely interested to achieve interdisciplinarity. That is, the assumption is that those involved have a basic attitude that recognises that the different (disciplinary) perspectives and approaches that exist – including their own – have their limitations and can provide only partial insights and partial solutions to the problem at hand, and that therefore ways need to be found to bring these different perspectives and approaches together in a (more) comprehensive mode of analysis and problem solving. This attitude can by no means be taken for granted, even in research projects explicitly defined as 'interdisciplinary'. By participants in these, interdisciplinarity may simply be treated as a label required by research funders, a criterion/hurdle to get research approved and supported, with the major task being to 'package' disciplinary research in such a way that the funders are convinced it is interdisciplinary. A less devious factor that may undermine the basic assumption is implicitly assumed superiority of a certain discipline, perspective or approach.

[45] My starting point is the existence of different institutionalised disciplinary perspectives and approaches regarding a research object or problem. This is not a statement of principle, but a practical observation that most interdisciplinary research at this time and age has to be forged from and by researchers trained and situated in a disciplinary context otherwise pursuing disciplinary research interests. Arguably, the number of 'hybrid' researchers is increasing, but critical mass remains small, and counter-incentives strong, at least in the academic domain. Moreover, the problems that interdisciplinary research addresses are just one class of problems; many others are better addressed through disciplinary work. Interdisciplinary research will thus always be a component of the overall body of research only, even when the problem definitions of disciplinary research might be increasingly derived from interdisciplinary analysis of larger scale issues. It therefore seems reasonable to me to assume that in the foreseeable future the existence of disciplinary boundaries has to be taken as a given, and that crossing them will continue to be problematic. Speculatively I suggest that it is perhaps not surprising that some of the most interesting initiatives for interdisciplinary research come from outside the university domain – an institutional structure that tends towards disciplining of researchers into given boxes. Two such other domains are the corporate sector and social transformation oriented NGOs/activists networks. Both are driven by strong 'complex problem solving' concerns, though of a very different nature – how to accumulate and make profit; how to change/save the world. If this is correct, this reasoning provides an extension to the observation above that most efforts at interdisciplinary research by universities are 'policy driven'.

In using the term 'boundary crossing', I follow Klein (1996). There are many boundaries to cross in interdisciplinary research. These include the boundaries between disciplines, which, apart from cognitive, have territorial and cultural features as suggested above. Also included are the boundaries between science and policy, between science and professions, and between science and societal interest groups. It depends on the scope and objectives of the research how many of these apply. Because a lot of interdisciplinary research, particularly larger projects and programmes, is policy-driven, aiming to contribute to resolving complex problems in society, the interfaces between research and professional practice, between research and policy, and between research and society are usually part of the research design.[46]

'Boundary crossing' is a useful metaphor because it quite accurately captures a number of dimensions of interdisciplinary research. 'Boundaries' is also a theme in the social studies of science and technology[47], and there is thus a theoretical reference for the metaphor. A large part of that literature focuses on the question how boundaries in science and technology are established and maintained or guarded. This applies to boundaries within science (disciplines), between science and society (scientists and lay people), between science and policy, and between science and professional domains (see Gieryn (1983) on the demarcation of science and non-science, and Halffman (2003) on the science-policy boundaries in regulatory – eco-toxicological – science).

The main concern in the present paper is how boundary *crossing* might be accomplished. The seminal paper regarding this question is Star and Griesemer (1989). It introduces the notion of 'boundary object', which they define as follows.

> "Boundary objects are objects which are both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use, and become strongly structured in individual use. These objects may be abstract or concrete. They have different meanings in different social worlds but their structure is common enough to more than one world to make them recognisable, a means of translation. The creation and management of boundary objects is a key process in developing and maintaining coherence across intersecting social worlds." (Star and Griesemer, 1989:393)

This somewhat cryptic description suggests that boundary objects are the things (devices, people, institutions, organisations, procedures) we use to do boundary crossing, to negotiate the different discontinuities in a given scientific/research situation.

In the Museum of Vertebrate Zoology at the University of California case that Star and Griesemer analyse, the social worlds that intersect are that of

> "university administrators who were attempting to make the University of California, Berkeley, into a legitimate, national-class university; amateur collectors who wanted to collect and conserve California's flora and fauna; professional trappers who wanted skins and furs to earn money; farmers who served as occasional field workers; Annie Alexander [who organized and funded the building of the museum], who was interested in conservation and educational philanthropy; and Joseph Grinnell [director of the museum], who wanted to demonstrate his theory that changing environments are the driving force behind natural selection, organismal adaptation, and the evolution of species." (Fujimura, 1992:172)

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[46] For example, all research plans of the CGIAR (Consultative Group on International Agricultural Research) institutes and programmes have to specify the 'impact pathways' of that research: how research output translates into societal impact, who are involved in this process and what are the methods deployed for achieving it. Contribution to concrete problem solving and the need for 'stakeholder involvement' are part of the European Commission's research funding policy also, as they are of much policy related funding bodies' research strategies.

[47] Or, science and technology studies (STS). Gieryn (1983) has been labelled the seminal publication that established the study of boundary processes in science and technology development. For a review of the literature on boundaries see Halffman (2003). There is also a field of studies called 'boundary studies' or 'borderline studies' that focuses on boundary crossing in the literal sense of processes that happen across and by virtue of geographical and political boundaries. This literature is briefly reviewed in Klein (1996). It is not a point of reference here.

Specific 'boundary objects' helped to engineer agreements across these different social worlds. These included

> "the museum itself as a repository, ideal-type concepts like species and diagrams, coincident boundaries like the outline of the state of California, and standardized forms like the forms Grinnell developed for trappers and amateur collectors to fill out when they obtained an animal." (*ibid.*: 173)

The framework presented here elaborates this notion of 'boundary object' into a trilogy of boundary concepts, objects and settings.[48]

4.1 Boundary Concepts, or, Thinking Multi-dimensionality

Boundary concepts are words that operate as concepts in different disciplines or perspectives, refer to the same object, phenomenon, process or quality of these, but carry (sometimes very) different meanings in those different disciplines or perspectives. In other words, they are different abstractions from the same 'thing'.

The concept of 'water control' is a good example to illustrate what a boundary concept is. The notion 'water control' is used in different disciplinary domains, referring to the same object (irrigation water management), but looks at this from very different perspectives and with very different interests. Three dimensions of water control can be distinguished (see Table 2).[49]

TABLE 2: THREE DIMENSIONS OF WATER CONTROL

Dimension	*Association/meaning*	*Disciplines*	*Example references*
Technical control	Guiding-manipulating-mastering of physical processes	(Civil) engineering, soil mechanics, hydraulics, hydrology, agronomy, meteorology, agro-ecology	Plusquellec, Burt and Wolter (1994: 35)
Organisational control	Commanding-managing of people's behaviour	Management science, extension science, public administration, organisation sociology	Hunt (1990: 144), Huppert (1989: 35), Lowdermilk (1990: 155)
Socio-economic and political control	Domination of people('s labour) Regulation of social processes	Political economy, economics, rural sociology, political science, social and cultural anthropology, gender studies, agrarian history, law	Stone (1984: 202), Boyce 1987: 198-199, 229, 233), Enge and Whiteford (1989: 5-7)

Source: Adapted from Table 2.1 in Mollinga, 2003: 38.

Technical, organisational and socio-economic/political control are generic categories. Within each category several forms of control can be identified – a true 'polyphony of meaning' as Löwy (1992:375) calls it. However, water control as a boundary concept is more than an ensemble or catalogue of meanings referring to the same process. The different dimensions of water control as referred to by the different disciplinary abstractions, are not independent, but are intimately related.[50] They define each

[48] Note that Halffman (2003) speaks of boundary work, boundary devices and boundary configurations, a vocabulary with a strong family resemblance with that used here, but addressing a different primary concern – that of the demarcation of science and policy.

[49] For detailed discussion see Bolding, Mollinga and van Straaten, 1995; Mollinga, 2003. Quotes from the different literatures using 'water control' as a concept can be found in Mollinga (2003).

[50] The empirical evidence underpinning this statement was generated through a historical case study of the introduction of the so called block system of irrigation management in the Nira Left Bank Canal in the Bombay Presidency (present Maharashtra), India in the early 20th century (Bolding, Mollinga and van Straaten, 1995), and

other: changes in one dimension trigger or require changes in the other two. Technical, organisational and socio-economic/political control are mutually constitutive, that is, internally related.[51]

A comprehensive understanding of water management practices would – thus – require understanding not only the different dimensions of it separately, but particularly their interrelations. This requires interdisciplinary thinking on the multi-dimensionality of this particular phenomenon (how does technical design influence management forms, how does political regulation shape organisational practices, etc.). 'Water control' as a concept can serve the purpose of generating such interdisciplinary analysis as it is what Löwy (1992) has called a 'loose concept'. By establishing or recognising a common concept across disciplinary boundaries, a cognitive space is created in which the multiple meanings of it can be elaborated. Interdisciplinarity is, according to Löwy, sometimes better served by not very precisely defined concepts that create space for creative exploration, than by tightly and precisely defined concepts that close off such space.[52] In the case of water control an effort at defining the concept precisely would probably amount to one of the perspectives trying to impose its particular reading of it. As these different disciplinary fields have been using the concept largely in isolation from each other, the point exactly is to raise curiosity in the 'foreign' meanings 'across the border', in order to move towards joint and interdisciplinary understanding.

There are many other concepts that have the feature of carrying different meanings in different disciplinary domains while referring to the same object. Examples relevant to natural resources management analysis include the concepts of value and valuation, scarcity, efficiency, risk and vulnerability. The fact that all these concepts are the subject of contestation in development policy debates may indicate that the interrelations of the different meanings/dimensions is a significant issue, but not something common understanding is reached on easily.

Sometimes multi-dimensionality is captured by designing a new concept. This seems to have happened with the concept of 'ecosystem services', which has now officially been mainstreamed on a global scale through the *Millennium Ecosystem Assessment* (MEA, 2005).[53] This concept allows ecologists, economists, sociologists and other disciplines to have a common language on the usefulness of ecosystems to human society. Together with value and valuation, much more contested concepts, it is an important building block for understanding, and acting upon, ecology-society linkages.

Another class of boundary concepts is the case of the same word/concept being used in different (disciplinary) domains not referring to the same object, but to one role, function or property of a series of objects. One example is 'capital' as used in livelihoods analysis frameworks.[54] That framework speaks of five 'capitals' as being important for people's livelihood strategies. These are natural capital, physical capital, human capital, financial capital and social capital. In this case the concept 'capital' refers to a similar role or function of a series of different objects for human beings: that of 'endowment' or 'resource' or 'asset' for pursuing livelihood strategies. In that sense it can be considered as a boundary concept.[55]

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the study of water management practices in the Tungabhadra Left Bank Canal, Karnataka, India in the early 1990s (Mollinga, 2003). Other studies have confirmed the intimate relations between the different dimensions of water control, but a substantive discussion is not entered into here. The purpose is only to illustrate the basic idea of what a boundary concept is.

[51] For the notion of 'internally related' see Sayer (1984).

[52] Löwy develops her analysis of the 'strength of loose concepts', and their potential value for interdisciplinary analysis through a discussion of the concept of the 'biological self' in the domain of immunology, a concept that was developed at the boundary of clinical practitioners and academic researchers active in this domain.

[53] The MEA (2005) synthesis report categorises ecosystem services into supporting, provisioning, regulating and cultural ecosystem services (p. vi).

[54] For a description of livelihoods analysis frameworks, see for instance http://www.livelihoods.org/ (accessed 8 October 2007).

[55] The choice of 'capital' as the word for this similar function has, however, clear political overtones also (cf. Harriss, 2001). It is debatable how much analytical work the word 'capital' actually does other than providing an umbrella term. An example where one word used to describe different objects seems not to do much analytical work is 'landscape'. This is no longer used only for physical landscapes, but also for social landscapes, cultural landscapes, 'waterscapes', and several other variants. 'Landscape' may be a useful metaphor in each of the added

Both 'water control' and 'ecosystem services' suggest that a boundary concept is more than a single word. When explored actively, operationalisations will be generated that give the concept 'body'. Furthermore, concepts are the building blocks of theories and models, and there may thus also be boundary theories and boundary models. The major challenge here is to theorise and model[56] the features of the complex systems that we refer to with terms like socio-technical, socio-ecological, socio-natural, or other hybrid categories.[57] To my knowledge, as of yet, no classification of types of boundary concepts exists that provides a systematic exploration of the different ways it can be understood and used.

To conclude this section, boundary concepts thus help to address what were called above the syntactic and semantic problems in interdisciplinary research. They help to create a vocabulary by means of which researchers from different disciplines and philosophical persuasions[58] can deliberate more fruitfully on common concerns and questions, by theorizing the 'intimate relations' of the different dimensions of a given research object. Put differently, boundary concepts aid to re-integrate the different abstractions made by the different disciplines. Well developed boundary concepts allow productive use of the plurality and polyphony of meaning that the diversity of scientific disciplines and approaches tends to produce.

4.2 Boundary Objects, or, Shortcuts to Progress for Acting under Uncertainty with Incomplete Knowledge[59]

If decision-makers would have to wait till comprehensive analysis of a problem situation, based on a fully developed causal, explanatory theory, would be available, they would never be able to take a decision.

Natural resources management systems are complex systems that exhibit non-linear behaviour. Many of the mechanisms operative in it are contingently, that is externally, related.[60] This is true for the physical

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domains of application, but seems not to do any work in analyzing the potential relationships between these different 'scapes'.

[56] I follow Britt (1997) here as regards the role of conceptual modelling in research seeking to produce causal explanations of concrete phenomena. In this perspective it is the richness of the concepts used that determines the quality of the explanation, as richer concepts allow more refined identification of the causal mechanisms at work and their interconnections. This applies as much to research that uses mathematical modelling as its analytical method and medium of expression, as it does to qualitative analysis through thick description.

[57] 'System' is perhaps a kind of meta boundary concept (all research aimed at causal explanation of specific phenomena has some sort of 'system' as the object of analysis, which all researchers 'model' in some way or another). System, and 'systemness', is understood very differently in different domains. This is unsurprising as the concept immediately leads to fundamental ontological and epistemological questions. Interestingly the study of complex systems and their emergent properties is an issue increasingly addressed in a variety of fields (randomly selected sources from a vast literature on complexity and complex systems are the Princeton Studies in Complexity book series, see http://www.pupress.princeton.edu/catalogs/series/psc.html; the journal Complex Systems, see http://www.complex-systems.com/, and the New England Complex Systems Institute (NESCI), see http://www.necsi.org/).

[58] Whether they do indeed help to overcome differences in 'philosophical persuasions', that is, in basic ontological and epistemological premises, or views of science, is a debatable point. As different 'persuasions' have different understandings of causality and explanation, among other things, this type of boundary crossing may remain elusive. Joint, concrete engagement with a particular research object may serve as a mechanism to let the testing of theory against reality do its good work, though in practice competing explanations and approaches can be very tenacious. Interpretative approaches to scientific analysis may feel excluded by, and take objection to, such formulations (though their strength is exactly to map the subtlety and plurality of meaning).

[59] Students of African development will know the phrase 'shortcuts to progress' as part of the title of Hyden (1983), being '*no* shortcuts to progress'. This refers to the *Ujamaa* development strategy in Tanzania in the 1970s, and other planned development attempts in the continent. Not only models of development may be too simplified, lacking sufficient empirical reference, and projecting unrealistic futures. The same is true for analytical and decision-making models deployed to help us design policies and technologies. The section title is thus meant to express a note of caution also, while acknowledging the existence and necessity of boundary objects for acting in development.

mechanisms at work, while the social mechanisms at work have the additional property that they can change. Social systems are open systems in which human actors can learn or otherwise decide to change the structural properties of the system. The structure and behaviour of natural resources management systems is thus not only location specific, but also historical, that is, such systems are variable in both space and time, and their development is inherently unpredictable.[61]

Increasingly pertinent demands are made, however, on scientific research to come up with useful and usable knowledge for addressing the complex societal problems of our time, including that of NRM. This creates a dilemma. Given the state of knowledge of the complex systems of NRM, plus the inherent nature of such systems, there is a problem for science to produce 'authoritative knowledge'. Responses to this that say 'be patient, and wait till science has advanced to the point that we know enough about this issue', or, 'we don't know enough therefore we cannot say anything', are unhelpful and unacceptable for decision makers – among others. Decision makers' time-horizons are short, and issues like sustainable NRM too important to be 'left on their own' for some time. Moreover, arguably, we are unlikely ever to reach the point of sufficient knowledge – given the evolving, changing nature of the systems concerned. Therefore 'shortcuts to progress' are needed. Science has to find ways to contribute useful and usable knowledge to decision-making processes in situations structurally characterised by incomplete, and sometimes unreliable, data, uncertainty, non-linearity and unpredictability.[62]

Science has attempted to cope with this in a variety of ways, which can not be comprehensively reviewed, or even listed, here. Generically, I suggest there are, in practice, three different ways in which science and scientists try to 'cut through' this problem, trying to adequately respond to society's demand for useful and usable knowledge to address complex NRM problems. I call these three 'routes', as they are ongoing journeys that could possibly also converge.

The analytical route: models as boundary objects

The analytical route attempts the modelling of the behaviour of complex systems, focussing on the key elements and relationships of a given situation/problem. The basic idea is that when these models represent reality's behaviour adequately enough, they then lend themselves for use as decision support systems.

On the science side of this type of approach a huge amount of (disciplinary as well as interdisciplinary) research has taken and is taking place on how to do best the modelling of the behaviour of different kinds of NR(M) systems – be it through the application of chaos theory to physical and biological systems, the development of Agent Based Modelling of social and hybrid systems, or any number of other scientific approaches.[63] The idea is to get a model 'running' that represents reality well enough to ask it 'if-then' questions: 'if this change or intervention would occur, then what would be the effects', or, 'if I want to achieve a particular effect, then what inputs or changes are needed'? The insight into the system

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[60] As Karl Marx said a very long time ago, "[t]he concrete is concrete because it is the concentration of many determinations, hence unity of the diverse." (Marx, 1973:101).

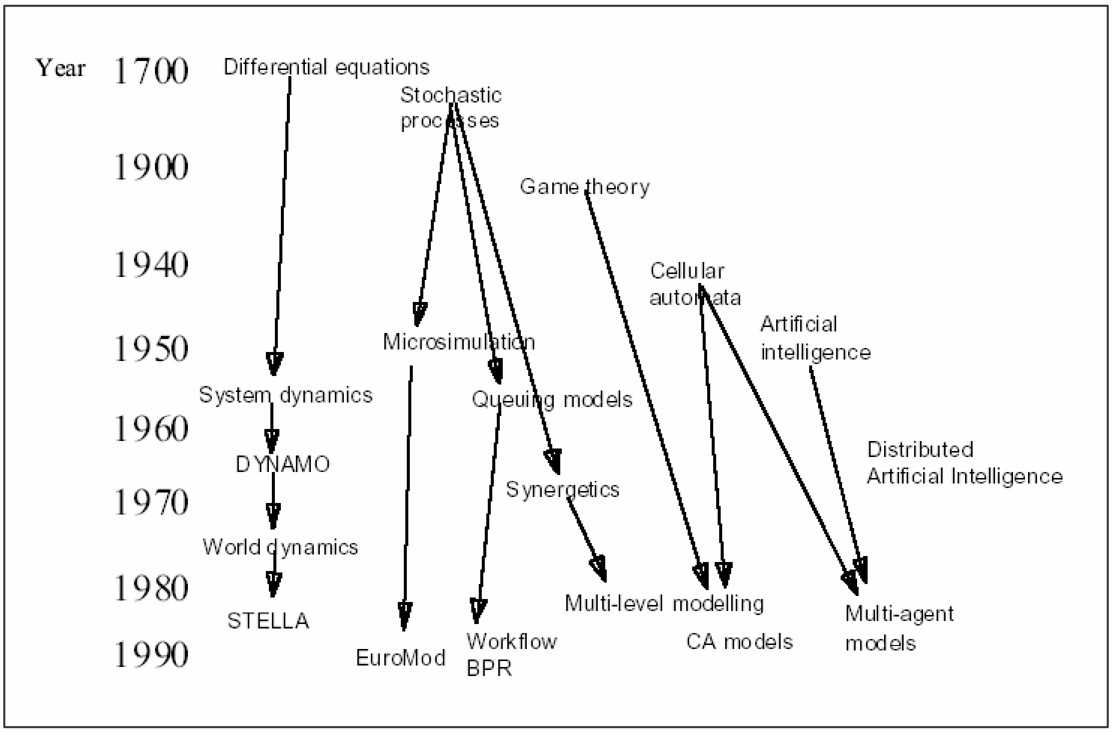
[61] This is the basic insight that informs approaches to 'adaptive management' of natural resources. The title of TERI and IISD (2006) summarises the perspective well: *Designing policies in a world of uncertainty, change, and surprise. Adaptive policy-making for agriculture and water resources in the face of climate change.* This research report contains an extensive literature survey on the topic.

[62] The need for 'shortcuts' is not exclusive to interdisciplinary research, but may exist in disciplinary research as well; it is, however, particularly pertinent in interdisciplinary research like that on natural resources management.

[63] In the 1980s many people in environmental studies supposed that (finally) one theory of environmental relations would define this (meta)discipline. (Zandvoort, 1995) That hope seems to have been abandoned. The practical state of affairs is that we have theories and models for certain parts or dimensions of complex systems, but not for the whole, and a wide variety of approaches as a result. On the natural science side these are better developed than on the social science side, partly caused by the different nature of the phenomena at hand. As noted above, social systems are not only open and evolving, but also learning systems, that is, system properties can change through purposive human action, and, in principle, in very short time frames. The most concerted effort at integrated theorisation/modelling across the natural/social divide is the integration of economics and the physical and technical sciences.

behaviour that the model embodies, is instrumentalised as a decision support system (DSS).[64] Scenario-development, simulation modelling, and the development of decision tools for specific issues, are typical examples.[65] By means of illustration, a diagram summarising the history of simulation modelling in the social sciences is reproduced in Figure1.

FIGURE1 HISTORY OF SOCIAL SCIENCE SIMULATION MODELLING



Source: Gilbert & Troitzsch, 1999

However, the track record of such science-driven decision support tools is rather weak, that is, very few make it to actual active use, at least in less-developed countries, but probably in industrialised countries also. The reasons for this can be understood by considering the following three points: 1) the reasons for limited 'uptake' by potential users, 2) the lack of attention to the process dimension of modelling, and 3) the use of models as a resource in contested decision making rather than as a neutral mediating tool.

The example of crop simulation models meant to help farmers to make crop choices or decide input levels and cultivation practices, can serve as an example to illustrate the problems that may be associated with the 'uptake' of science-based decision support tools. Though the scientific quality of such models may be high, the uptake in actual decision-making is very poor (see Stephens and Middleton, 2002). Stephens and Middleton suggest that crop simulation models are used only by researchers and hardly ever outside the research domain. "Attempts to use models for the direct benefit of small-scale farmers and extension workers in less-developed countries (LDCs) appear to be still in their infancy." (ibid.:131). The authors suggest that seems to apply more generally (ibid.: 129-131). Positive examples come from developed countries and the commercial sector in developing countries, but it has also been reported that in 1990 less than 5% of Australian farmers used DSSs (ibid.:131). The reasons why uptake of these models is poor are summarised in Box1.

[64] Almost anything that is used in decision making can be called a decision support system, and it is therefore a very unspecific term. The meaning implied here is DSSs as analytical tools used in decision-making that work on a 'good science' principle, that is, try to understand actual system behaviour as the basis for considering options for intervening in its behaviour and development.

[65] Five case examples briefly discussed in Cash et al. (2003) are CIMMYT's efforts in the 1990s at enhancing agricultural productivity, the management of aquifer depletion in the U.S., the use of El Niño forecasts, the management of ocean fisheries, and the negotiations of transboundary air pollution, with references for further discussion.

Box1: Reasons for poor uptake by users of agricultural DSSs

Model Construction Constraints
- Inappropriate focus on scientific issues
- Not relevant to routine on farm decisions
- No clear advantages
- Questions are asked in the wrong way
- Failure to define target user group of client
- Failure to involve the client in the model development

Marketing and Support Constraints
- Poor marketing
- Poor dissemination
- Lack of training in the development and use of software
- Short shelf-life of DSS software
- Institutional resistance

Technical and Operational Constraints
- Poor access to hardware and software
- Lack of data
- Limited validity of models in less-developed countries
- Poor user interface

User Constraints
- Lack of faith in models' predictive powers
- Technophobia

Other Constraints
- Importance of the policy environment
- Problems with acting on decision support
- Lack of validity of model outputs

This example may perhaps be taken as illustrative for the problems involved in the use of real-system modelling-based DSSs in NRM. One weakness of the 'analytical route' seems to be how to make the knowledge, or the methodology to produce knowledge, that science develops, practically 'work' in concrete situations.

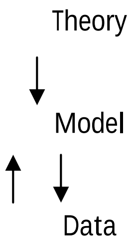
This leads to the second point regarding the weak track record of science based DSSs. Underlying these approaches is often a rather simple notion of 'good science gives good decisions'. However, it is increasingly recognised that science to have impact in the real world needs to fulfil not only the criterion of credibility, but also that of salience and legitimacy (Cash et al., 2003).[66] Scientists and engineers have traditionally focused on *credibility*; that is, how to create reproducible and scientifically accurate information to address a given natural resources management problem. Sources of knowledge must be deemed trustworthy along with data, theories, and causal explanations and physical mechanisms. However, knowledge also needs to be salient and legitimate. *Salience* refers to the relevance of

[66] I owe this reference and subsequent description to Prof. Shafiqul Islam, Tufts University, USA. I gladly acknowledge the inspiring exchange on interdisciplinarity in water resources studies we had in 2005-2006. The Cash et al. (2003) paper from which this is drawn, makes the following, sobering, problem analysis. "Efforts to enhance [the] capacity [to promote sustainable development] over the past quarter century range from developing more efficient cook stoves for burning biomass, to nurturing an international system for agricultural research, to applying [science and technology] to the challenges of stratospheric ozone depletion. In this pursuit, there have been few successes and many failures." (p.1 of 6) The paper also has an interesting classification of the ways in which scientific knowledge may impact policy and practice of NRM: 1) through influence on 'policy issue evolution', a long term process of agenda setting, 2) by directly addressing a specific issue, where the questions of credibility, salience and legitimacy come in, 3) by doing 'boundary work', and develop boundary-spanning institutions or procedures (*ibid.*: 1 of 6). This runs parallel to a considerable degree with the boundary concepts, objects and settings subdivision developed in this paper.

information for stakeholders and decision makers. Information needs to be timely, accurate, and specific for it to be salient for real world applications. *Legitimacy* refers to the fairness of the information gathering process. For a process to be legitimate, it needs to consider appropriate values, interests, concerns, and specific circumstances from perspectives of different users. If salience and legitimacy aspects are not adequately addressed, knowledge may remain unused.

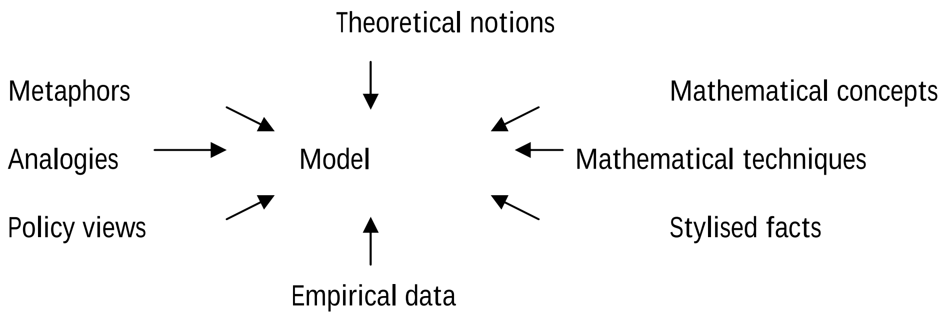
This consideration of salience and legitimacy issues is not fully external to scientific activity, but also internal. This can be clarified by looking at the nature of modelling activity, that is, at modelling as a social process or practice. Models are usually conceived by scientists "as instruments to bridge the gap between theory and data", as represented in figure 2 (Boumans, 1999:93).

FIGURE 2



Boumans argues that in actual fact "models integrate a broader range of ingredients than only theory and data", as depicted in Figure 3 (*ibid.*:93).

FIGURE 3



Modelling is thus mediating work – hence the title of the book in which Boumans' paper is included: 'models as mediators' (Morgan and Morrison, 1999).[67] In other words, models, certainly those of complex systems, are 'cognitive boundary objects'. They bring together, and assemble, different types of knowledge, including (policy) objectives and other normative claims. Such objectives and normative claims may also be present in the way facts are stylised (because processing, ordering and simplification tend to involve selection and making information suitable for certain specific purposes). Salience and legitimacy can be addressed and the concerns related to it incorporated in this manner, provided this assembly and mediation work is self-consciously undertaken and not left implicit, under the cover of neutrality and objectivity.[68] Cash et al. (2003) come to a similar conclusion. "(...) because different actors often want different outcomes from applying [science and technology] to sustainability problems,

[67] Morrison and Morgan (1999) is an excellent introduction to the mediating role of models. They want to produce "and account of models as *autonomous agents*, and to show how they function as *instruments* of investigation" (ibid.:10). For this they look at how models are constructed, what the functions of models are (theory construction, measurement, design and intervention), whether and how models represent reality, and how models are used for learning. For an interesting paper on the epistemology of simulation, discussing modelling as a specific kind of practice, see Winsberg (1999). Also see Fox-Keller (2000).

[68] On the social construction of national economic models, see Bogaard (1999).

effective knowledge systems must also serve as venues for negotiation and mediation." (p.5 of 6). If models and modelling would be conceived more self-consciously in the way depicted in figure 3, the way would be open to reconsider and reshape the *process* of knowledge production, and issues of salience and legitimacy could be much more easily addressed in research activity. This process dimension is the emphasis of the 'participatory route' discussed below.[69]

The third point regarding the track record of science-driven DSSs regards the use of models as political resources. Models themselves can become resources in social and political decision-making processes. King and Kraemer (1993) show how in economic government policy decision making in the USA different lobby/interest groups use different models, assumedly suiting to their own viewpoint, in order to influence decision making. As a result, the models themselves become the subject of political contestation. This suggests, once more, that an understanding of models as neutral, objective mediators between interest groups is not tenable. Models may or may not function as boundary objects for integrating or mediating different types of knowledge, and they may or may not, as decision support systems, function as boundary objects mediating the interaction of the different interest groups involved in the issue for which the model is meant. Strategic deployment of models in decision-making processes to legitimate certain positions, or push certain agendas, seems to be very common, though such observations generally causes considerable uneasiness among scientists when made explicit. As Cash et al. (2003) note, many scientists find participation in mediation and negotiation as part of developing knowledge systems for sustainability "at best uncomfortable and at worst inconsistent with real scholarship." (p.5 of 6) At the same time "many managers see participating in [knowledge] systems [for sustainability] as at best an expensive time investment with uncertain returns and at worst a risk to their perceived autonomy and independence." (*ibid.*:5 of 6) There are thus still a few boundaries to cross.

The concrete scientific outputs that the 'analytical route' approaches produce are operational models of the behaviour of NRM systems, intended to be used in policy and management decision making. If they are actively used, they can operate as boundary objects connecting science and policy makers and/or science and the professional domain of resource managers, and/or science and resource users, or a combination of these actors groups, and provide them with a common tool. The scope and purpose of such models can range from being a technical tool for NRM decisions by a single stakeholder, to scenario building exercises for global policy formulation. They can also function as bringing together, integrating or mediating different kinds of knowledge, including policy objectives and other normative claims, and thus function as 'cognitive boundary objects' for interdisciplinary analysis.

However, as noted above, this promise is not always, and as it looks like, not very often, fulfilled. There can be good reasons for limited uptake of good quality science; the process of modelling as an activity is underemphasised, thus ignoring issues of salience and legitimacy of knowledge; and models can themselves be political resources in decision-making processes, and are not always, if ever, neutral, objective mediators of different knowledge claims and interest groups. Some of these issues are addressed in the two other 'shortcuts to progress' as regards useful and usable knowledge for NRM decision making, to which I now turn.

The assessment route: frameworks as boundary objects

The development of 'frameworks' is at present probably the most common strategy in the field of natural resources management to achieve integration and interdisciplinarity. It is closely associated with the practical problem solving orientation of much disciplinary and interdisciplinary NRM research. Given the fact that development funding and other intervention-oriented agencies support much of that research,

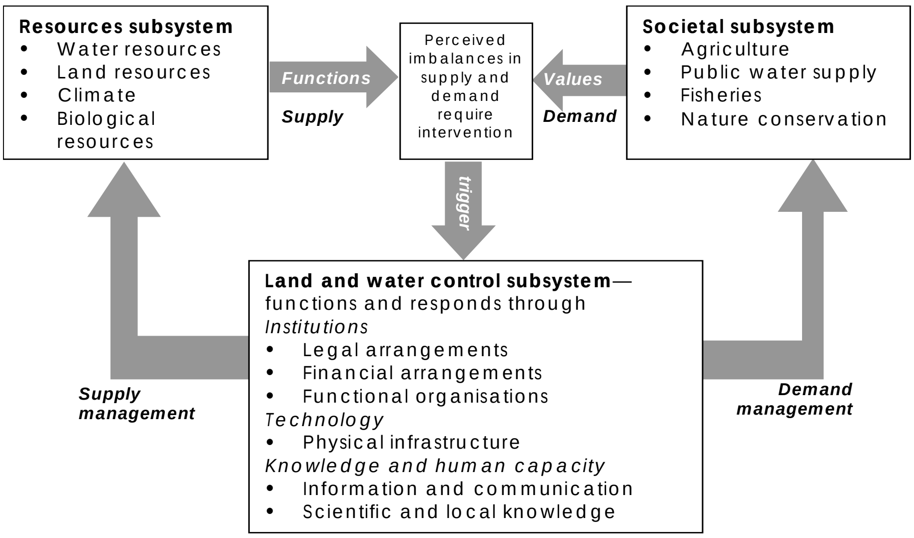
[69] The case of models as decision support systems for farmer decision making, and the problems associated with their use has been intensively discussed for the case of Australia (see McCown, 2002; McCown, 2005; McCown, Brennan and Parton, 2006; McCown and Parton, 2006; I thank William Stephens and Rolf Sommer for these and other references on experiences with modelling for farm-level decision making). The direction into which this discussion is moving is the development of approaches that strongly emphasise process, famers' lifeworlds, and the construction and negotiation of meaning (critiquing approaches primarily based on a concept of information transfer).

the desired outcome of research projects is often defined not only in cognitive terms, but also in terms of policy recommendations and frameworks for action.

With 'framework' I refer to a conceptual construct with limited theoretical (explanatory) ambition as such, but which is mainly oriented towards bringing together different pieces of knowledge together in a 'workable' manner. These are 'models' and are often called as such, but they do not have the objective to adequately represent the behaviour of a particular NRM system. Frameworks are simplified, generic conceptual models, often in the form of an 'assessment framework'. Frameworks have practical purposes, ranging from ordering data to be collected to assisting decision-making. They are simplifications of complex realities, summarising the main features, factors and mechanisms in relation to a given problem in a manner that allows deriving practical conclusions for action from it.

Figure 4 gives an example of a framework for an integrated analysis of drainage. The figure is taken from a World Bank technical paper (Abdeldayem et al., 2004). It aims to situate drainage, usually only discussed from an agricultural production perspective, as part of both a broader natural resources system and of society, and to develop a practical tool for designing and implementing 'integrated' drainage interventions.

FIGURE 4 THE THREE SUBSYSTEMS OF THE SOCIOECOLOGICAL SYSTEM: THE RESOURCES SUBSYSTEM, THE SOCIETAL SUBSYSTEM AND THE LAND AND WATER CONTROL SUBSYSTEM



Source: Adapted from Slootweg, Vanclay and van Schooten 2001.

What the framework says is that to understand drainage in an 'integrated' manner and identify its relation with NRM and society, two concepts can be usefully employed: functions (or ecosystem services) and values. 'Functions/ecosystem services' summarise the properties of natural resources systems by identifying the environmental goods and services that such systems provide: processing and regulation functions, carrying functions, production functions, and significance functions.[70] 'Values' is the concept

[70] This is a slightly different (and older) classification of functions/ecosystem services than presented above when referring to the Millennium Ecosystem Assessment (MEA). This illustrates that despite the apparent simplicity that 'frameworks' often exhibit, they black-box a lot of underlying conceptual work. 'Frameworks' can attract a lot of academic critique, in which they are 'deconstructed', and their biases revealed. One very clear example of this is the livelihood analysis framework, as developed and popularised particularly by DFID (the U.K. Department for International Development). See for instance O'Laughlin (2004) for an excellent review and critique of livelihoods analysis and frameworks publications, which in her view tend to present themselves as "a method without a theory" (ibid.:387). Given their pragmatic orientation, frameworks are inherently political, and therefore inevitably biased or selective, while, paradoxically, development assistance, and academic, discourse often demands the denial of that. In this author's view critiques that hold against 'frameworks' the fact that they are biased and selective

through which societal preferences, perceptions, and interests with regard to functions provided by natural resources are summarized. These values are social, economic, and (temporal and spatial) ecological values. Drainage is part of a land and water control system, with certain composing elements: institutions, technology, and knowledge and human capacity. This is a formal summary of the system properties of human-made socio-technical systems for the regulation of the behaviour of land and water resources. The mechanics of the ensemble is cast in an economic vocabulary of supply and demand. The basic idea is that mismatches between the supply of environmental goods and services and societal demand trigger interventions and changes in specific land and water control systems. The framework can be developed as an analytical tool (functions and values analysis and assessment) and as a planning tool (embedded in a participatory planning process). What could be added to it is a social impact assessment component, to identify the 'winners and losers' of development interventions.

In the context of this discussion it is relevant that this framework is not meant to be a new scientific theory or model of socio-ecological dynamics, but a *practical tool* for enabling interaction and decision-making across different disciplines and concerns. It is full of black boxes: functions, values, system, supply, demand, *et cetera*. All of these mobilise elaborate bodies of literature. In the eyes of all disciplines concerned this framework would be regarded as a very violent abstraction or crude simplification when seen as an analytical, explanatory model. However, as stated, that is not its purpose. It is an attempt to simplify so much that interdisciplinary interaction becomes possible, while keeping it conceptually sophisticated enough to generate sufficient theoretical depth in operationalisation and application. The latter is done by a set of marker-concepts that refer to specific bodies of theory and methodology, like for example environmental and social impact assessment.

The framework presented is a very simple one, and possibly, and hopefully, a first step toward more differentiated approaches. However, such simplicity is a feature of many assessment frameworks and procedures, like those for biodiversity for example.[71] It is exactly that which makes them attractive to and usable for decision-makers.[72] 'Frameworks' are thus typical examples of boundary objects, building connections between the worlds of science and that of policy, and between different knowledge domains.

Assessment frameworks do not always address the process dimension of their use as an explicit part of the framework. Environmental Impact Assessment (EIA) frameworks are an example – they are mostly basically a protocol for producing an EIA report for a decision-maker, usually a government. Assessments may be mandatory as defined in law and policy (like for instance in land use planning, licensing of industry establishment, and the like), and the process therefore may already be defined. However, there is increasing pressure to enhance 'stakeholder involvement' in NRM management, governance and policy making processes, with implications for the organisation of the assessment *process*. In many contexts also, the process may not be defined at all, and many interest groups excluded from the processes of NRM decision-making. Some of these issues are addressed in participatory route approaches towards useful and usable knowledge on NRM, to be discussed next.

The participatory route: processes and people as boundary objects

The development of participatory approaches to knowledge system development for NRM may have somewhat different reasons in the relatively highly regulated and data and resource rich industrialised countries, and in developing countries with relatively low levels of environmental regulation, and severe constraints in data and resource availability.

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miss the point. 'Frameworks' *have* to be biased or selective – the question is how exactly, for what purpose, and for whose benefit.

[71] For more examples and background information, see the website of the International Association for Impact Assessment (IAIA) http://www.iaia.org/. The Association also publishes a journal *Impact Assessment and Project Appraisal*.

[72] Something similar is the case as regards the use on 'indicators' for monitoring policy implementation processes, and development processes more generally. A well known example is the Human Development Index. For a critical discussion of the efforts to develop a Water Poverty Index (WPI), and the pitfalls in this shortcut to progress, see Molle and Mollinga (2003).

What is lacking in most approaches as referred to under the analytical and framework routes, is explicit and detailed attention to (social) learning and political mediation/negotiation as part of knowledge system development for sustainable NRM (Pahl-Wostl, 2002; Dutton and Kraemer, 1985). The 'third route' type of approaches for dealing with uncertainty, unpredictability and complexity emphasise exactly this dimension: the social process through and in which knowledge is generated, negotiated and used as the key factor in designing 'adaptive responses'.

I use the 'Rethinking the Mosaic' approach developed by a group of Nepalese and Indian researchers for adaptive water resources management as the illustrative for this third route.[73]

The 'Mosaic' approach states the complexity and uncertainty issue as follows.

> "Since both natural and social conditions are changing and subject to substantial uncertainty, we cannot make linear plans that will solve water problems for our lifetimes or for future decades. Instead, we need the capacity (information, forums and processes for decision-making, legal and regulatory mechanisms, executive capabilities, and governance with embedded dispute resolution mechanisms) to enable society to respond to constraints that could be local or regional, short or long-term, political, economic or technical. This is the real challenge." (...) (Moench et al., 2003:3)

The statement is that the core of adaptive capacity is a set of specific institutional arrangements and their related processes that allow sensible responses to emerging and evolving NRM problems. This emphasis on process is further elaborated as follows.

> "[M]uch greater effort is needed to devise management approaches that can adapt to:
> - Hydrologic variability;
> - Limited amounts of data and basic scientific knowledge;
> - Social, demographic, technical, institutional and economic change; and
> - The fundamental dynamics of human organisation and politics."
>
> "Specific solutions are less important than the existence of processes and frameworks that enable solutions to be identified and implemented as specific constraints arise and contexts change." (Moench et al., 2003:9, 9)

It is thus suggested that the process of knowledge generation is *part of* the process of adaptive response, implying a continuing process of learning, rather than bringing to bear prior and/or externally developed knowledge. This is partly out of necessity. In many natural resources management situations in developing countries (and industrialised countries to a lesser, but certainly not negligible degree) basic

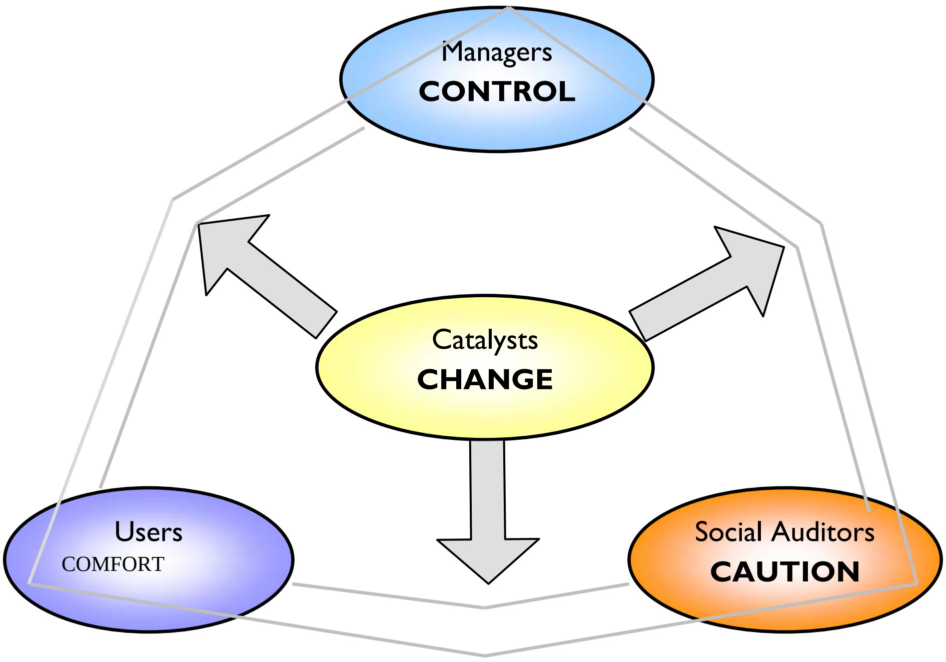
[73] However, there are several other examples. An argument for participatory model building in watershed planning in the USA can be found in Loucks (1998) He argues, "The need for model building tools that can be used by all stakeholders to build their own models and databases, ones that they will have confidence in and have a feeling of ownership, has never been greater. These tools must provide opportunities for participation in the watershed model building and testing process by all interested stakeholders, without any of them having to engage in computer programming. These tools must be suited to building models that consider ecosystem restoration and watershed protection along with economic development and costs. The models built from these tools must cross disciplines and include multiple objectives without perceived bias. (...) The development and use of models must facilitate an open decision-making process, not a closed one." (ibid.: 41) In a very different domain, corporate management, participatory model building of organisations is a developed practice. See for example the website of the Interdisciplinary Institute of Management (IIM) at the London School of Economic and Political Sciences (LSE). For a cautionary tale about 'optimisation' oriented modelling see Haimes (2000) who argues, "(...) the optimum *doesn't exist in an objective sense per se.* An 'optimum' solution to a real life problem depends on myriad factors, which include who the decision makers are, what their perspectives are, what the biases of the modeler are, what the credibility of the database is, etc. Therefore, a mathematical optimum to a model does not necessarily correspond to the optimum for the real-life problem." (ibid.:40-41; his emphasis) For a discussion of how the application of system analysis in water management in Germany happens as part of a political process, see Schultz (1989). For an example interdisciplinary participatory research in wetlands conservation, using 'asset-maps' as a tool, see Wali et al. (2003). For agroforestry, see the 'Co-Learn' collaborative learning tool (URL: http://www.cifor.cgiar.org/acm/ accessed 8 October 2007) and Van Noordwijk et al. (2001) on 'negotiation support systems' in the agroforestry domain.

information necessary for understanding even only physical behaviour of the NR system concerned has not been collected. Historical data is often not available or not reliable, and cannot be recreated. In real situations researchers (and decision makers) often have to accept they will have to deal with absence or partial and fragmented availability of data and information. This is not only a historical problem. It is very unlikely that there will ever be sufficient resources available to do the fine grained data collection in all relevant places that is necessary for precise analysis. What can be concluded from this is that approaches for analysis and assessment have to be designed in such a way that information generation and iterative learning-by-doing are central features of the management approach.

Moreover, natural resources management situations can be highly heterogeneous, again particularly starkly in developing countries, but again this is certainly not fully absent in industrialised countries. Physical heterogeneity is evident in some landscapes like steep mountain areas with very different ecosystems at very close distance, but a characteristic of many areas – in different ways. Social heterogeneity can take many shapes and forms. In terms of knowledge, different groups of people may be the carriers of different kinds of knowledge, and there may be large social barriers for sharing that knowledge across groups. Knowledge held by state and scientific organisations may be very poorly accessible to marginalised communities, or to the public at large. The existence and value of local knowledge may not find acknowledgement by state and scientific organisations. Different groups may also have very different understandings of apparently the same problem. Underlying such heterogeneities and divisions are often broader social relations of class, gender, caste, and other categories, and regional, organisational, or other vested interests – knowledge is indeed power in many situations. What can be concluded from this is that knowledge system development must be conceived as an inherently political process, in which not only different perceptions but also different interests need to be mediated.

Different categories of people play a role in the institutional arrangements and processes that are necessary for sensible 'adaptive responses', including knowledge generation and negotiation. The 'Mosaic' approach models this as in Figure 5.[74]

FIGURE 5 THREE STRANDS OF EFFECTIVE RESOURCE USE



Source: Moench et al., 1999:xii

[74] A very insightful paper on adaptive co-management is Ruitenbeek and Cartier (2006), focusing on forestry. Adaptive management strategies are an important policy and research priority in the context of the European Union's Framework Directive for integrated water resources management (see for instance Pahl-Wostl, 2002). For ongoing debate and exchange on 'adaptive management' see the NeWATER project website at www.newater.info .

Moench et al. distinguish four categories of actors, each with their own 'logic'. Change agents (pursuing, obviously, change) push against the network of relationships of resource users (interested in comfort, that is reliable resource use and access) and managers (focused on controlling the NR system and other aspects of the situation), and of a third category that Moench et al. introduce, that of social auditors. The latter are "the 'watch dog' social activists as well as various organs of the state that are responsible for assuring appropriate justice." (Moench et al., 1999:xi) In this scheme the balance of power in the process of resource planning is the central issue. The key elements of an effective governance structure required for this process according to this perspective are (Moench et al., 2003: 61-62):

1. Freedom of information (and access to the diversity of information sources).
2. The right to organise (social demands need to be articulated in organisations).
3. Explicit or implicit mechanisms to balance power in society (constitutions, separation of powers, representative forums, arbitration etc.).
4. Enabling financial mechanisms (f.i. access to resources for marginal groups).

The point in the context of this discussion on interdisciplinarity is that processes and people (and the institutions and organisations they create) are the boundary object through which integration of knowledge is achieved – or more correctly put for this example, through which integrated forms of knowledge are generated. This perspective strongly resonates with the literature on action research, local knowledge, participatory technology development, and other 'participatory approaches' in (rural) development, and in a broader sense with the literature on innovation and social learning.

When research and capacity building are situated in such an interactive, participatory and negotiation-focused process, the role of the expert-researcher differs rather strongly from 'conventional' academic pursuits. S/he becomes a (political) actor in a development process, rather than a neutral outsider, and will have to consciously address the issue of 'knowledge as a resource' in the power struggles that are part of natural resources management policy and practice.

Convergence?

The three different routes towards interdisciplinarity can be characterised by their basic strategies for knowledge integration: 'conceptual/theoretical modelling', 'pragmatic mapping and assessment' and 'communication and negotiation for social learning and transformation'. In principle the three different routes could converge into a single one. Both the 'assessment' and 'participation' route would benefit from analytical models that identify the causalities, trends and forces in the system better. The 'assessment' route's focus on problem solving may be strengthened by adopting the 'participation' route's emphasis on mobilising local knowledge, contextualisation and negotiation. The 'analytical' route could benefit from the grounded knowledge that the other two routes provide. However, in practice these routes seem to be associated with different policy and political standpoints and strategies. The 'assessment' route seems to be primarily associated with state/government and development assistance initiatives, the 'participation' route with civil society and 'alternative development' initiatives, and the 'analytical' route more with (relatively) independent academic work, or at least 'science-driven' work.[75]

This situation of practically few signs of convergence extant, is not unlike that at the conference described by Kann, summarised earlier in this paper: socio-political constituencies and standpoints map onto scientific groupings and approaches. This raises the general issue of the relationship between politics and method (see for instance Massey and Meegan, 1985). However, enquiry into this relation shows that there are no simple 1:1 relations in this respect. At a more practical level, this means there is room to manoeuvre to forge more comprehensive integrative approaches to the development of knowledge systems for sustainable NRM, and human development more generally. This is the agenda of transdisciplinary research as discussed above. There may thus be an inter- or transdisciplinary, adaptive or integrated Rome to which all roads lead, but there are still quite a few potholes, diversions and other obstacles to be negotiated *en route*. Some of these have to do with the context and setting of such endeavour, which is the topic of the next section.

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[75] This statement is somewhat speculative and would need research on the evolution of natural resources management research and its driving forces for substantiation.

4.3 Boundary Settings: Getting the Structure and the Process Right

The discussion of (the problems in) interdisciplinary research above already suggested that there are both incentives working for and disincentives working against the credibility, salience and legitimacy of interdisciplinary research. In order to flourish, interdisciplinary research needs a conducive, enabling environment or setting. This environment or setting can be divided in two, interrelated parts: firstly the internal organisation and dynamics of the specific research activity (project or programme) under consideration, and secondly the broader external environment in which that activity is embedded.

The first, 'internal' dimension refers to a series of organisational features of research projects and programmes.

- how it creates sub-units to implement the research work, nowadays often called 'work packages'; [76]
- which data sharing procedures it adopts;
- what intra-project research funds allocation procedures are used;
- how it organises communication among partners;
- how quality control is assured;
- on what criteria staff working in the project is recruited;
- what frameworks for internal learning are created;
- *et cetera*.

The second, 'external' dimension refers to a series of different factors. Given that much interdisciplinary NRM research is funded in the context of global, regional or national policy initiatives for sustainability or policy reform, it is not surprising that the priorities of the funding organisations of such research have a strong impact on the research projects. In some contexts there are legal regulations as regards to the conduct of the research, for instance prescriptions for stakeholder involvement and consultation as part of plan development protocols. The university as an institutional and organisational environment produces certain incentives and disincentives, and other constraints and opportunities for interdisciplinary research. Furthermore, internal and external factors are not independent, and may influence each other.[77] Part of the external boundary settings of interdisciplinary research (and of any research) are more general societal conditions like the governance conditions mentioned in the previous section, like free access to information. The existence of such conditions are not self-evident in much development research, particularly in the setting of an authoritarian political regime for instance, or in (post-)conflict situations.

Put in the metaphorical frame of this paper: for interdisciplinary research to work, a lot of 'boundary work' and 'boundary management' is necessary to align the different views, interests, approaches etc. into a joint endeavour, that is get the structure and process right, and achieve the objective of

[76] My—admittedly unsystematic—sampling of interdisciplinary research projects on NRM suggests that they are often internally organised in 'boxes' (work packages) divided along disciplinary lines, with a separate 'integration' box. This may defy the objective of interdisciplinarity, except when there is a fully agreed and developed interdisciplinary analytical framework, which is usually not the case. See Pohl and Hirsh Hadorn (2007) for 'principles for designing transdisciplinary research', looking both at internal organisation and embedding of research. Also see Klein (1996) for detailed discussion of the characteristics of successful and unsuccessful interdisciplinary research.

[77] One example of the relation between external and internal environment was given in the discussion of the research project in Section 3: the research funder (external) influenced the composition of the team, and the role different team members were going to play in the research (internal). Apart from the external setting influencing the internal dynamics and *vice versa*, conceptually, the very distinction is problematic. For instance, the individual attitude or disposition of a researcher active in a project may, in the first instance, be considered as an 'internal' matter, but that attitude or disposition emerged from, and expresses to some extent a history of socialisation in a scientific environment with certain structural properties, of which this person is the social carrier. Despite these conceptual complications, distinguishing between how a project is internally organised, and how it relates with the rest of the world is a useful heuristic.

interdisciplinary analysis and action. Cash et al. (2003) summarise how effective knowledge systems are organised as follows.[78]

1) They treat boundary management seriously.
2) They have dual accountability.
3) They make use of boundary objects.

Knowledge systems that take boundary management seriously invest in communication, translation and/or mediation, and thus balance credibility, salience and legitimacy. Communication has to be active, iterative and inclusive. Translation is necessary because mutual understanding is often hindered by jargon, language, experiences and presumptions about what is a convincing argument (see the discussion of syntactic and semantic problems above). Mediation is necessary because there are trade-offs between credibility, salience and legitimacy, which may lead to conflicts among partners/stakeholders. The point is that none of this happens automatically. It needs conscious design of structures and procedures through which these processes can happen effectively. Individualistic as scientists tend to be, they are often not prepared to take such aspects of 'boundary work' and 'boundary management' seriously. That the appointment of experienced 'boundary managers' might be useful, also seems to be an uncommon consideration.[79]

Accountability is as important an issue in research projects and programmes as it is in, say, good public governance. Particularly the acceptability of boundary managers is crucially important, which can be strongly enhanced by clearly defined accountability rules and procedures. This is true for discipline-discipline boundaries, as well as for researcher-resource user, researcher-professional manager, and researcher-policy decision maker boundaries. Dual accountability induces boundary managers to look for balanced solutions to problems through inclusive processes of interaction and decision making.

The use of boundary objects refers to the deployment of specific devices to facilitate the processes just described. As suggested above, there are many different kinds of boundary objects, ranging from repositories (like databases), expert systems, joint protocols, models of different kinds (physical, mathematical, simulation, etc.), assessment frameworks, but also devices/technologies like Computer Aided Design software (see Carlile, 2002), and also people can function as boundary objects (or, rather, perhaps, subjects) (see Frost et al., 2002).[80]

In summary, to create settings conducive for effective interdisciplinary research, the generic requirements are:

1) favourable organisational and institutional structures and arrangements,
2) inclusive and transparent interaction, management and governance processes, and
3) smart tools that can function as boundary objects in the conduct of collaborative scientific practice.

[78] Their analysis refers to science-policy interfaces/boundaries in research. The principles are, however, in the view of this author equally applicable to the internal organisation of research projects.

[79] For a description of the creation of a specific 'boundary organisation' to achieve an integrated approach, see White et al. (2008).

[80] For use of 'boundary object' and 'boundary-ordering device' as concepts in different concrete settings, see for example also Fujimura (1992), Shackley and Wynne (1996), Chrisman (n.d.), Ackerman and Halverson (1999), and Arias and Fischer (2000)

5. Some Concluding Remarks

Even when this paper exceeds 40 pages, it still is only a relatively sketchy and descriptive treatment of the issues related to the conduct of interdisciplinary research on natural resources management. Those who would explore some of the literature in the list of references, would soon discover that on each of the issues presented a rich body of work exists, in which a diversity of perspectives can be found. The main objective of this paper has been to present a framework with the aid of which readers can start to explore the issue of interdisciplinarity somewhat systematically.

The 'boundary crossing' framework presented is very straightforward in some respects. It basically states that doing interdisciplinary research in a context of societal problem solving (like in the case of NRM) requires three types of boundary work:

- *analytical* work to be able to think across disciplinary boundaries, that is, to be able to conceptually (and by inference, methodologically) capture the multidimensionality of complex problems (product: boundary concepts);
- *instrumental* work to be able to make knowledge useful in concrete settings of decision making or other forms of action and intervention by designing appropriate instruments for that (product: boundary objects);
- *organisational* work to shape incentives, processes and organisations, and people's knowledge, skill and attitudes in such a way that they facilitate interdisciplinarity (product: boundary settings).

All three types of boundary work have their own 'science'. How to go about them is itself the subject of scientific analysis. This is part of the professionalization of interdisciplinary research that is slowly happening through systematic reflection on its practice. This means that for the design of new interdisciplinary research an increasing volume of intellectual resources is available to draw *'how to'* ideas from.

A question often asked about interdisciplinary research is whether there is any theoretical challenge in it, or that it is basically about 'applying' existing theory, without 'original' or 'fundamental' theoretical work. The presentation in this paper suggests that inter- and transdisciplinary research provide opportunities for theory development in at least three different ways.

1) The first, suggested immediately above, is the development of a science of inter- and transdisciplinarity as such. In the vocabulary of the framework developed in this paper this would mean theorising the different types of boundary work required.
2) A second type of theory formation lies in the development of boundary concepts, or more generally put, the theorising of multidimensionality and complexity.
3) A third and large terrain for theoretical work is the development of inter- and transdisciplinary method. This theme has not been discussed explicitly in this paper, but the framework presented above does require methodological translation. Just like disciplinary theories are difficult to combine, so are disciplinary methodologies. The combination and translation problem presents itself at all levels of methodology – from data collection and analysis techniques (f.i. issues of qualitative and quantitative methods, space and time scales for data collection, and many other issues), to types of research (f.i. comparative research, case study based research, experiment based research, etc.), to overall differences in approach (f.i. structural *versus* historical approaches, and others).

I have attempted to avoid making a normative statement on how interdisciplinarity *should* be done, and have tried to focus on presenting a systematic overview of issues related to conducting it. Nevertheless, in line with some of the insights presented in the paper, no perspective can be totally neutral and objective. Speaking from a certain standpoint is inevitable. The best service to objectivity is to make that standpoint explicit. Here are, to conclude, some of its key elements.

The paper is certainly influenced by my earlier experience of intra-interdisciplinarity at the Irrigation and Water Engineering group at Wageningen University, the Netherlands, but probably more so by the experience at ZEF, since 2004, of involvement in larger-scale interdisciplinary research projects. The fact that a prime theme of the paper is the classification of the problems associated with doing interdisciplinary research, reflects the experience that achieving cross-departmental and cross-disciplinary collaboration is, indeed, quite a struggle. A lot of the presentation was born out of the effort to understand the problems that I was also personally experiencing in specific research projects. It is very clear from the literature that the difficulties experienced at/by ZEF are very common. Therefore, the classification of problems and the elements of the framework are, I believe, not locally specific but quite generic.

Where the standpoint from which I look at interdisciplinarity shines through most clearly, is in the quotation of Lele and Norgaard on disciplines and communities and the discussion of Burawoy's division of labour matrix. Lele and Norgaard basically state that framing the problem of collaborative research in terms of the difficulty of making disciplines work together is misleading. What really counts is commonality in approach, which defines a scientific community and is not discipline-dependent. One might say also, what counts is the 'paradigmatic fit' in the interdisciplinary research group or team. This strongly resonates with my own experience in interdisciplinary research projects, and hence my emphasis on it.

I have used Burawoy's matrix to describe my standpoint on water resources studies elsewhere (Mollinga, 2008), and that perspective is also part of the presentation in this paper. A lot of research on natural resources management falls into Burawoy's upper, instrumental half of the matrix, and, in my view, too often lacks the reflective dimension of the lower half. The standpoint is that critical and public forms of natural resources management studies merit strengthening. As Burawoy argues, to avoid the potential pathologies of each of the four different approaches these approaches should preferably stand in a relationship of 'antagonistic interdependence'. That is a different way of saying that interdisciplinarity is about the 'rational organisation of dissent', the phrase I chose as the title of this paper.

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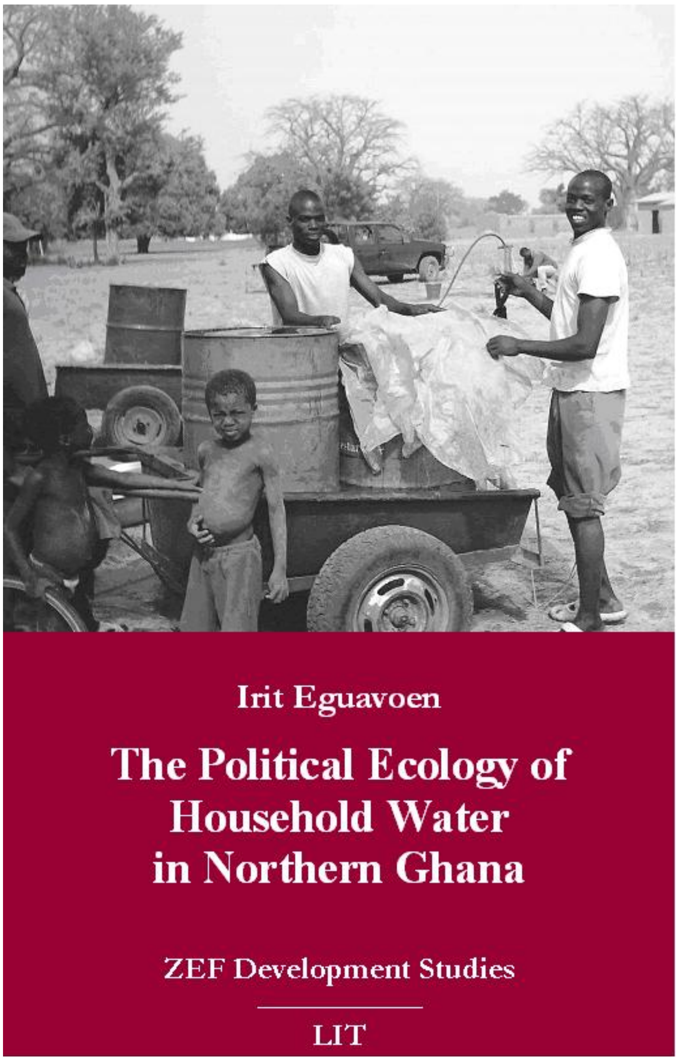

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