The soft side of land: socio-economic sustainability of land use systems

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ABSTRACT

Sustainability of land use can be defined as a "hard" criterion based on scientific indicators of carrying capacity or sustainable exploitation. This type of definition is useful and important, if only because it brings to bear the credibility of natural science and can therefore raise the priority given to sustainable land use on political agendas. However, although allowing for hard criteria for evaluating human activity to enhance the sustainability of land use, this type of definition is not very effective for informing the human activity itself. Yet, sustainability has become an important issue in our present-day "risk society" precisely because of land degradation, erosion, loss of water retention capacity, loss of biomass, loss of biodiversity, loss of soil fertility, soil pollution and other problems, which are all caused by human activity. Natural science can deal with the biophysical consequences of human activity; it can tell us about the destruction wrought by people. It can provide us with standards to which human activity must adhere. It can help us understand the principles, norms, indicators and types of management of land that are required. Thus we have recently seen important shifts in our understanding of ecosystems. We now accept these to be complex, non-linear, chaotic, self-organizing, non-equilibrium and discontinuous. As a result, we have accepted that not control but adaptive management, involving continuous exploratory probing, monitoring, and adaptation of our interventions, is essential for the sustainable management of land. But science does not deal with human activity itself, *ie*, with human intentionality, sense making, organization, power, the momentum of history and other issues that must be the key to dealing with the causes of unsustainable land use. The paper will try to tackle this problem by starting out with a definition of sustainability which posits that sustainability land use is the emergent property of a soft system, ie, the outcome of processes of learning and interaction among land users. This makes sustainability into a social construct. Instead of an absolute criterion based on a scientific assessment of the state of the land, the soft definition emphasizes sustainability as learned, negotiated and agreed upon. Sustainability becomes an outcome of human activity grounded in institutions, policies, culture and power. Sustainability becomes the interface between the human ability to learn and the biosphere of which we form part. The major part of the paper will try to give hands and feet to this perspective by exploring various approaches to fostering the kind of learned collective action that could make land use more sustainable.

The term "ecologic services" is used for all the direct and indirect benefits people derive from the biosphere, such as drinking water, food, space, clean air, beauty and silence (*eg*, [22]). The term has the advantage of drawing attention to our dependence on the biosphere and of making that dependence tangible and subject to costing. One could say that sustainable land management refers to the capacity of land users to maintain the ecologic services of the land.

But the term has disadvantages too. It suggests that people are independent consumers who buy services from an industry called the biosphere, much as they buy services from other industries. The Gaia hypothesis [57, 15], however, positions the Earth as a living system of which humans are part. Life itself is the most important "ecologic service", maintaining the conditions for its own existence. The question then is whether the changes brought about by the activities of land users will be capable of sustaining the conditions necessary for human existence. Human land users now play a dominant role in maintaining the condition and state of the biosphere. Vitousek *et al* [87] estimate that humans appropriate (directly or indirectly) 40 percent of the potential terrestrial net primary productivity (photosynthesis)—and that percentage seems likely to increase. On the other hand, the total energy estimated to be controlled by humans is 12 x 10 (to the 12^{th}), whereas the biosphere uses 44,000 x 10 (to the 12^{th}) only for cycling water (Giampietro, pers com). As far as our current knowledge goes, biosphere dynamics are extraordinarily robust. The question is whether or not the biosphere will continue to support human life if human activity continues along its current trajectory.

Whereas in the past the human preoccupation has been mainly the struggle to carve out a niche in the biosphere, that quest now threatens the very conditions for sustaining human life [44]. We have taken on a lot of responsibility without knowing how to go about it.

An analysis of land use systems must be positioned within a new context; the control of human activities is of greater relevance to continued human existence than the control of natural forces. Beck [6] speaks of this context as "risk society", *ie*, a society in which a generalized uncertainty, with respect to issues for which the stakes are high [28], leads to the need for widespread reflection on the future. Beck speaks of "reflexive modernisation", a discourse which feeds back into decisions about the design of the future.

Preoccupation with carving out a human niche in the biosphere leads to an agricultural science whose mission is to develop the best technical means to achieve given, undisputed ends, such as higher productivity and (more recently) efficient use of natural resources. But in a situation where human activities are such a great threat to society, such a mission defines the agricultural sciences as part of the problem, not the route to the solution.

Agricultural sciences can no longer ignore the human intentionality and societal dynamics that are the root of our predicament. Although the natural sciences, and especially the earth and life sciences, remain of vital importance, not least to monitor and analyze the dynamics of "nature" so as to inform normative frameworks for sustained land use [24], social sciences must play their role among the agricultural sciences to analyze human activity as emergent from intentionality and greed, economic systems, human learning and agreement. The

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mission of agricultural science in this perspective changes to helping society learn to live within its ecologic opportunities.

This does not mean that the ball is now in the court of the social sciences. This is not because they are, as yet, unable to provide guidance for "social engineering". The problem is not amenable to "solutions" provided by science of any kind. There is no technical or economic "fix" to be discovered by science. There is no engineered design that can lead humanity away from the brink. Human survival, I would argue, depends on a societal "prise de conscience", on society-wide learning, and on collective action at household, community, national and global scales.

This is what I understand Habermas [37, 38] to mean by the pursuit of communicative, rather than instrumental and strategic rationality; Beck [6] to mean by reflexive modernization; Funtowicz and Ravetz [28] to mean by post-normal science; and Brown and Mikkelsen [12] by "popular science". These and others point the way to informed based on widespread adaptive learning. Agricultural science can play an important role in bringing this about should it so choose. But such a constructive role will require considerable change in the present position and a better understanding of the "human factor" among agricultural scientists.

It is my experience that increasing numbers of earth and life scientists are realizing the importance of bringing the human factor into agricultural science, and are, indeed, taking the lead by creating opportunities for social scientists to address problems such as sustainable land use, integrated pest management, irrigation, land and water conservation, agroforestry, etc. This is a challenge too for social scientists. They must leave their comfortable inward-looking disciplinary nests and expose their ideas to the scrutiny of those whose understanding of the state of the environment leads to an urgent need for "ideas that work".

This paper is an effort to clarify the socio-economic dimensions of sustainable land management. In order to do so, it will address the following issues:

- interactive agricultural science
- mechanisms for science impact
- hard systems
- soft systems
- coupled systems
- technology, economics and collective action
- social dilemmas
- sustainable land use as a coupled system
- the management of change.

INTERACTIVE AGRICULTURAL SCIENCE

It is not useful to discuss the human factor in sustainable land use without first clarifying the differences between the study of natural systems and the study of people.

Giddens ([32]; Leeuwis [55]) uses a catchy example. Whether people think the Earth turns around the Sun or the Sun around the Earth does not affect the behaviour of these celestial bodies. But people's behaviour does change as a result of what other people think. Giddens called this ability of people to be affected by other people's ideas "the double hermeneutic", for reasons which shall be explained below. For the moment, it suffices to say that natural systems are governed by causes, while people are guided by reasons. Predicting human behaviour on the basis of causes has consistently led to failure. The same can be said for efforts to change society on the basis of instrumental intervention or "social engineering" [56].

People change their activities when they have reason to do so. Typical "reasons" include attitudes, fear, power, agreement, learning, greed, relative deprivation, knowledge, new information, commitment, motivation, trust, ethnic identity, culture, incentives, etc. Understanding people's reasons requires the deployment of a different logic from the one required for understanding and manipulating causality in the natural world.

Some social scientists approach reasons *as if they caused* human behaviour. An example might clarify this point. A PhD student used causal logic to explain the observed differences in effectiveness of regional extension services. For each regional service, he collected data about the nature of leadership, the size of the service, the resources available, the methods and strategies used, the level of training of the staff, salary levels, etc. These he used to construct independent variables. He then operationalized effectiveness and measured it for each service, thus creating a dependent variable. Quantitative statistical analysis did not lead to a single significant result or insight. One could say that he failed to identify the causes of effectiveness. But one could also say that he failed to understand the reasons that motivated some groups of extension workers to perform better than others.

Another PhD candidate studied the same extension services, this time to explain the resistance to the new requirement that extension workers programme 25 percent of their time. He could have gone about his task by making a detached statistical analysis of the factors that could explain differences in acceptance of programming among extension workers, as the first PhD student would have done. But he did not. Instead he used an empathic interactive method to construct the reasons or sense making behind the resistance, *together with the extension workers involved*. The results of this "research" were very interesting and greatly clarified our understanding of the relative immunity of a bureaucracy against regulatory measures. Of course, nothing could be "proven", but the result was highly credible. After the study, a panel of 10 extension workers claimed it "recognized" the findings as reflecting their reasons.

The caricature above should not be taken to imply that quantitative and quasi-causal studies carried out by social scientists always come up with useless results. In fact, in some cases, such analyses can prove very useful for our understanding. My main point is that they are, in themselves, insufficient for understanding the human factor in sustainable land use. An example of a useful study is the work of Kerr and Kaufman-Giligand [51]. Their quasi-experimental study "showed" (*ie*, made plausible) that commitment to an agreement among college students continued to influence individual behaviour even when no other member of the group that had agreed was present, and long after the operative period of the agreement had lapsed.

In other words, this study showed that an agreement (which could be observed by scientists) had effects (which could be observed by scientists), and hence allowed the inference that commitment to an agreement (which could not be observed by scientists) can be a strong motive for behaviour. Unobservable reasons can be "very real in their consequences", in the famous phrase used by Robert Merton. Imputing reasons for observed behaviours is an approach favoured by some social scientists. It can be contrasted to approaches that use interactive participatory methods to help people to formulate their reasons for themselves.

The example of the PhD studies not only reflects the difference between a causal and hermeneutic logic, but also illustrates different epistemologies, respectively positivism and constructivism. The first study assumes that "facts"—in this case social facts—exist so that a researcher can develop objectively true knowledge about them by using scientific method to "expose" them. The second study assumes that descriptions of reality are socially constructed (*eg*, [7, 54, 61, 52, 74]).

"Reality is not passively received, it does not imprint itself on the mind. It is slowly constructed through active, varied and persistent exploration, and what is learned about it is how to deal with it: what actions produce what effects on what objects." [90]

There is here no question of a single objective truth claim about reality, but multiple perspectives on the outside world, which are each taken to be "real" (*eg*, [70]). What is taken to be real among people does not depend on validity, reliability or objectivity, but on trustworthiness (*eg*, credibility) and authenticity [36]. The rigour of the methods used to generate credible and authentic statements is, of course, important. We are not talking here of unsupported opinion, but of a totally different way of being rigorous (*eg*, by triangulation of methods and respondents).

Constructivism is increasingly accepted as a description of the way we acquire knowledge, including the way natural scientists develop "facts" (*eg*, [52]). For social scientists who try to bring the human factor to bear on land use, a constructivist perspective is essential because people's activities can only be understood on the basis of how they construct reality, and not by some causal factors that a scientist "reveals". What's more, if we want to change the way we collectively deal with the biosphere, we shall have to deliberately reconstruct reality and live by the results. Table 1 tries to clarify the different ways by which human behaviour can be understood.

The different logics of causes and reasons, as well as a lingering positivist realism, are key problems in bringing the human factor into agricultural science. They beset efforts to take the human factor into account in modelling. Modelling of the human factor can work only if people are *assumed* to have the goals which are specified in the model, such as risk aversion, utility optimization, if not profit maximization. In making assumptions, the models violate the variability, diversity and the negotiated, contextual, contingent and adaptive nature of human intentionality, and the flux of trade-offs people make among their different goals.

What's more, such models *assume as fixed the very stuff that needs to be changed* if sustainable land use is to become reality. The collective action required essentially involves adapting wants to gets, instead of the other way around, essentially involves taking less from the commons and giving more to the public good than the selfish choice assumed by economics would advocate (*eg*, [65]). Hence agricultural science must deal with human intentionality itself, instead of assuming it.

TABLE 1 Understanding human behaviour

POSITIVIST PERSPECTIVE	CONSTRUCTIVIST PERSPECTIVE
(1) Causal logic - Genetic factors, human biology - Environmental determinism (design environmental conditions for desirable behaviour) - Operant conditioning (design reward systems) - Experimental (especially behaviourist) psychology seeks direct causal links between stimuli and behaviour, sometimes inferring intervening reasons. Quasi-experimental manipulation of communication stimuli can affect behaviour (design policy instruments, social engineering). - The "invisible hand" of market mechanisms	*(2) Causal logic* - Basically an empty cell because in a constructivist perspective human reason affects all causal logic in the social construction of reality. Causal paradigms are subject to paradigm shifts [54]. The purpose of science is not to accumulate a body of knowledge, but to formulate fresh perspectives.
(3) Logic of reasons - Neo-classical economics assumes reasons (optimization of value, profit motive, economic man) and hence allows modelling *of* goal-seeking behaviour. Market liberalization, global competition. - Attitude research (based on surveys and "law of large numbers") statistically links attitudes to behaviour. KAP (knowledge, attitudes and practice) surveys. Needs assessment studies. Marketing research. Design strategies for attitude change. Advertising. Public information campaigns. - Reasons (attitudes, motives, etc) might be invisible or not measurable directly, but they can be "very real in their consequences".	*(4) Logic of reasons* - The people studied are subjects and can say what their reasons are. Reason cannot be measured but must be understood: (1) by *Verstehen* [89], *ie*, trying empathetically to understand or interpret reasons people have for what they do (2) by interactive and participatory methods which allow deliberate construction of a shared reality on the reasons for behaviour. Such a construction of shared understanding is essential for reflection and voluntary change. Modelling can be used *with* people as a dialogic process to construct shared perspectives and negotiate shared objectives.

There are two ways in which agricultural science can deal with intentionality.

(1) Explanation

The scientific effort focuses on detached scientific (sociologic, psychologic, economic) analysis, which tries to extract the factors that affect intentionality, such as compliance, internalization, or identification [49]. Such social science research can either be positivist (Table 1, cell 3) or constructivist (Table 1, cell 4(1)). In the latter case, the researcher tries to explain by "creeping into the other's skin". The famous sociologist Weber [89] called this "*verstehen*" in German, *ie*, interpretation or hermeneutics. In neither case does the explanation add up to a causal logic or prediction, even if a certain probability or plausibility based on laws of large numbers can be established (as in the case of the study by Kerr and Kaufman-Giligand [51], quoted earlier). Where there is no prediction, there is no instrumental control, no "social engineering" or "planned change". And no modelling. Even the most devious advertising campaign based on the most advanced psychologic research tends to sway only a few percent of the choices (which is still very important in terms of market shares).

This is a serious conclusion with respect to bringing the human factor into agricultural science. Modelling has become its basic methodology. It profits from the expansion of human cognitive ability by computer technology. But computer-assisted modelling cannot deal with the human factor. This has meant that people have not been taken into consideration.

Even if it cannot be modelled, the explanation of human behaviour is not entirely powerless. Giddens' "double hermeneutic" implies that the findings of social science research can re-enter society … which might change the very behaviour about which the scientific pronouncement was made. The best known example is of course the work of Karl Marx, whose analysis deeply affected society with respect to the very issues he was talking about. Another example is the influx of settlers, in search of compensation, into an area about to be inundated by a reservoir, as a direct result of a survey of the number of settlers that would have to be compensated. A third example is that the extent to which economics now informs policy and dominates global thinking about how society should be designed is beginning to lead to second thoughts. Economics seems more an enthusiasm that is liable to fade than a set of scientific laws about society.

With social science, one cannot repair Mir, but one can certainly affect human behaviour, the key factor in the quest for a sustainable society. But it must be said that, aside from economics, the trillions of words social science has produced *about* people have hardly affected society. And since they do not add up to causal logic which can be captured in formulas, the masses of words of the social scientists and the models of the natural scientists remain separated and without operational linkage. Participatory approaches which involve people in constructing their own reality (possibly with the aid of models) and in agreeing on their own reasons for collective action promise to be much more powerful.

(2) Interaction

A radically different way to study reasoning and intentionality is, therefore, interaction (Table 1, cell 4(2)), *ie*, the active participation of those being researched in the construction of the "findings" about themselves, a most curious procedure from a positivist causal logic point of view. Yet it is a very powerful procedure. And we have little choice but to take it seriously if we want to change the collective impact of selfish human activities on the biosphere.

Let's face it. As we have seen, causal reasoning is not able to identify the causes of human behaviour or to predict it. In fact the prediction might change the prediction (double hermeneutics); conversely, the prophesy might fulfil itself. With people, trend is not destiny [47]. Intervention on the basis of policy "instruments" assumes causality, usually based on the expectation of fear of punishment or compliance with rewards. But especially in environmental issues, such efforts to change behaviour have had limited impact. Policies require public support to begin with. The environment is not a constituency. The economic interests affected usually exert disproportionate political influence to undermine political commitment. And implementation is easily circumvented or corrupted as surveillance is never perfect. Mass educational campaigns to educate the public tend to lead to change in awareness and knowledge but not to change of activity. So what is left?

What is left is shared learning, negotiation, accommodation of conflicting goals, building rich pictures from multiple perspectives, consensual approaches to the resolution of distributive conflicts, covenants among stakeholders in natural resources, but above all agreement to do things differently and collective action based on shared learning at different levels of social aggregation. In other words, what is left are solutions which emerge from interaction (*eg*, [86]). And with them comes a different portfolio of interventions, including mediation to resolve conflicts, facilitation of learning, and participatory approaches that involve people in negotiating collective action. The future emerges from interaction.

What does this mean for agricultural science? I think it means that computer-enhanced modelling, including such tools as GIS, GPS, crop simulation, remote sensing and so forth, become tools for interactive learning, *ie*, they are not so much models for learning by scientists with some vague assumed impact on policy or public opinion, they are first and foremost tools for learning by land users themselves (*eg*, [39]). Sustainable land use has to become an enthusiasm. There seems no other way to go. That is why I coined the phrase "interactive agricultural science" [74].

MECHANISMS FOR SCIENCE IMPACT

The double hermeneutic is not specific to the social sciences. All science can be effective only through the double hermeneutic. A scientist can "discover" a new truth and re-interpret reality. But that interpretation only becomes effective if it is picked up by other people and becomes truth for them, if it is translated into policy, industrial activity, technology, or into norms and standards which lead to less destructive land use. Science can "work" only on the basis of the double hermeneutic. There is no other way.

Often scientists are not too interested in the mechanisms of the double hermeneutic. It is enough to publish results in journals which are considered to be credible sources of information. This ensures that the results become part of "the body of scientific knowledge". Contributing to this store of human knowledge has long been the goal of most scientific activity. The "application" of science in technology, policy, commercial activity or collective learning is other people's business. Most social scientists behave in very much the same way, even if they cannot produce causal explanations that can be amalgamated into bodies of theory.

We are now in a different ball game. As said before, the core problem is no longer to enhance our understanding of nature or to develop the best technical means to control it for selfish purposes. The core problem is that the collective impact of human activity to exploit the biosphere for ever-rising human expectations is leading to environmental feedbacks which are inimical to human well-being. Therefore, the core problem is the adaptation of human activities to environmental feedbacks.

This means that the double hermeneutic itself becomes a key issue in human survival. The challenge is to make it work to a different purpose: transforming "the human project" from becoming as rich and comfortable as possible, to living within our ecologic means. In a way, this new human project is very similar to those launched by people like Jesus, in that it also targets intentionality, *ie*, focuses on adapting wants to gets rather than the other way around. Except that this time, it is not the treatment of fellow men and women that is at stake, but collective human survival. Let us take a brief look at what the new project implies for the working of the double hermeneutic in the case of agricultural sciences.

For one, it means that some of the "automatic" ways in which the double hermeneutic operated cannot be relied upon any longer. These include the autonomous adoption of technical or business innovations because they work better, *ie*, provide increased technical control or give competitive advantage. Market forces (*eg*, the treadmill [21]) can stimulate wide utilization of such scientific results. Attractive ideas can also diffuse without the help of market forces. Since most people of this world are connected to one other through an amazingly small number of intermediate links, also across networks (Granovetter's [34] strength of weak ties), such diffusion can be rapid and comprehensive. Alas, such autonomous diffusion of ideas that allow people to better satisfy *existing* intentionality ("more of the same") does not usually work to enhance sustainable land use.

Yet, the translation of science into cost-cutting environmentally benign products, procedures and services that rely on market forces for their widespread utilization is one presently much favoured route for achieving sustainable land use. But this approach appears to be insufficient to ensure sustainable land use, as the Dutch experience when attempting to transform arable farming demonstrated (*eg*, [85]). Other research (*eg*, [60, 77]) shows that the transfer of technology such as used by most conventional extension services is not effective in changing unsustainable land use practices, even if these practices make economic sense and hence help realize existing goals. As we have seen, the problem is to change the goals themselves.

The same can be said for the route through professionals or specialized agencies. Research results reach medical doctors, advisors, consultants and other experts, who apply the new knowledge in their professional practices. But affecting human intentionality is only possible to a very limited extent through expert professional knowledge (see also [28, 92]).

Another favoured route for science utilization is through policy, as we have seen. Experts translate the results into new policies, which impose contexts that constrain certain behaviours and enhance others, depending on the effectiveness of implementation and surveillance. The policy route seems to provide limited scope for changing human intentionality, quite apart from the fact that policy change requires widespread electoral support and commitment for its enactment and social acceptance for its implementation. In the Netherlands, for example, the imposition of the nature policy plan to ensure an "ecologic infrastructure" that links isolated elements of natural value has led to widespread resistance and impasse. As a result, interactive policy development has been advocated which involves stakeholders in area-based planning (*eg*, [86, 88]).

There is also a more sinister operation of the double hermeneutic: appropriation of research results by "social actor networks" [14]. Science has impact when people recreate and maintain the (laboratory) conditions within which the scientific results were obtained. This implies networks of social actors or "interest coalitions" [9] which benefit from these conditions. An example is market liberalization to create the conditions in which economic theory works. It is not too difficult to think of the social actor networks that benefit from the instalment of such conditions, and to explain, for example, why the countries with the most advanced, efficient and hence competitive industries are strongly supporting global market liberalization.

It can be expected that powerful social actor networks will defend and protect their economic interests. Hence, the new human project can be seen to require new coalitions and actor networks which can effectively engage in the struggle with the networks and coalitions defending the old pursuits. Indeed, one opening gambit is that the American way of life is not negotiable.

A final route for the double hermeneutic is (social) learning. Individuals and collectivities learn to act more effectively (*ie*, reach their objectives) and appropriately (adapt their objectives) in their domains of existence on the basis of new "facts", new reasoning or new interpretations. Science plays an important role in this learning by influencing curricula, by providing fresh perspectives, by reshaping "the facts" and by affecting interpretative frameworks and narratives. Since reality is not imprinted on the mind but is constructed in inter-subjective sense making, collective learning about our environment is a necessary condition for understanding how we can adapt to ecologic imperatives, and for formulating the norms and criteria which ensure that we act within our ecologic means. But, barring a major environmental disaster, such social learning is seldom enough in itself to overcome the momentum of our economic system and the ambiguity of our own objectives.

The new human project can only succeed, I am convinced, if the social learning about the environment is coupled to mechanisms for negotiating agreement about collective action, *ie*, to consensual approaches to distributive conflict resolution [80]. If I understand it correctly, this is what Habermas [37, 38] called “communicative rationality”, *ie*, the search for solutions that emerge from agreement in free speech situations as the only way to cope with the momentum of “the system” and economic forces. If it is to effectively contribute to the new human project, agricultural science needs to feed into such interactive situations at various levels of social aggregation.

The next section explores how learning about (1) hard systems and (2) soft systems for arriving at negotiated agreement on collective action can lead to (3) coupled systems for sustainable land management.

HARD SYSTEMS

Systems thinking was introduced into the domains of science, policy and management to overcome the debilitating effect of reductionism and its tendency to break up biophysical reality into ever smaller bits. The realization that reductionism does not lead to a better understanding or to a better ability to solve complex problems led to a search for a holistic perspective (*eg*, [8, 64, 13, 45]). The introduction of systems thinking has had major benefits in the practical world of purposive change. It has also, of course, been a powerful stimulus in agricultural science, leading in Wageningen, for example, to the development of understanding of the plant as a system. This has allowed an integration of disciplines such as soil science, climatology, physiology, agronomy and even economics into “theoretical production ecology” and useful simulation models which command international attention (*eg*, [25, 71]).

It is relevant to this presentation to make a distinction between hard and soft systems [17]. Hard systems thinking assumes that real systems exist independently of the human observer (realist ontology)—I leave the discussion of “real systems” aside for the moment [2]. One can therefore make models of existing systems. Hard systems are generated when you map a real system (you will never know what it really is) against a chosen space-time scale (Giampietro, pers com). Hard systems thinking uses causal logic and focuses on natural or designed systems. Hard systems have built-in goals. Even if one assumes alternative goals, the focus of the system analysis is on (improved) goal seeking. Sustainable land use in hard terms means maintaining a certain hard state of the land: there is a posited, if as yet undetermined, threshold to exploitation, *eg*, the land’s “carrying capacity”, beyond which its ecologic services to human society cannot be maintained.

In recent years, hard systems thinking has undergone major and exciting developments. Key words are adaptation, complexity, chaos, self-organization, non-linearity, and non-equilibrium state (*eg*, [43, 15]). I will not go into these issues here. One example suffices. Complexity means that, although phenomena in dynamic open systems far from equilibrium might be causally related, their pattern of organization cannot be specified by reductionist science. While the rules governing the underlying order can be established, the outcomes cannot be determined or predicted (this formulation was suggested by Jiggins, pers com). Rosen [78] suggests that complexity refers to causally related phenomena that are the product of cross-relations among hierarchic levels. Everything depends on everything else, but processes affecting each other occur on different space/time scales. This mechanism of “reciprocal entailment” escapes the conventional scientific approach. The reductionist paradigm which attempts to collapse phenomena into one unique space/time window of observation cannot understand, and hence predict, the outcome of complex processes (Giampietro, pers com).

Complexity undermines our erstwhile optimistic belief in the human ability to eventually build a complete “body of scientific knowledge”, to control our environment or to design solutions in advance to satisfy stated goals. The demise of this belief can be considered the latest instalment of the Copernican revolution [81, 29, 75].

Life sciences, such as ecology, play a major role in creating a new understanding of the feedbacks that result from the collective impact of human activity on the biosphere. They develop indicators and system models, and monitor the state of the environment. They pinpoint human activity as the cause of our predicament. They indicate the criteria for the kind of management required for a sustainable global society. But they must leave begging the question how the implicit transformation of society can come about. Hence they seek to develop interdisciplinary collaboration with economists and other social scientists in exciting new approaches which mock the disciplinary organization and management of academia (*eg*, [24, 40]). Soft systems thinking provides a useful basis for such interdisciplinary collaboration.

SOFT SYSTEMS

Checkland ([17], with Scholes [19], [18]) developed soft systems thinking to deal with purposive human activity systems. Soft systems, like hard systems, are constructs with arbitrary boundaries. But they differ from natural (*eg*, plants) or designed (*eg*, computers) systems in two major ways. First, they are guided by reasons and not driven by causes (see Table 1). Second, they do not have assumed goals; instead, the major issue is how they come to shared system goals. This second point needs some elaboration.

Hard systems thinking proved inadequate to understand the messy world of human affairs. In the case of people, one cannot assume goals and focus on goal seeking, even if economists make a valiant attempt. As Checkland puts it: “goals are the bone of contention.” One must be able to deal with multiple and conflicting goals before anything else. Hence the “human activity system” is a soft system, which exists only to the extent that the people comprising it (1) agree that they form a system and act accordingly, and (2) have negotiated and agreed upon shared system goals so that they can engage in collective action for optimal goal seeking. In that sense, soft systems can become hard.

Usually, most hard systems are, in fact, a subset of soft systems—also because nearly all conceivable hard systems, including ecosystems, can be seen as being incorporated into human activity systems. Even a complete wilderness, such as the Yellowstone National Park, turns out on closer inspection to be a soft system-in-the-making, because its goals are hotly contested among stakeholders, with major consequences for forest fires, the density of the buffalo population, the occurrence of wolves, etc [48]. The same can be said for the biosphere. Land use can usefully be seen as a soft human activity system. Hence "the soft side of land".

In soft systems thinking, ecologic sustainability is the emergent property of a soft system [5], *ie*, sustained land use can only come about as the result of collective action based on (1) shared common perspectives (the perception of a common problem and the accommodation of multiple perspectives on causes and effective courses of action) and (2) negotiated agreement on a common goal, on self-restraint and on contribution to collective effort. In other words, the notion of soft systems is helpful as a background to interactive agricultural science. But there is more to it than that.

Röling ([72, 73] and with Jiggins [76]) used soft systems thinking to formulate the concept of a "platform for land use management". A natural resource perceived to be in need of collective management for sustaining its ecologic services requires decision making at a level of social aggregation which is commensurate with the level of the natural resource. The use of the natural resource is usually contested among stakeholders, who exploit it with conflicting objectives and who increasingly experience the negative impact of their own and other stakeholders' use of the resource. Therefore, the only way to manage it in a sustainable manner is to construct a soft system among the stakeholders, based on shared learning, negotiation and accommodation. The platform perspective implies attention to soft system methodology (SSM—not to be confused with site-specific management!) [17], participatory approaches (*eg*, [70]), mediation (*eg*, [4, 1]) and methodologies for the facilitation of social learning (*eg*, [68, 58, 35]) so as to take stakeholders along a learning path towards effective platform development. The platform concept has proved heuristic in suggesting further land use research (*eg*, [23]). The idea that a system perceived as "hard" (such as a natural resource) requires a "soft" platform to manage it sustainably leads us to coupled systems.

COUPLED SYSTEMS

The Chilean biologists Maturana and Varela [61] analyzed how organisms observe. They concluded that the environment is not "projected" on the nervous system. Instead, the nervous system is informationally closed, but the environment can trigger changes in the nervous system and vice versa. Organism and environment form a coupled system in that they are linked through mutual perturbations which trigger adaptive changes in each other. "Knowledge is effective action in the domain of existence." Humans live in an environment which they have created themselves, so that the human coupled system is largely self-referential.

A good metaphor for the coupled system is a plane which flies on its instruments in a dense fog. The instruments are "informationally closed", in that their electronic operations preclude direct projection of the environment on the nervous system. Yet the environment can trigger changes in the instruments which adjust the navigation and (usually) prevent the plane from flying into a mountain. Survival means maintaining the coupled system.

Consistent with the coupled system is a new approach to cognitive psychology [20] that does not consider the mind as a "rational deliberator", but as an "adaptive responder". Brain, body, world and artefact are locked together. Mind and action are inseparable. We think because we interact with the world. Coherent thought and planned action are only possible because we have constructs, language and other artefacts, such as computer-based systems, including GIS, for structuration, representation, computation and analysis of data. Soft systems models are "epistemologic devices useful to question the world" (Checkland, pers comm). Our actual cognitive processes, including intuition, are not so different from those of other animals as has been assumed. But language and other tools for reflection have allowed the replacement of genetic evolutionary advance by the "evolution of human tradition", as Huxley [46] called it.

Consistent with the notion of a coupled system and Clark's approach to cognitive psychology is Holling's [43] notion of adaptive management.

"The success in managing a target variable for sustained food production or fibre apparently leads to an ultimate pathology of less resilient and more vulnerable eco-systems, more rigid and unresponsive management strategies and more dependent societies .... The release of human opportunity requires flexible, diverse and redundant regulation, monitoring that leads to corrective responses, and experimental probing of the continually changing reality of the external world" [43].

In other words, it requires deliberate learning and attention to creating the conditions for such learning. I find the notion of adaptive management of crucial relevance for sustainable land use systems. One of the key issues, as Holling and Sanderson [44] pointed out, is the inherent disharmony between natural and human systems. The latter aim for continuity and stability, which is not consistent with the nature of the former. But policies and management that apply fixed rules to achieve constant yields lead to systems that lack resilience and may break down from disturbances that were previously absorbed. They violate the coupled nature of human/biosphere interface. "Therefore, human management has to be flexible, adaptive and experimental at scales compatible with the scales of critical eco-systems functions." This is a tall order for platforms for land use management.

It is perhaps useful to point out here that adaptive management, as used by Holling, seems not to be the same thing as the adaptive management made possible by precision agriculture [10]. In precision agriculture, farms and fields are segmented into small land management units which are homogenous with respect to agronomic characteristics. Farm machinery is equipped with a global positioning system and an on-board computer in which information about the land management units has been stored. Thus the machinery can execute land management operations that are adapted to the needs of the specific land management unit and can therefore take into account the diversity that characterizes most fields. This type of adaptive management implies a refinement, and a much more efficient/less wasteful modern system of agriculture than we have had to date. But there is no question here of adapting human goals, only of reducing costs for wasteful inputs to achieve given goals. And there is a presumption that precision micro-management aggregates to support ecosystem functions at the scale of the ecosystem (Jiggins, pers com). I understand Holling to talk especially about adapting human intentionality and social organization to ecologic imperatives, which might be not only diverse but also variable, at higher scales and time dependencies than implied by precision agriculture.

The coupled system is relevant for us because land use can be considered as a system that couples (1) a system perceived as hard and (2) a platform. Coupling occurs through adaptive management which is based on:
- learning
- making visible the state of the land
- monitoring the impact of human activity
- negotiated agreement with respect to the norms for sustained use of the land
- collective action, for example, with respect to resolution of distributive conflicts.

Such a coupled system seems essential for *sustainable* land use, because it is only in such coupled systems, at different system levels, that negotiated self-restraint of human greed seems possible.

THE RUSSIAN DOLLS OF TECHNOLOGY, ECONOMICS AND COLLECTIVE ACTION

It is time to consider in more detail the consequences of the shift from the preoccupation with carving out a niche in the biosphere to a preoccupation with risk society, in which reflexive modernization and collective action hopefully lead to deliberate management of the collective impact of human activities on the biosphere.

For thousands of years, people have dealt with the natural environment by way of a combination of hard work and prayer. Even if people had criteria for happiness, they did not have much control over the events that affected them. Hence, all too often happiness had to be postponed to the afterlife, and fatalism and prayer were the only way to tolerate suffering. Anthropologic research has shown, however, that such fatalism, although an adaptive response to intolerable circumstances, seldom keeps people from innovation once new realistic opportunities to escape their predicament present themselves [27]. Slowly people improved and expanded their niche.

The development of science and technology has expanded human opportunity in an unprecedented manner and led to secularization and to arrogance with respect to the biosphere. European agriculture, which until the 1950s was not very different from the peasant farming painted by Pieter Brueghel the Elder, was stimulated through research, extension, agricultural education and land development to develop very rapidly in terms of productivity. The peasant became a professional. This technical development continues until the present day. My neighbour now gets 12 tons of wheat from a hectare, whereas a peasant farmer got no more than one or two. The peasant had an image of the limited good [27], which meant that the good was a cake of fixed size so that one could only get more if another got less (which led to strife among Nigerian peasants as a result of the FAO fertilizer programme in the early ‘60s). The new professional farmer considered growth as a mountain without a top, which must be climbed forever to stay in business [42]. Unlike the Nigerian peasants, modern farmers believed for a while that, through such technologies as inorganic fertilizers, the good itself could expand, seemingly without limit. More recently, the evidence that there are ecologic limits to this kind of growth has been accumulating daily. But that is not what has changed the image of the “mountain without a top”.

The growth of production has led to second-generation problems of an economic nature. The farmer can no longer sell anything he produces. I remember very well how in the early ‘60s a deliberate shift in extension policy occurred in the Netherlands. The farmer was not only required to be technically proficient, he was also to be an entrepreneur. It was no longer production, but gross margins, interest rates and profitability that counted. Extension was no longer a question of “extending” science-based technologies, but became “enterprise development”. Farming became a competitive business, driven by the market. That did not mean that technology had become less important; it meant that technology became an element in the rat race or “treadmill”, as Cochrane [21] called it. In other words, concern for economy did not replace technology. Technology became embedded in an economic context, much as the smaller Russian doll is embedded in the larger one.

We still farm in a context in which the dominant mode of interacting with the biosphere is defined by economics. Or to put it another way—conforming more to modern sociologic theory (*eg*, [14, 9]): dominant coalitions consider it in their interest to create and maintain the societal conditions in which economics works. All our problems are expected to be solved by market forces, or by liberation of those forces so that they can work more efficiently.

But resistance is mounting. The market fails in too many respects. A nearly perfect market such as primary production, in the sense that its many firms are each too small to affect the price, destroys itself in the end [30]. Productivity gains in agriculture ultimately are passed on to agribusiness and the consumer, and do not benefit the farmer. Farmers can survive only as long as they can increase productivity by being ahead of the pack in terms of innovation and by absorbing the resources of the drop-outs. In Western Europe, the feasibility of this strategy seems to be rapidly running out of steam, even without taking into account its consequences for the environment and employment [83].

Furthermore, the market fails in preventing the destruction of open-access resources such as silence, clean air, the ocean and biodiversity and in preventing the degradation of most common property resources such as village grazing grounds as a result of population pressure and the breakdown of traditional arrangements.

The market fails in preventing toxic emissions into the environment and the externalization of environmental consequences to other sectors or future generations [84].

Finally, the market fails by creating or maintaining inequity in a world dangerously divided along many fracture lines. For example, labour costs in the North are 22 to 28 times higher than in the South, but agricultural labour productivity is 37 times higher, so that production costs are now lower in the North than in the South. This has contributed to forcing developing countries to become net importers of food [3].

Other critics of the current dominance of belief in market forces point to the local loss of control caused by unlimited global competition, in terms of regional economic development, social welfare, employment and local ecology [26]. In fact, in several industrial countries, movements (*eg,* Actie Strohalm in the Netherlands and the New Economics Foundation in Britain) have started up to develop alternative economies. Given Maslow's popular "hierarchy of needs" [59], which posits self-expression as the need which prevails when needs for food, shelter and security have been satisfied, one could say that the global market is an arena for destructive forms of self-expression for very few through dominance and control. There will perhaps be a time when the public tolerance of global market liberalization will seem as strange as the enthusiasm for head-hunting on Ceram. Building a sustainable society seems a promising alternative arena for self-expression as a basic human need.

Market failure to deal with the ecologic imperative can, according to environmental economists such as Van Ierland [84], be countered by regulation or fiscal policy, and by assigning prices to non-market values. Many environmental economists are busy developing formulas and methods for pricing environmental values such as songbirds. However, regulation, fiscal policy and the commodification of non-market goods require political acceptance, which has so far not been forthcoming on any significant scale. Giampietro and Mayumi [31] put it as follows:

"the challenge to ecological economics, in our view, is to deal with the following three issues: (1) irreducible uncertainty generated by the hierarchical nature of social and ecological systems when dealing with sustainability; (2) unavoidable existence of legitimate and contrasting perspectives due to the heterogeneity of human and ecological holarchies, (3) the fact that scientists performing the analysis are active parts of the system they are describing. This challenge requires [among others they mention, NR] using the relations between different sets of indicators to build conflict management tools (to discuss and weigh trade-offs with stakeholders) rather than looking for optimal solutions (optimal for whom?)."

With their plea for building conflict management tools, they enter the logic of soft systems and collective action, and leave the world of hard systems, "objective" optimal solutions and the normative models presently favoured by economists.

I believe that the shift to a society that gives priority to the need to deal with the destructive collective impact of human activity on the biosphere leads to a third Russian doll: *collective action.* Collective action is required to conserve and regenerate the productive capacity of our natural resources. Only through collective action can we reach negotiated agreement on what we shall call enough and among whom and how it should be distributed.

Just as the shift to an economic imperative did not replace technology, but became the context for it, collective action will become the context within which technology and economics are expected to work. Collective action will envelop the other two as the third Russian doll.

This third Russian doll emerges from greater public awareness of the issues at different levels of social aggregation. It emerges from social learning and the social construction of a new understanding of the nature of ecologic services. It emerges from collective decisions to give more to public goods such as public transport and take less from common goods such as the biosphere. It emerges from new management structures and procedures, such as interlocking platforms for adaptive land management at relevant system levels which allow us to overcome our social dilemmas.

I see no other way that does not lead to authoritarian governance, unrestrained market exploitation and a radically transformed natural world that will support the relatively few at the expense of (the survival of) the rest.

At present, the enthusiasm for collective action is just beginning to gain momentum in such areas as common property resource management, consensual approaches to distributive conflict resolution, interactive policy development, international protocols such as UNCED, etc. Eventually the enthusiasm for collective action is likely to develop its own cracks. I am not very optimistic that we shall be able to make it work. One source of optimism is that human societies have performed incredible feats before. Human intentionality is more malleable than chewing gum … and humans can be intelligently self-interested, also over the long term.

Another source of optimism is my experience that if I have an idea, many others have had the same idea—usually many years ago. What seems underdeveloped at present is movement on the ground, and political commitment. Among the difficulties in forging political commitment are (Jiggins, pers com):

- the relative weakness of the nation state in restraining global capitalism
- the relative weakness of the nation state in raising revenue to protect social goods such as ecosystem services within existing economic relations
- the growing influence of organized advocacy outside established democratic representation
- the relative weakness of operational capacity to execute and enforce agreements negotiated in regional, international and global fora
- the lack of access of citizens to negotiations which lead to such agreements
- the very limited use of public media to support reduced consumption and their continued promotion of more consumption
- mutual re-enforcement of an uninformed public and lack of courage among politicians to provide leadership.

I think agricultural science should begin to provide at least the intellectual leadership required for a radical change.

But one should not underestimate the hurdles. Our main systems of public education and entertainment are driven by both commercial and sectoral interests; they promote unlimited consumption instead of living within our ecologic means, they focus on narrow expertise rather than a broader grasp of pattern, process and structural relations. We believe that our livelihoods and short-term survival are dependent on the existing economic system, which blocks out understanding. Voters tend not to accept curtailment of their short-term securities. Farmers continue to consider cost price as their bottom line and, indeed, in the current system would not survive if they did not. Religion and morality are based on ancient human ecologic conditions and tend not to target our modern predicament. And elites in the past have been inclined to use their prerogative to maintain lifestyles that are no longer feasible, instead of providing leadership for change [67]. In other words, we seem locked into a global system with considerable momentum, and it is indeed a question whether communicative rationality [37, 38, 11, 91], reflexive modernization [6], post-normal science [28] and collective action can get us out of it. Below we examine social dilemmas, a key mechanism in collective action.

SOCIAL DILEMMAS

Hierarchy is an essential aspect of hard systems. Systems are always part of larger systems and they themselves are comprised of subsystems. Characteristic of hierarchies is the ambiguity of the terms "part" and "whole" when applied to any of the sub-assemblies [53]. Wholes and parts in the absolute sense do not exist anywhere, either in the domain of living systems or of social organizations. Depending on the way you look at them, sub-wholes always display some of the characteristics commonly attributed to wholes, and some that are attributed to parts. "The members of a hierarchy, like the Roman god Janus, all have two faces looking in opposite directions: the face looking towards subordinate levels is that of the self-contained whole, the face turned upward towards the apex, that of the dependent part." Koestler [53], who wrote these words, called these two-faced sub-assemblies in the hierarchy "holons". This concept has since entered complex systems thinking.

In hard systems thinking, holons are defined by space/time dimensions. And the term hierarchy suggests that hard boundaries exist in time and space while they can only be constructed by people on the basis of arbitrary cut-offs. Capra [15] speaks of "nested" systems to avoid this pitfall, while maintaining the need to take into account complex inter-system level relations, *eg*, the fact that what seems unchangeable at one level might be variable at a higher one. The fact that we are not necessarily dealing with hierarchies but with nested systems is fundamental to the shift in thinking advocated in this paper (Jiggins, pers com).

In social organization, the nested nature of (sub)systems is determined not only by time/space dimensions but also by identity and community. The Janus-faced nature of the holon transforms into the basic dilemma of choosing between the selfish interest or the collective interest. This has been called a social dilemma, and a great deal of research has been directed at it (*eg*, [65, 40]).

A social dilemma occurs when individual interests conflict with collective interests, *ie*, in situations where a person is confronted with the choice between the individual interest and the collective one. The selfish choice gives a better result for the individual than the cooperative choice, but if everyone makes the selfish choice, the collective goal is not reached. If everyone made the cooperative choice, all would be better off in the end. These dilemmas have been elaborated in game theory (*eg*, the well-known N-prisoners' dilemma). Hardin's [41] formulation of the "tragedy of the commons" drew attention to social dilemmas (in what later proved to be the special case of open access resources). The tragedy is inevitable if each herder chooses to graze as many animals as possible on common land, leading to its ultimate destruction.

There are two main dilemma situations: common good dilemmas, where the commons can be saved only if everyone takes less (or in another way), and public good dilemmas, where the good can be maintained only if everyone gives more. In some situations, the dilemma is mixed. In an irrigation scheme, for example, water can be regarded as a common good, whereas the scheme and its infrastructure are a public good. Collective management in an irrigation scheme might actually lead to every farmer receiving more (*eg*, [82]).

Understanding social dilemmas and the conditions under which people are willing to opt for the collective choice is a key issue in sustainable land management. Social dilemma models have become particularly important with respect to the study of the management of common pool resources, *ie*, resources for which (1) exclusion or control of access by potential beneficiaries is problematic and (2) each user is capable of extracting from the welfare of all other users [66].

These are exactly the kinds of natural resources involved in sustainable land use: the quantity and quality of subterranean and surface water, fisheries resources, clean air, silence, biodiversity, genetic integrity, the water retention capacity of a catchment, the forest cover of an area, the biomass on common grazing lands and in forests, and interdependency with biosphere dynamics such as the effects of El Niño. Some aspects of soil fertility, such as its organic matter content, pest control, etc, are directly affected by the state of such common pool resources.

It is common to distinguish among four types of rights to common pool resources (*eg*, [40]). *Open access* resources are those to which everyone has unlimited access. The "tragedy of the commons" typically applies to this situation. Fishing stocks in the open seas are a classic example. At the other extreme is *private property*. Neo-liberal ideology is in favour of this type of access as a guarantee for sustainable management, and privatization of common pool resources is often advocated. But many types of common pool resources cannot easily be privatized. Privatization conflates the rich mix of resource use rights and collapses multiple usufruct into the ownership right of a single owner.

A ploy often used by governments in the past was to declare the common pool resource *public property* and to formulate strict laws to regulate the use of the resource. Typical are colonial governments which appropriated forests. More often than not, corruption, lack of means to carry out proper surveillance and other problems soon led to a situation where the public property became an open access property, which resulted in worse conditions than those before centralization.

The fourth form of access is the *common property* right held by a limited group, which has formulated clear rules of access, can monitor access, and has commonly agreed sanctions for misuse of the resource (*eg*, [62]). This type of property right has commanded a great deal of interest as a potential model for sustainable land use (*eg*, [65]). It includes a platform of stakeholders commensurate with the resource, and involves collective action (negotiated rules, self-imposed limitation of greed, and maintenance of public goods) by the stakeholders so as to overcome the social dilemma and ensure sustained use of the resource. A considerable research effort is ongoing, analyzing the conditions under which such common property rights can be established, improved or resumed.

Of course, this model does not apply equally easily to all ecologic services involved in sustainable land use. In the case of subterranean water resources, for example, it is difficult to identify the boundaries of the resource, and many communities and public institutions might be involved in decision making about their use. Agreements on use are hard to monitor (*eg*, [79]) . But, on the whole, the work on social dilemmas has brought us a lot closer to the socio-economic dimensions of sustainable land use. It is time to make a synthesis for the purposes of this paper.

SUSTAINABLE LAND USE

Ifugao in the Philippines has become world-renowned because of the breathtaking sight of its complexes of rice terraces, which cover entire mountain sides [33]. These terraces have supported a dense population for 3000 years. One cannot imagine the building and maintenance of such an intricate, sustainable and productive land use system without an equally intricate soft complement to the hard terraces. This soft system, comprised of interlocking nested platforms for land use management, guaranteed the practices which made the land use system productive and which reproduced it. These practices were embedded in ritual, in shared beliefs, in political leadership, in institutions such as property rights and in procedures for ensuring that cooperative choices prevailed over selfish ones [33].

Since the conquest of the Spanish, this soft system has been undermined, first with the introduction of Christianity and the destruction of the supporting “cosmovision” [63], and later through various other changes, such as the imposition of an administrative structure that was totally unrelated to the indigenous system. In recent years, the process has been accelerated by the price squeeze that results from competition with cheap rice produced in the Philippine low lands using “green revolution” technology. At present, frantic efforts are being made by various organizations to save the terraces for purposes of tourism and vegetable production. However, the question is not to save the terraces but to maintain a complex coupled system, of which the terraces are but the hard expression.

Ifugao makes dramatically clear that fostering sustainable land use requires a coupled system, comprising a soft human activity system and a hard land system. It is not only a question of technology, not only a question of economics, and not only a question of managing collective action. Sustainable land use requires all three. Therefore, the coupled system serves to:

- overcome social dilemmas so as to ensure voluntary co-operative collective choice for taking less from the common good and giving more to the public good (*ie*, collective action, the largest Russian doll)
- create a local economic system that is subservient to imperatives of sustained ecologic services provided by the land use system (the second Russian doll)
- develop adaptive management that is sensitive to environmental feedback, *ie*, a capacity for ecologic learning (technology, the smallest Russian doll).

It is clear that such a perspective on sustainable land use systems has important implications for agricultural development and for agricultural science. It is not enough to establish databases for land use planning based on land suitability criteria. It is not enough to engage in precision agriculture. It is not enough to price environmental effects and to lower the cost price in the competitive struggle. It is not enough to model scenarios of outcomes for different choices. It is not enough to focus on primary production as a separate industry, or to focus on the marketing chains within which primary production is embedded. These are all partial enthusiasms, which do not add up to sustainable land use. What is needed is the participatory design of coupled systems for sustainable land use. This involves facilitating multiple stakeholders at different levels of social aggregation to form nested platforms, so as to create common perspectives on a constructed hierarchy of land use systems and their ecologic opportunities, to negotiate common goals and an equitable distribution of access to the ecologic services the land provides, and to agree on collective action for adaptive management.

Designing coupled systems requires new ways in which stakeholders can learn about and monitor the land on which they depend. It requires new management tools to interlink nested platforms (themselves holons). In other words, designing coupled systems implies many new tasks for agricultural science and many new ways in which existing expertise and achievement can be deployed. Designing coupled systems for land use raises many issues that need further research. One issue, for example, is the question of the consistency between the arbitrary boundaries and time scales of land use and platform. Another is the nested nature of different hard systems and levels of social aggregation. Many natural resources, such as ground water, are very difficult to pin down in terms of system and subsystem boundaries; hence it is difficult to create appropriate platform levels (*eg*, [79]).

A key issue for design is to make market forces subservient to collective action negotiated by platforms, or at least to reduce the destructive impact of global competition on local development. In this respect, we could learn a great deal from the case of Cuba.

Ever since the USSR collapsed in 1989—and given the trade embargo imposed by the United States in the ‘60s—Cuba has been forced to adopt, wholesale, low external input agriculture as a national policy. After an initial fall in production of 42 percent, national food security seems to have been restored [16]. It is indicative of the dominant ideology that the unique experience of Cuba has not been studied more systematically. Its experience seems to show that a poor, densely populated country in the South can autonomously develop agriculture in a sustainable manner while ensuring national food security (except apparently for wheat) and exporting fruits and other products. A major research and educational effort seems to have been necessary to achieve this. However, there is little use of external inputs, while protection from competitive global marketing seems to have been a necessary condition for Cuba’s achievement. Of interest is the extent to which the Cuban experience leads to both, the productivity *per hectare* needed for national food security, and the productivity or reward *per man-hour* needed for sustained farming (Giampietro, pers com).

In all, the coupled system for sustainable land use seems to suggest a formidable new agenda for agricultural research.

THE MANAGEMENT OF CHANGE

It is one thing to suggest a destination, quite another to indicate how to go about getting there. The Chinese say: "If you do not want to end up where you are going, you have to change direction." True, but easier said than done. Changing direction towards a more sustainable society would be a major discontinuity in the green history of the Earth [69]. There is not much experience with such a change. And for the time being, the failure of the various summits that seek agreement on, *eg*, reduced emissions of greenhouse gases does not seem very promising for generating that experience.

The one fairly large-scale experience which I continue to draw on for visioning the management of change required is the Indonesian Training Programme for IPM in irrigated rice, which has now become an international showpiece (*eg*, Röling and Van de Fliert [77], who report on the work of FAO's Dr Peter Kenmore and Dr Russ Dilts and the Indonesian Government's IPM team under the leadership of Bapak Ekowarso). Based on this and other experiences, the following elements can be suggested for a strategy to manage change.

(1) The conventional non-sustainable land use system is a coupled system comprised not just of the manifest and productive sawas, but also of a soft system of interlocking interests, shared visions and common objectives. Hence the conventional land use system is a formidable coalition of interests [9] that actively resists change towards a more sustainable system. International pesticide industries, national politicians with interests in the pesticide trade, local extension workers who add to their income by selling pesticides, ministry departments that depend on chemical crop protection for their survival, farmers who fear reduction of "protection" against crop loss, national politicians who fear "outbreaks" of pests and their impact on national food security, all actively resist change. A new direction therefore requires strategic manoeuvring and active creation of its own coalition of interests at international, national and local levels.

(2) Science has played a major role in making visible the self-interest of the national government and local farmers in changing direction. The scientific work of Kenmore [50] and others has demonstrated beyond doubt that pesticide use causes pest outbreaks, and hence negatively affects food security. Since the availability of cheap rice is a cornerstone of political stability in Indonesia, this scientific work led to a presidential decree in 1986, forbidding the use of 57 broad-spectrum pesticides, removing the subsidies (of 85 percent) on pesticides and introducing IPM training. This decree legitimated the change of direction and provided it with a supportive policy context. Even then, vigilance for attempts by conventional interests to undermine the effort must be maintained at all times. Constant pressure emanates from the international competitive market for pesticides and the aggressive and often corrupt practices of international pesticide industries that cannot afford to lose the large Indonesian market.

(3) Science has played a major role in developing, testing and consolidating a low external input alternative to conventional farming, which is profitable for farmers. In Indonesia, this was a necessary condition for success. Luckily, the robust agro-ecosystem of irrigated rice makes it possible to reduce pesticide use and rely on biologic control without loss of yield. Under other conditions, it will be necessary to make a more elaborate effort to ensure that farmers benefit, *eg*, by designing appropriate fiscal policies, by creating a locally autonomous economy, and by paying more attention to overcoming social dilemmas so as to prevent free-rider behaviour.

(4) Conventional high-input agriculture has been operating since the beginning of the green revolution in the early '70s. Hence a second generation of farmers who have never used indigenous agricultural practices is now using the land. They have become dependent on pesticides. Accepting another system of farming requires more than adopting an innovation. It means a major learning effort, involving new theoretical knowledge, new risk assessment, new indicators, new methods of making things visible, and reliance on observation and anticipation rather than on a quick-fix poison. In short, farmers must learn to become managers of complex agro-ecosystems. They also have to learn that a number of crucial aspects of the new way of farming transcend the boundaries of the individual farm. Maintaining an effective population of parasitoid wasps and controlling the population of rats (the greatest pest of all) requires collaboration among groups of farmers with adjacent land.

(5) Facilitating this kind of learning is not a question of conventional extension. In fact, conventional extension has consistently failed effectively to introduce IPM throughout Asia [60]. The Indonesian training programme was lucky in that it was led by a specialist in non-formal education. Hence an imaginative farmer field school approach was developed to provide groups of local farmers with experiential hands-on discovery learning, involving active agro-ecosystem analysis of rice fields, the keeping of "insect zoos", etc. The farmer field school approach has now been adopted in 15 Asian countries and many others in Africa and Latin America. The curriculum for the farmer field school was initially developed by scientists (entomologists) and adapted on the basis of careful field testing by Indonesian field leaders.

(6) Such a large programme initially required a strong project structure, a large number of professional field staff, and non-replicable financial outlays to get it going. At present, some exciting new dimensions of the institutional support structure are being developed, which have much greater promise that farming along IPM principles can be maintained. These new developments are called "community IPM", which involves:

- trained farmers training farmers
- these trained farmers forming active local networks or associations within which experiences are exchanged and new initiatives are being developed (which often go far beyond IPM)
- increasingly relying on local government finance (supported by the fact that the often influential farmers involved can influence local politics).

Hence, at the local level, platforms are being created which lock into the national IPM project structure.

In all, the Indonesian IPM programme suggests that the management of change has the following dimensions [76]:

(1) sound and profitable sustainable farmer practices
(2) (collective) farmer learning
(3) the facilitation of such learning

(4) a supportive institutional framework involving decentralized local networks of trained farmers, embedded in a national project that is able to create a coalition of interests in the struggle with the conventional interest coalitions

(5) a conducive policy framework.

CONCLUSIONS

The perspective of a coupled system for sustainable land use seems inescapable both on the basis of logic and on the basis of current experience. Yet the implications are formidable. Imagine that such an approach were adopted in the Netherlands. It would mean that old institutions, such as water management boards with their complex rules and regulations, local governments at community and provincial levels with their intricate apparatus for zoning and land use management, and various ministries with their own responsibilities for various types of land use and ecologic services (*eg*, water, forests, etc) would all need to be integrated into interlocking nested land use units. It would mean that the actual stakeholders in those coupled systems, the local inhabitants, be they farmers, hunters, house owners, gardeners, participants in the traffic, etc, would form platforms for social learning about the local land use system; agree on shared goals for its sustained use, regeneration and conservation; and agree to develop a local economy of exchange and recycling between producers and consumers that would enable primary producers to make a living without destroying the land, effectively protecting the local economy from destructive global marketing.

Does it add up to a pipe dream? I hope to have at least presented a sufficiently convincing case to stimulate further discussion. I believe that the coupled system for sustainable land use is a plank (if not a platform!) on which the agricultural sciences can unite to formulate a new mission and research agenda.

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RESUME

La durabilité de l'utilisation des terres peut être définie comme un critère "dur" basé sur des indicateurs scientifiques de capacité de charge ou d'exploitation durable. Ce type de définition est utile et important, si au moins il amène à justifier la crédibilité des sciences naturelles, et peut par conséquent, leur donner la priorité sur les ordres du jour politiques à l'utilisation durable des terres. Cependant, tout en acceptant des critères durs pour évaluer l'activité humaine pour réhausser la durabilité de l'utilisation des terres, ce type de définition n'est pas très effectif pour informer l'activité humaine en soi-même. La durabilité est déjà devenue une importante question dans notre société à risque actuelle, précisément à cause de la dégradation du sol, de l'érosion, de la perte de capacité de rétention de l'eau, la perte de la biomasse, de la biodiversité, perte de la fertilité du sol, sa pollution et d'autres problèmes, tous causés par l'activité de l'homme. Les sciences naturelles peuvent traiter avec les conséquences biophysiques de l'activité humaine; elles peuvent nous parler des destructions faites par l'homme. Elles peuvent nous donner des standards auxquels l'activité humaine doit adhérer. Elles nous aide à comprendre les principes, les normes, les indicateurs et les types de gestion des terres qui sont requis. Nous avons récemment vu d'importants changements dans notre compréhension des écosystèmes. Nous devons accepter maintenant, que ceux-ci soient complexes, non-linéaires, chaotiques, d'organisation propre, non équilibrés et discontinus. Il en est résulté que nous avons accepté que soit essentielle pour une gestion durable des terres, une gestion non de contrôle mais adaptée, y compris une exploration continue et explicative, une surveillance et une adaptation de nos interventions. Mais la science ne traite pas avec l'activité humaine directement, c-à-d, avec les intentions de l'homme, avec le sens donné à la vie, l'organisation, le pouvoir, l'élan de l'histoire et autres questions qui doivent être la clé pour traiter des causes d'une utilisation des terres non durable. Cet article va essayer d'aborder ce problème qui prend pour position que la durabilité de l'utilisation des terres est une propriété émergente du système flexible, c-à-d, le résultat de processus d'apprentissage et d'interaction parmi les utilisateurs des terres. Ceci place la durabilité dans un contexte social. Au lieu d'un critère absolu basé sur une évaluation scientifique de l'état de la terre, la définition flexible augmente la durabilité telle qu'apprise, négociée et convenue. La durabilité devient l'aboutissement de l'activité humaine basée sur les institutions, les politiques, la culture et le pouvoir. La durabilité devient l'interface entre la capacité d'apprendre de l'homme et la biosphère dont nous faisons partie. La majeure partie de cet article va essayer de faire son possible dans cette perspective par l'exploration de différentes approches pour développer une sorte d'action collective apprise qui pourrait rendre l'utilisation des terres plus durable.

RESUMEN

Sostenibilidad del uso de las tierras puede ser definida como un criterio "duro", basado en indicadores científicos de capacidad de carga o de explotación sostenible. Este tipo de definición es útil e importante, cuando menos porque viene a soportar la credibilidad de la ciencia natural, y por lo tanto puede aumentar la prioridad que se le da al uso sostenible de las tierras en las agendas políticas. Aunque la definición permite tomar en cuenta criterios fuertes para evaluar la capacidad de las actividades humanas en mejorar la sostenibilidad del uso de las tierras, este tipo de definición no es muy efectivo para informar la actividad humana en sí misma. Aun así, la sostenibilidad se ha vuelto un tema importante en nuestra presente "sociedad de riesgo" precisamente debido a la degradación de las tierras, la erosión, la pérdida de capacidad de retención de agua, la pérdida de biomasa, la pérdida de biodiversidad, la pérdida de fertilidad de los suelos, la polución de los suelos y otros problemas, los cuales están todos causados por la actividad humana. La ciencia natural es capaz de tratar con las consecuencias biofísicas de la actividad humana; ella nos puede contar la destrucción causada por la gente. Ella nos puede proveer pautas a las cuales la actividad humana debe adherirse. Nos puede ayudar a entender los principios, las normas, los indicadores y los tipos de manejo de las tierras que se requieren. Es por esto que recientemente hemos visto cambios importantes en nuestro entendimiento de los ecosistemas. Ahora aceptamos que estos ecosistemas son complejos, no-lineares, caóticos, con organización propia, sin equilibrio y descontinuos. Como consecuencia, hemos aceptado que lo que es esencial para el manejo sostenible de las tierras no es el control pero el manejo adaptivo, el cual implica un continuo ensayo exploratorio, monitoreo, y adaptación de nuestras intervenciones. Pero la ciencia no trata con la actividad humana en sí misma, por ejemplo, con la intencionalidad humana, el sentido común, la organización, el poder, el impulso de la historia y otros temas, que deben ser clave en analizar las causas del uso no-sostenible de las tierras. Este artículo trata de abordar este problema, principiando con una definición de la sostenibilidad que propone que el uso sostenible de las tierras es la propiedad emergente de un sistema suave, o sea el resultado de procesos de aprendizaje y de interacción entre usuarios de las tierras. Esto hace que la sostenibilidad sea una construcción social. En vez de usar un criterio absoluto basado en una evaluación científica del estado de las tierras, la definición suave pone énfasis en la sostenibilidad como algo aprendido, negociado y acordado. La sostenibilidad se vuelve un producto de la actividad humana fundado en instituciones, políticas, cultura y poder. La sostenibilidad pasa a ser el interface entre la habilidad humana de aprender y la biosfera de la cual hacemos parte. La mayor parte de este artículo trata de dar manos y pies a esta perspectiva mediante la exploración de varios enfoques que fomenten el tipo de acción colectiva aprendida, que pudiera hacer el uso de las tierras más sostenible.

PAGE VI Sustainable land use for the 21st century | Executive Summary. tend to better allocate land use to areas with minimal effect on the ecosystems. The models better capture the potential productivity of different land uses and are better able to reflect land management than economic models. However, geographic models assume that prices and other international feedback variables are exogenous.Â Economic models focus on the demand and supply of land-based goods and services. They more effectively reflect the effect of international trade and globalization on LUCC change. Additionally, economic models use scenarios to capture the influence of policies and other socio-economic factors on LUCC. Selected sustainability indicators were quantified based on land-use/transport interaction model and integrated into a single index. Results were compared for 2006 and 2030 in Melbourne as a case study, to evaluate progress towards sustainability in the future. The framework developed in this study provides a promising basis for decision-making to support sustainable land-use planning in urban areas. MSE and R values for ANN models. â€¦ Prediction of land-use/transport interaction model for 2030. â€¦ No caption available. â€¦ No caption available. KEYWORDS Sustainability; environmental sustainability; social sustainability; economic sustainability; institutional investors; actuarial science; models; assumptions; triple bottom line.Â Also, the capacity of the Earth to accommodate the increase in waste, effluents, pollutants and land-use changes generated by a growth-orientated economic system is limited (Meadows et al., 1972; Daly, 1996). Such changes are already occurring and are having material effects on society. The changes affect environmental sustainability, social sustainability and economic. sustainability. As and when these changes become more serious they will seriously affect the economic assumptions we as actuaries currently use in our models. However, placing land evaluation and land use systems analysis in the broader context of land use planning revealed a potential gap between technology-oriented land resource specialists, concerned with the present and future performance of the land, and human-oriented scientists concerned with the land users and their well being.Â Farm household models have been developed to make sustainability issues operational at a level where socio-economic disciplines meet with bio-physical disciplines. Quantitative models at this level calculate changes in land quality specifications due to both natural occurrences and human intervention. Figure 2: shows the major features of a land use system. De Bie et al.