# Implicit Sociology, Interdisciplinarity and Systems Theories in Agricultural Science

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## Abstract

*Recurring political and economic crises in agriculture lie behind policymakers' demands for more interdisciplinary, problem-solving approaches. This article examines different systems theories in agricultural sciences that claim to adopt interdisciplinarity and to bridge a supposed gap between the natural and social sciences. It analyses the debates and differences between so-called 'hard systems' and 'soft systems' approaches, or positivist and interpretative approaches. It aims to make the confrontation between these two approaches more legible as well as to reveal the shortcomings of each position. In particular, the implicit and unsophisticated sociology underlying the hard systems approach is a key issue. Critical realist theory is explored as an alternative to both the hard and the soft systems approach towards interdisciplinarity since it opens up space for thinking in a non-reductionist way about multiple determinations without rejecting the value of single disciplines for uncovering the working of important causalities.*

## Introduction

The notion of 'interdisciplinarity', by which I mean the integration of natural science, science-driven engineering and social science, forms an important part of the critique of reductionist approaches in agricultural science and is also used to translate academic science into a 'science for impact'. The term implies that a single discipline alone cannot adequately meet the major challenges faced by the agro-food sector and that only an interdisciplinary, collaborative focus can resolve complex contemporary problems ranging from environmental degradation and climate change to the low productivity of small farmers in the South. Indeed, the notion of interdisciplinarity also calls into question the problem-solving power of an agrarian sociology that is unconnected to other disciplines.

Discussions on interdisciplinarity in the agricultural sciences predominantly focus on issues of organising group work and communicating research questions and outcomes. Only to a lesser extent are ontological claims about the separateness or connectedness of the social and the natural worlds examined. This latter task, which involves exploring interdisciplinarity beyond the issues of process (communication, interaction) and rethinking the content (or object) of science, questions disciplinary boundaries much more strongly. Systems theory is one attempt to integrate the different claims or subject matter as constructed in the separate disciplines. This article examines the ways in which system theories in agricultural science, particularly those relating to cropping and farming systems in developing countries, have tried to connect the natural, technical and social elements of agricultural production. Although systems theory does not enjoy a high status in contemporary social theory[1)] it remains an important source of inspiration for scientific networks undertaking interdisciplinary research and action in the field of agriculture. As these networks are strongly involved in the technical and social engineering of the world around us, they warrant critical analysis. Applied sociologists and anthropologists participating in such networks have accepted, either loosely or stringently, the usefulness of systems thinking for bridging the work of the natural and social sciences (e.g., Fresco 1986; Röling 1999; Bawden 2005). In studying the deployment of systems thinking, the aim of this article is not to reinstate the concept of system in social theory but merely to reflect on its usage in the world of interdisciplinary agricultural science.

To illustrate the argument, this article draws on the debate in Wageningen University (the major Dutch life sciences university in the field of agriculture) between two systems approaches. At first sight, the debate appears to take the form of a confrontation between natural science and social science. On closer inspection, however, it involves a much more complex entanglement of arguments about the relationship between the natural and the social, and the proposed methodologies for researching these fields. The participants themselves have characterised the debate as one between a ‘hard system approach’ and a ‘soft system approach’ (Röling and Leeuwis 2001; Tuinstra *et al.* 2002). The latter sees itself as the critical opponent of the (supposed) positivism of the former by arguing that systems, system boundaries and input–output relationships cannot be defined in a fixed way but are subject to varying meanings according to the different actors involved in examining or acting in these systems. The first section of this article analyses the scope of this critique, which has been presented as a sociological critique of natural science and technical engineering in agriculture. The next sections explore how each approach considers the role of the social in explaining system behaviour. Subsequently, the article reconsiders the debate between hard and soft system approaches by drawing on critical realist theory (Archer *et al.* 1998).

## Methodological individualism and empirical realism in system approaches

Current system thinking in agricultural science has strong roots in both theoretical production ecology and farming systems research (FSR). Production ecology, which draws on the natural sciences and on agronomy, plant physiology and soil science in particular, studies the relative importance of growth factors and inputs (integrating basic information on physical, chemical, physiological and ecological processes) in explaining actual yield levels and resource-use efficiencies. It has developed a series of complementary crop models in order to simulate crop performance under a wide range of conditions (Ittersum *et al.* 2003). By analysing differences between potential and actual yield levels the approach proposes strategies for system improvement (Bindraban *et al.* 2000; Ittersum and Rabbinge 1997 p. 198).

FSR evolved about three decades ago out of the field of applied agricultural sciences, particularly those concerned with agriculture in developing countries. FSR criticised conventional commodity-oriented crop research undertaken by international agricultural research institutes for its inability to improve the agricultural performance of many poor farmers in developing countries. It aimed to close the observed yield gap between the high yields obtained on research stations and the actual yields obtained on farmers' fields (Fresco 1984). Whereas the production ecology approach investigates the yield gap by identifying the factor which most limits system improvement, FSR focuses on the problems of transferring technologies from high-tech experimental agricultural research stations to resource-poor farmers as well as the level of take-up of technology by imagined clients, such as poor farmers. A range of different explanations have been offered for the low take-up of technology by poor farmers. Among these are poor communication, which means that poor farmers do not always understand the technology, and the lack of technology that is adapted to the particular ecological conditions and/or to the economic, cultural and social circumstances of poor farmers and the farmers' own lack of resources. FSR argues that the work of social scientists and economists needs to be integrated from the start into the development trajectories of any new technology (new crop varieties, new production methods, new farming systems). It has developed a wide range of methods to involve farmers in the innovation process (Collinson 1987, 2000).

During the past two decades FSR and crop-growth modelling by theoretical production ecology have drawn closer together, thereby making their claims for incorporating social science into the modelling activities more or less explicit. At the same time the focus has shifted from the farm level to policy design at the regional or national level. System building and modelling are now viewed as key instruments for formulating land use scenarios that recombine and link 'science-driven technical information' with 'value-driven objectives' (e.g., Ittersum *et al.* 1998). Production ecologists use their simulation models to identify and make visible the consequences of specific policy decisions and the impact of management scenarios on land quality. For example, they aim to make the trade-offs between various policy objectives, such as pesticide input reduction, nitrogen surplus production, and farm income level more transparent (Ittersum *et al.* 1998; Bindraban *et al.* 2000; Stoorvogel *et al.* 2004). The claim of interdisciplinarity, by integrating the sphere of the social into agricultural science, appears to be predominantly based on two moves. The first move concerns the inclusion of such variables as farmers' decisions in terms of economic cost benefit and input–output reasoning into the model, while the second move concerns the inclusion of stakeholder views and decision-makers' preferences into modelling system behaviour. The first move results in the incorporation of economic data on farming (site-specific production, input and price) into bio-economic optimisation models. Bio-economic modelling approaches develop mathematical representations of managed ecosystems with the aim of predicting the effects of management decisions on those processes (Antle *et al.* 2001; Barbier and Bergeron, 2001; Ittersum *et al.* 2003; Antle and Stoorvogel 2006). The second move builds on the increased attention paid to farmer participation in the innovation process and a general revaluation of farmer knowledge, as initiated by FSR. This has led to the inclusion of a broader range of stakeholders in science-driven innovation processes in agriculture than previously occurred. For example, Ittersum *et al.* (2004) describe a systems research network that quantifies alternative land use options to support policy formulation. This approach considers the 'design of natural resource management systems as a learning and negotiation process, rather than a top-down decision process' (p. 103) and organises stakeholder participation at various phases of the research process.

These two moves to construct interdisciplinarity reflect a particular view on the kind of social science that should be included. A key feature is their individualist interpretation of the *farmer as decision-maker*, the farmer as 'homo oeconomicus', who behaves according to the assumptions of rational choice theory. This viewpoint originates from a basic tenet of FSR that holds that farmers operate *rationally* and respond in a utilitarian way to the cultural context, the availability of technologies and existing market relations, and to bio-physical production conditions. In this view, farmers are neither resistant to change nor traditional in outlook but are oriented towards making the best choices under given conditions.[2)] Here, the farmer is regarded as a rational individual actor who chooses between different technological options by employing some universal, pre-given categories (profit maximisation, risk reduction, optimal cost-benefit relationships, optimal yields). These accounts assume that all crucial conditions or 'facts' (prices, risks, potential yields given certain factor combinations) as well as the decisions taken by individual farmers can be measured or calculated, and the resulting regularities developed as theory. In this 'hard systems' 'individualistic sociology', farmers as decision-makers are regarded as conventionally deciding upon given facts (Bhaskar 1989, p. 22).

There is a long history of sociological critique (by different schools) of such methodological individualism. People do not passively observe and react to a given world but are active agents in a complex but structured world (Bhaskar 1989; Archer 1996a, 1996b). According to this perspective, farmers should not be seen as flat social figures who are restricted to moving the bio-physical blueprint of cropping systems to output A or output B but are otherwise powerless to influence the bio-physical and social determinations of cropping systems. Preferences of farmers are not essences, which are given or which are innately attached to individuals, as many economic theories presume, but are better theorised as the rapidly shifting outcomes of interaction, for example, after communication between farmers. In other words, rather than interpreting variations in farmer decisions as rational choices of a universal type responding to different factor endowments, they can be examined as a reflection of the different pathways people follow through interaction chains that emerge out of a set of complex and dynamic conditions. In this sense, farmer decisions are the precipitate of past interactional situations (Collins 2004).[3)]

Apart from its methodological individualism, the second characteristic of hard system approaches that is open to discussion relates to its attempt to integrate bio-physical and economic variables into a single model. Hard system approaches of this form tend to consider the social field as empirically real, that is, one that can be directly observed, measured and quantified, and thus one that is capable of being mathematically modelled. Bio-physical factors are seen as the primary determinants of farm systems, while socio-economic factors are merely modifiers of farm systems. The social field is reduced to farmers' individual preferences, choices or decisions (assuming that these remain constant if other external factors remain constant) and the task of science is to identify and record any regularities.[4)] In this way, methodological individualism is closely linked to empirical realism. As the nature of the social science perspective in hard systems approaches –its methodological individualism and empirical realism– is nowhere discussed in the hard systems literature, we refer to it in this article as its 'implicit sociology'.

A third element of this implicit sociology appears in those hard systems approaches that propose a rapprochement between scientific modelling and policy practice. This rapprochement assumes that science can aid decision-making by pointing out the consequences of diverse policy measures, derived from alternative values (such as cultivating crops with or without pesticides) (e.g., Bindraban *et al.* 2000; Ittersum *et al.* 2004). Contemporary systems thinkers have taken up the constructivists' idea that 'there is not a single "truth"' (Bouma *et al.* 2007, p. 263) and that different stakeholders make competing claims about the management of natural resources. However such statements tend to be immediately followed by positioning science outside the sphere of claim-making, emotion and interests. Such systems approaches separate 'science-driven technical information' (the outcome of hard system studies) from 'value-driven objectives' (e.g., the economic interests of farmers or policy aims of policymakers) (Ittersum *et al.* 1998; Sterk *et al.* 2006). The role of systems analysis is then currently seen as that of helping people (stakeholders, policymakers) by modelling the effects of different land use options to illustrate what might happen if certain values are translated into policies that change agricultural practices. Acknowledging the importance of divergent views, learning processes and stakeholder negotiations thus keeps the classical distinction between facts and values intact, in which science is concerned with the former and politics with the latter.[5)]

## Social constructivism in soft system approaches

Systems approaches such as production ecology have been characterised as hard system approaches (Röling 1999). Röling presents his approach as an alternative to hard systems thinking. He argues that land use is not solely defined by the variables and coefficients of the crop growth models of production ecology but is better regarded as the outcome of human interaction and agreement, learning, conflict resolution and (collective) action, which together can be labelled the 'soft side of land'. This argument goes back to the work of Checkland (1984) and his 'soft systems methodology' which claimed to offer a structured way of tackling badly structured problems without imposing the means–end reasoning of hard system approaches. Instead of the optimisation of the hard systems approach it proposes 'learning' as a key activity. Röling adopts a social constructivist position in the spirit of Berger and Luckmann (1967). Accordingly, he argues that 'Human behaviour is not so much determined by cause and effect, as by peoples' construction of reality, i.e., their *reasons*' (Röling 1999, p. 79). Human behaviour is driven by reasons, human intentions, perceptions and so on.[6)] 'Not only are all systems socially constructed, but most systems with apparently unproblematic goals and boundaries eventually turn out to be systems determined by human intentionality with arbitrary boundaries' (p. 81). The soft system approach attempts to bring together the different *Weltanschauungen* on a specific issue and to negotiate proposals for change. This makes it possible to take people on a learning trajectory, to become a collective with a shared definition of the problem, shared goals and an ability to engage in concerted action.

In his own work Röling adopts a number of different positions on how best to study nature and nature–society interactions. The first position Röling defends is one which advocates a hybrid approach 'that combines the causal logic of the sciences with the hermeneutic logic of the social sciences' (Röling and Maarleveld 1999). Underlying this position is the view that nature and society are essentially different and thus need to be studied by very different sciences. While nature can be approached by positivist science (*erklären*), the understanding of society and culture requires a hermeneutic or interpretive approach (*verstehen*) in order to capture the norms, values, meaning, cognitive abilities and so on that characterise human agency and inform, therefore, the way agriculture is practised. This view tends to regard natural science as positivist and positivism as inadequate for studying social processes. It separates social systems, processes, relationships and interaction from natural systems. The former cannot be explained by referring to non-social factors, that is, they do not depend on bio-physical powers: natural generative mechanisms do not play any role in them. Natural and social factors enjoy a different status in the explanation of culture. In this position 'culture' basically refers to knowledge (cognition, learning) rather than to practice, materiality and context. This definition, however, provides only a limited explanation of the social shaping of agriculture. Questions about this are reduced to the descriptions of agents who construct their view of reality through social interaction (see Berger and Luckmann 1967). This reduction tends to rule out any non-human causality.[7)] A Kuhnian incommensurability characterises many of Röling's statements about the contrasting paradigms of the natural and social sciences. Both have to exist and engage in 'a battle of paradigms'.

A second, rather different, position, which is also present in Röling's work, conflates the natural and the social into one and the same thing.[8)] This stance comes to the fore in his plea for holism. Like Checkland and other soft system approaches in agriculture (Bawden and Packham 1993; Bawden 2005), Röling views hard systems as a special case, a subset of soft systems. Both hard and soft systems should gradually be incorporated into a more encompassing 'holo-centric' paradigm, one that moves from reductionism to holism and from positivism to constructivism (Röling 2005).

The problem of holism is that it aims to explain the parts from the whole (a radical reversal of reductionism). However, the chemical properties of plant hormones, for example, cannot be explained by reference to farm systems. This critique of holism does not mean that there are no wholes. Both holism and reductionism stand in contrast to critical realism, which sets itself the task of identifying and unravelling the diversity of underlying mechanisms. In this view social practices (as well as bio-physical things and processes) are governed by a large number of mechanisms that may be triggered at different levels (such as the physical, the chemical, the biological, the social and the psychological). Critical realist theory "*allows us to conceive of real, irreducible wholes which are both composed of parts that are themselves real irreducible wholes, and are in turn parts of larger wholes, with each level of this hierarchy of composition having its own peculiar mechanisms and emergent powers*" (Collier 1994, p. 117).

## Interdisciplinarity that is neither hard nor soft

As indicated above, hard systems research networks have come closer to soft systems thinking over the last decade by incorporating stakeholder-based negotiations into the development of their research agendas. These new, integrated approaches, however, scarcely address the critical points mentioned above, nor do they transcend the terms of the debate between hard and soft systems thinking. The existing literature on this debate often supposes the existence of two opposing alternatives alone: a hard system approach that addresses facts and science and a soft system approach that addresses meaning, reason and values (e.g., Tuinstra *et al.* 2002). Brouwer and Jansen (1990) have pointed out that the hard system–soft system debate does not take note of other approaches, such as the critical systems approach, which have developed a consistent critique of both hard and soft system thinking.[9)] To date, the systems debate in agriculture remains trapped within the confines of a wider, dominant debate between positivism and constructivism. Mingers makes a similar observation about Checkland, the key soft systems thinker who 'takes positivism as the only alternative to interpretivism as a philosophy of (social) science' (Mingers 2000, p. 1266). In this opposition between positivism and constructivism three issues, which are important for the debate about interdisciplinarity in agricultural science, tend to fall by the wayside. These concern the analysis of power, the notion of open versus closed systems, and the notion of stratification versus hierarchy or a flat ontology.

Issues of power, inequality, and social structure have been seriously under-theorised in both hard and soft systems approaches. Encounters between *Weltanschauungen*, a core concept in the early versions of the soft system approach, are not free of power imbalances; the *Weltanschauungen* themselves are socially shaped and cannot be isolated from their political economic context (Brouwer and Jansen 1989, 1990). Neither hard nor soft system approaches provide concepts or methodologies to examine the source of power and domination. Although the notion of multi-stakeholder negotiations presupposes that participants have different interests and resources, these tend to be seen as static givens rather than the outcome of social processes, negotiation, contestation, or appropriation. Why some actor groups or 'stakeholders' participate or not in stakeholder platforms, or why and how specific actors and thoughts (reasons, values) are excluded, remains largely invisible. The current practice of multi-stakeholder negotiations has been characterised by its lack of a substantial theory to identify and understand power imbalances (Edmunds and Wollenberg 2001). There is little serious engagement within the hard and soft systems approaches with the rich field of political economy of agriculture and the contemporary sociological literature on agriculture and food. This somewhat conventional sociological critique in which the two dominant system approaches in agricultural science are held to either lack a theory (hard system approaches) or to have an underdeveloped theory (soft system approaches) of the causal properties of social difference (inequality, power, and generating social change), can be expanded into a more general discussion of causation. Accordingly, in the following sections we first discuss the problem of abstraction in open rather than closed systems and then address the issue of hierarchy.

*Closed and open systems*

The hard system approach composes its models from a set of known bio-physical laws. Most of these laws have been formulated from the results of creating closed systems in experimental settings; artificially produced environments under which some hypothetical mechanisms become observable. But this closure, this 'physical control over nature' (Sayer 1992, p. 123) is practically impossible to achieve when it comes to actual cropping and farming systems that are open systems. 'In open systems, mechanisms operate and have effects other than those they would have in experimental situations, due to the co-determination of these systems by other mechanisms' (Collier 1994, p. 36; cf. Bhaskar and Danermark 2006). There are hardly any regularities, as in each cropping season different factors may be important for effecting the outcome. Farmers may cultivate differently the following year because they have learned from previous experiences. Apparently small differences between two farm systems (differences that may not even be observable) can, over time and/or under varying conditions, develop into quite different farm trajectories (Jansen 1998). Farming conditions change continuously, be these internal changes in the field, such as soil degradation, a farmer's enthusiasm or loss of inspiration for experimentation or external changes, such as climate, prices or theft. Because of this openness of actual crop and farm systems, technologies developed on research stations, such as new crop varieties, will always lead to different and varied outcomes once adopted (and adapted) by farmers. The conditions and the internal dynamics of cropping and farming will always vary (and many of these variations are not directly perceivable) and result in multiple outcomes. In constructing models, the natural scientist works with research objects that lend themselves to the creation of closed systems to uncover mechanisms, whereas the farmer has to work in open systems where the effects may differ from those generated in experimental closed conditions.

Hard system approaches generally counteract this problem of openness not by recognising the difference between closed and open systems but by emphasising that the simulation models are still in development and that the models can be refined when more data become available. They thus retain the ideal of closure based on the notion that one can derive causality from observing and modelling regularities, for example, in farmers' management decisions.[10)] The constructivist, soft system position towards openness is that variation in system output is a logical consequence of human agency. It is the reasoning of the farmers and the meaning they attribute to their environment and the conditions of their work that define the system. In this way, Röling substitutes reasons for cause and effect relationships (Röling 2003). This interpretation of openness is also unsatisfactory. Firstly, natural systems themselves have to be regarded as open systems; it is not human reason that makes the system open but the multiplicity of causes and the manifold contingent relations. Secondly, the fact that a system is open does not mean that 'natural' mechanisms, revealed through isolation in closed systems under experimental conditions do not act upon the farm system. Crops only exist (presuppose for their effectiveness) when nutrients and water are available for plant growth. Constructivists have a problem in recognising these properties and the part they play in the farm system. For sociological contributions to interdisciplinary research to be meaningful, explanations cannot be solely based on reference to meaning and farmers' reasons to the exclusion of other properties of cropping and farm systems.[11)]

This argument about open and closed systems has implications for the soft system critique of hard system thinking. The problem of production ecology-based hard system thinking is not so much that the social (in the sense of reasons) is negated (as soft system critics argue) but that the role of experimental work in natural science is minimised, as is the possible importance of social mechanisms that are not directly observable. In hard systems thinking, modelling has surpassed experimentation in building explanations. Experiments have been assigned the function of testing models and determining coefficients, instead of testing hypotheses about as yet unknown mechanisms. This overemphasis on the power of modelling may draw attention away from the explanatory power of experiments. The extent to which models themselves can be seen as explanatory, as is often claimed (e.g. in Ittersum *et al.* 2003), can also be questioned. If this point holds, agricultural sciences should focus more on exploring causalities rather than less, as soft systems thinking proposes.

*Stratification versus hierarchy or a flat ontology*

The multiple determinations and contingencies in open systems should not be confused with an acritical, anything goes pluralism. The alternative to mechanistic reductionism is not holist idealism (Levins 1998). The wholeness of, for example, a farming system, can only be understood if we make distinctions between its relatively autonomous parts (plants, soils, seed selection, timing of planting and so on) and then show their interpenetration or mutual determination. This brings us to the notions of emergence and stratification, both of which are important for coming to grips with the openness of cropping and farming systems.

Emergent properties of cropping systems are the provisional outcome of a heterogeneous multiplicity of changing mechanisms, agencies, and circumstances. They exploit possibilities in nature that were not being exploited at the lower level (that is, at the chemical or biological level) from which these properties emerged (cf. Archer *et al.* 1998, p. 600). In other words, the properties of cropping systems and the output of cropping systems cannot be predicted from the properties of soils, water, or genes (and likewise neither from, for example, rural community culture) just as the properties of water (e.g., extinguishing fire) do not follow from the properties of oxygen and hydrogen (fuelling fire) and as the psychological properties of individual people do not predict the specificities of societies. This notion of emergence challenges both hard and soft systems thinking. It replaces the hierarchical separations of explanation found in hard systems thinking with thinking in terms of stratification, and it critiques the tendency in soft systems thinking to flatten out the social and the natural and to refrain from studying causalities.

The idea of hierarchy became prominent in agricultural system approaches through the work of Hart (1982, 1984). Hart describes agriculture as a hierarchy of systems wherein the cell is a lower level subsystem of the plant, the plant is a sub-system of the crop, the crop is a subsystem of the field and so on. Fresco developed Hart's model into a hierarchical systems approach with the aim of specifying the relationships in an agricultural system and deriving from this the nature of scientific inquiry required to understand such a system (Fresco and Westphal 1988; Fresco *et al.* 1992). This approach distributes the traditional disciplines into horizontal, single level disciplines (e.g., entomology, soil fertility) and vertical disciplines (e.g., ecology or economics), which connect different levels in the hierarchy. Both types, it is argued, should be present in multidisciplinary teams. This model disconnects the different levels, locating the social at the higher level and what are seen to be pure bio-physical subsystems at the lower level. For example, the nature of seed is seen as given, natural, even where breeders have selected and improved seed by recombining traits. This disconnection contrasts with recent studies of seeds that show how historical changes in the gene composition of crop varieties are a product of social shaping. Corporate interests (Kloppenburg 1988), the organisation of formal breeding systems (McGuire 2008), and household level management of gene flow, partly shaped by gender differences (Nuijten 2005), co-determine with natural characteristics the gene composition of crop stands. This example of the social shaping of seeds raises two considerations that are difficult to fit into the hierarchical approach of agro-ecosystems. Firstly, the lower subsystems may be restructured by the whole. In other words, the whole does not just emerge from the subsystems but acts back upon them (Archer 1996a). These forms of structuring are not revealed by a form of inquiry into social mechanisms which is restricted to the higher level subsystems and views these as separate from the lower level ones. Secondly, the identification of a hierarchy in agro-ecosystems seems rather intuitive, basically referring to empirical entities (directly observable phenomena or events) and being constructed around a space component. The higher system levels occupy more space (cell–plant–crop–field–farm–village/watershed–region). This model primarily organises (disciplinary) research along the constructed separation of observable events (or subsystems) and not according to the type of mechanism to be explored. It thus overlooks the possibility, for example, that a plant-disease system may be successfully examined (i.e., provide reasonable knowledge) not only by plant pathologists but also by agronomists, soil scientists, geneticists, plant physiologists, sociologists, political scientists and so on, with each looking at (partly) different mechanisms to explain the same event (similar to the above-mentioned case of seed systems).

Hierarchical models were subsequently modified in an attempt to overcome the drawbacks of the classically outlined hierarchy in which bio-physical criteria were mainly used at the lower levels (cell–plant–crop) and socio-economic criteria at the higher levels (village, district) (Stomph *et al.* 1994). The alternative land-use model of these authors presents two hierarchical pillars, an 'administrative–economic' one (household members–farm household–village–country and so on) and a bio-physical one (crop/livestock–cropping/animal husbandry system–physiographic units at different scales). This pillar-type separation of the social from the bio-physical, however, supports my reading of the hierarchical systems approach which considers hierarchy not as levels of different mechanisms but as levels of phenomena. Hence, the embryonic idea that a hierarchy in agricultural systems could help to locate the scientific work of disciplines and the work of interdisciplinarity (as present in Fresco's earlier work) has not been explored to its full potential.

This comment on the use of hierarchy in hard systems thinking calls in its place for a non-reductionist interpretation of hierarchy, which can be better termed 'stratification'. Stratification means that the power or potentiality of a cropping or farming system to produce food and other useful matter exists in a different stratum from those of genes, nutrients, light, and water (that is, it cannot be reduced to the latter). Furthermore, while hierarchical systems thinking sees a cropping system as being located in one specific stratum, composed of and constituted by lower strata particles, the notion of stratification considers a cropping or farming system to be stratified in itself, being the result of a complex set of diverse mechanisms from different strata (the physical, the biological, the social and so on). Stratification, which reflects and dissects the real multiplicity of natural and social mechanisms, can be seen as an alternative to those forms of interdisciplinarity that call for a single holistic science, as it grounds a real plurality of sciences which study it. It places as central the issue of where to look for causes in accounting for phenomena, acknowledging that these are not necessarily only social or only physical, chemical, or biological generative mechanisms, thus challenging both naturalistic determinism and 'oversocialised views' of farming practices (cf. Benton 1994).[12)]

## Conclusion

This analysis of the debate between hard and soft system approaches in agriculture science, a debate that strongly influences the design of integrated research programmes, leads to the conclusion that neither approach, whether separate or integrated, provides as yet a convincing framework for an interdisciplinary agricultural science. The debate contains serious lacunae which the framing of the differences between soft and hard systems in terms of a 'battle of paradigms' (between positivism and interpretivism, between natural science and social science, between cause and reason) has not helped to fill. This article has postulated the possibility of an alternative framing.

The soft system critique of hard systems theory, though valuable for drawing attention to farmers' reasons (meaning), learning processes, and the social construction of the goals of farming, is limited when it comes to the supposedly positivist thinking of hard system approaches. Although the latter may hold positivist views on how the social should be studied (related to its implicit sociology), to qualify its natural science component as positivist is incorrect since it is concerned to discover intelligible connections in a given subject matter through experimentation rather than by inferring empirical laws from the constant conjunctions of events (Bhaskar 1998, p. xv). It is argued here that the interdisciplinary study of cropping and farming systems should build on the experimental approach of natural sciences in order to reveal the underlying mechanisms (the typical 'why' and 'what-if' research questions), what Bhaskar refers to as a qualified critical naturalism.[13)] It is not so much the naturalistic thinking that is problematic in hard systems approaches but, what I have called, its implicit sociology.

This implicit sociology comprises, firstly, a social science whose primary role is to identify and classify people's values (and to bring stakeholders together to negotiate research agendas or cost alternative scenarios) rather than to develop sociological explanations of the shaping of agricultural systems. Secondly, this implicit sociology tends to be an individualistic sociology in which farmers and farming are reduced to individual decision-makers. Thirdly, it conceives of a social science that hardly needs sociological research. Natural scientists who tend to dominate integrated programmes are apt to forget that revealing unobservable, yet unknown mechanisms (for which they create costly experiments) is also hard work where the social field is concerned. Social mechanisms, like natural mechanisms, are not directly observable but have to be uncovered and an empiricist social science is inadequate for this task. Finally, this implicit sociology is a sociology that devotes little attention to issues of social relations, power and inequality, which shape not only the social but also the nature of agricultural resources, such as the traits in crop varieties, soil fertility and so on.

It follows from my identification of an implicit sociology in hard systems thinking and of the limited and flawed critique of the latter made by soft systems scholars that we need to take another route towards developing interdisciplinarity in agricultural science. The call is for a social science input that is more explanatory than the implicit one of hard systems approaches and the communicative one of soft systems. Further progress in interdisciplinary thinking depends on the answer to the crucial question as to what it is in the world that leads to (which 'causes') the issue of interdisciplinarity to be raised in the first place. It has been suggested here that it is the stratification of the world and our limited knowledge of this stratification that causes interdisciplinarity to be a problem for science and action. The concept of stratification aims to transcend the dualism between nature and society (cause and reason in soft system terms) and emphasises the importance of 'multiple determination'. Crop and farm systems are research objects that emerge from both 'social' and 'natural' mechanisms and we should not be afraid to use and combine both social science and natural science abstractions. The particular combination will depend on the question at hand rather than being derived from models that aim to be all-inclusive about agricultural systems. To transcend dualism in this way also implies that the concept of stratification challenges those proposals for non-dualism that conflate or dissolve nature and society, since it seeks to explore multiple determination by making distinctions and examining interactions between different types of causes. The idea of stratification will need considerably more development before it can provide a proper theory of interdisciplinarity. It does not as yet map out a clear path of how to undertake such interdisciplinary research in agricultural science, but it may shed some light on where we have to look to make progress.

## Notes

1) One systems approach that still receives recognition in the social sciences is the work of Luhmann. Scholars referring to Luhmann's work, however, eagerly point out the differences between his theory and the functionalism of conventional structuralism and cybernetic system approaches (e.g., Robertson 2006).

2) This notion of small farmers in developing countries as rational producers was a response to views supportive of colonial domination, in which native agricultural practices in tropical countries were regarded as traditional and constrained by local cultures (and hence irrational).

3) It is not implied here that explanations of farmers' behaviour based on previous patterns of interaction and relationships can predict future behaviour. It is precisely the assumption that the behaviour of farmers in managed ecosystems can be predicted that allows bio-economic modelling to claim authority in policy advice (cf. Antle *et al.* 2001, see also Ittersum *et al.* 1998).

4) In models of hard systems approaches the resources available to farm units appear as ahistorical and given. Hard system thinking does not provide a framework for analysing the historical shaping of (unequal) resource distribution.

5) This strict demarcation has been deconstructed over the last few decades by science and technology studies (e.g., Jasanoff 2004) so needs no further discussion here. Although recent hard systems texts refer to some science studies and sociological literature, as yet there is little recognition of its crucial argument that values play a role in the construction of facts and that science cannot act as an independent arbiter in the controversies over different land-use options nor solve the controversies on its own. In my view this science studies' argument does not mean that we are left with values alone and that facts do not matter. It is not necessarily a defence of the 'value-to-fact' reasoning that forms part of some soft systems approaches. Explanation and explanatory critique can argue from facts-to-value, that is, that the factual content of arguments matter (see Collier 1994, p. 169–204).

6) In this article the term reason refers to Röling's utilisation of the word to signify people's construction of reality and as a sort of synonym for meaning.

7) Although Röling remarks that 'There is no given truth' and 'Reality is socially constructed' (Röling and Maarleveld 1999, p. 296) he seems to object to the ultimate consequence of

these ideas that nature and society are nothing more than constructions of the human mind (thereby implying that only *verstehen* is possible); that nature has to be conceived as a discursive concept. Such a post-modernist position does not necessarily deny the existence of reality but challenges the possibility of a non-discursive access to that reality and considers it impossible to make any statement on how nature is independent of discursive constructions (cf. Dingler 2005, pp. 215–216). Although Röling comes quite close to this position at times, in other places he writes that 'constructivism combines very well with realism', referring by the latter to organisms existing in their environment quite independently, as I understand it, of their social construction (Röling 1999, p. 80). However, his writing is rather vague when it comes to discriminating between an 'anything goes' approach and his constructivism cum (empirical) realism.

8) In this respect soft system methodology and actor–network theory share a flat ontology with little to no explanatory capacity to make distinctions between social and natural causes or mechanisms (see Latour 1994, for his elaboration of non-dualism). Within actor–networks 'actants', the term used to conflate human and non-human actors, are not existent entities but only 'come into existence'. Natural 'actants' only become relevant in so far as they result from interactions in the network. There is no space here to address the problem of flat ontology and the neglect of capabilities or causal properties of entities in actor–network theory; see, for an effective critique, Benton and Craib (2001, pp. 67–73), Sayer (2005), and Belt (2003).

9) Original formulations of the critical system approach make emancipatory interests central. They drew on Lukes' characterisation of the dimensions of power and displayed an interest in coercive problem contexts (e.g., Jackson 1988).

10) Although hard system thinkers make casual remarks about the difference between the modelled system (the optimal crop system) and the actual cropping system realised by farmers, they do not raise relevant research questions about the causation of either of them. Such questions involve taking up the idea that cropping systems generate products because they have both the right combination of soil, nutrients, water, plant varieties and so on, and the right human and social environment (cf. Lewontin 2001, p. 28). One very problematic response to differences between the model and the actual is that 'In practice actual production levels may differ from these calculated levels due to *deviant* agricultural management' (Bindraban *et al.* 2000, p. 105, my emphasis). Here the model becomes the standard, the normal state, while the actual is the deviant, influenced by socio-economic conditions. In any subsequently constructed policy advice the model forms the starting point, and not the actual.

11) Röling's argument about reasons could become useful once we recognise that reasons can be causes. But this opens up the question as to what it is about reasons that gives them causal properties and what causes specific reasons. This would open up explanations in terms of causality, which may go against the point that Röling wants to make.

12) Benton's point that the properties of nature (e.g., human nature) make social behaviour possible has been variously criticised as reproducing dualistic thinking (Castree 2002), environmental determinism (Robertson 2004), technological determinism (Burkett 1998) and biological determinism (Jackson 1997). Benton (1997, 2001) has responded convincingly, at least in my view, to these criticisms by pointing out how his arguments have been misread and how his non-reductionistic naturalism is in fact a critique of these very kinds of determinisms. There is no space here to elaborate on the richness of Benton's argumentation, but the debates illustrate how any reference to the causal properties of nature is met with great suspicion. The fear of being accused of essentialism has paralysed critical social science but the attempt to dissect conflations such as 'socionatures' does not

mean that one thinks in dualist oppositions. Benton (1997) considers organic, bodily, psychological, social relational, cultural and ecological dimensions of human social life as interwoven and interconnected with one another. His whole project is 'to avoid dualist oppositions between mind and body, action and behaviour, culture and nature, and so on, in a way which resists reductionisms which either absorb material dimensions of life into "culture", or, in the opposite direction, treat culture, language, thought, etc., as the mere expressions of genetic, physiological, etc., determinants' (p. 86).

13) It is not implied here that experiments as in the natural sciences can be copied by the social sciences as the possibility of closure is generally absent in the latter case.

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