30. EXPLORING THE INTERFACE BETWEEN COMMUNITY-BASED FOREST MANAGEMENT AND SYSTEMS MODELLING

Guillermo A. Mendoza

Participatory modes of development, in general and community-based forest management in particular, have been widely accepted as a better alternative to traditional management paradigms, which have been discredited for being too expert-driven, centrally planned, and essentially top-down with strong adherence to principles of rationality. Recently however, participatory approaches have also received some criticism for their lack of rigour and highly empiricist orientation. Traditional modelling approaches have often been associated with traditional management paradigms in part because they are highly structured and systematic in their approach. Despite their perceived limitations, participatory approaches and modelling offer a number of desirable properties and strengths that can enhance both the practice and theory of community-based management. This paper explores alternative ways by which systems modelling can be adopted in a participatory framework. Combining these two approaches offers the flexibility, inclusivity and practicality of participatory methods, and the systemic, systematic and analytical capabilities of systems modelling. Examples of models that adhere to this hybrid approach are described in this paper.

INTRODUCTION

Community-based resource management has now become the mainstream approach to managing natural resources – including forest resources – worldwide, but especially among many developing nations. Consequently, the literature is rich with management philosophies and paradigms supporting various types of participatory methods such as community-based resource management, joint forest management, co-management, adaptive management, participatory action research, and integrated resource management. While these methods are somewhat different in their overall approach, they have some fundamental similarities and commonalities in terms of their general process and the nature of issues and problems they are designed to address, which generally include multiple stakeholders and their multiple interests, plurality of perspectives, and the empowerment of stakeholders or communities so that they can participate actively in the planning and decision-making process.

The popularity and wide acceptance of participatory or community-based approaches grew out of the perceived failures of traditional 'top down', command-and-control approach to natural resource management. This approach has received widespread criticism and has essentially been discredited by development scientists and practitioners. Familiar critiques have been that it is too expert-driven, centrally planned, and overly emphasizes economic rationalism at the expense of other objectives (cf. the concept of 'satisficing'), and the decision-making process is restricted in a way that local communities are either excluded or marginalized.

The backlash – some authors even call it a tyranny – against the traditional model of development and resource management led to advocates for alternative approaches that are more participatory and collaborative. Most visible early promoters and developers of such approach were Chambers (1994, 1997) and Fals-Borda and Rahman (1991). Chambers, in particular, was highly influential in arguing against traditional models of development claiming that participatory methods made development more collaborative, empowering, democratic, just and effective. His pioneering efforts led to the development of the widely used method called participatory rural appraisal, and more generally, a method of inquiry called participatory action research. This method promoted collaboration and power-sharing in the management of natural resources through the incorporation of the perspectives of local communities. Such democratic and levelling of the power imbalances of these approaches were touted as having highly positive far-reaching effects not only in the development and design of management strategies, but also in their implementation.

Much has been done over the last decade to pursue participatory methods. Current literature is rich with descriptions of participatory approaches, which have been reported in various forms and a range of names, including joint forest management (Misra 1997, Kumar and Kaul 1997), adaptive co-management, participatory action research (Selener 1997), community-based resource management, and integrated resource management (Saxena *et al*. 2002). The method has become a staple in most community-based resource management.

Despite their widespread adoption and the enormous amount of reported successes, concerns have been raised about these participatory methods and the degree to which they lived up to the great claims about their effectiveness. Cooke and Kothari (2001) for example, outlined a critique of several authors, which include academics and practitioners. In fact, their book labels participatory approaches as the 'new tyranny'. Mohan and Stokke (2000) also argued that participatory methods, particularly the widely used rural participatory appraisal (RPA) developed by Chambers (1994), downplay local socio-economic inequalities and, more importantly, tend to focus on 'localism' and ignore broader national socio-economic orientation. Kapoor (2002) went further and identified weaknesses of RPA in particular, and participatory development in general, on their 'empiricist' methodological orientation, and argued that it is this empiricist orientation that begets 'localism'.

This paper explores the interface between the two management paradigms, namely the participatory management paradigm and the more structured (or scientific) paradigm. The paper takes the posture that one paradigm is not necessarily better or more effective than the other. The paper explores the interface, and in the process attempts to bridge the gap between the two approaches. A unifying framework by which the two methods can be linked or combined is laid out.

SYSTEMS MODELLING AND COMMUNITY-BASED FORESTRY

In this paper, *system modelling* is taken as an inclusive term to embrace any structured or highly systematic approaches to management. It may also be broadly described as falling under the umbrella of 'scientific' management, a paradigm that relies heavily on the principles of objective analysis, rational decision-making, comprehensive and systematic evaluation, and quantitative methods. In its purest form, it is a computer-based analytical and simulation modelling approach that attempts to 'mimic' the management problem, the decision environment, and the rational thinking of individuals or groups of individuals.

Inherent in systems modelling is the systems approach which Grant *et al.* (1997) defined as 'the process of conceptualizing, quantifying, evaluating, and using a simulation model – allows us to recognize causal relationships in complex systems that can not be identified by other methods'. This simple definition captures the basic building block of systems modelling – that of recognizing causal relationships among elements of complex systems. Clearly, natural resource management problems, including small-scale forestry, are intrinsically complex systems, that lend themselves well to systems modelling.

The systems approach offers a convenient and suitable platform to adopt a multi-disciplinary approach to natural resource management. It has a broad enough perspective to accommodate multiple disciplines and it is 'systematic' in the sense that different disciplinary perceptions or 'pieces' of the puzzle can be put together, not in a random or arbitrary manner but rather one that follows a 'structured' process. As Grant et al (1997) indicated, two simple but powerful principles at the core of systems modelling are that systems are composed of inter-related elements or parts, and that system function is related to system structures. Grant et al (1997) also stated that these two principles make the system approach in general, and systems modelling in particular, a solid basis or foundation for sustainable, multiple use of natural resources by facilitating multidisciplinary (or perhaps more appropriately, transdisciplinary) planning by creating an effective communication interface between scientists and policy-makers. Systems modelling within a participatory framework can be difficult primarily because there can be some gaps in perception as well as in analytical frameworks when non-experts such as local community members or non-modellers are included in the multidisciplinary teams. Invariably, technically trained experts are more likely to shape the planning process following the 'scientific method' or some other structured analysis framework. In fact, systems modelling was originally conceived from an engineering perspective; hence, a basic assumption is that the *system* can be understood adequately, and the causality relationships between and among the system parts or elements are also well understood. To some extent, this assumption may be valid for some aspects of the natural resource management problem. Production systems, for example, may be sufficiently understood so that the causality or mechanistic relationships and dynamic interactions and processes between and among the different elements are adequately understood and *modelled*. This assumption may be difficult to satisfy if the *human* dimensions of natural resource management are included in the analysis. Integrating the social or human dimensions with the biophysical aspects could render the modelling process, and the model itself, much more complex.

In an attempt to make systems modelling more adaptable and robust, Belton and Stewart (2001) proposed the general modelling framework described in Figure 1. This integrated modelling framework is a five-step modelling process that starts with the soft or qualitative problem exploration phase in step 1, to the development of action plans in step 5. The purpose of the initial stages is to draw out the values or objectives of the stakeholders. The point of departure from the initial qualitative stages of value exploration to the next stage is not distinct. Belton and Stewart (2001) considered the transition as essentially a phase of problem structuring with the aim of 'beginning to think about managing uncertainty and complexity and to understand how to move forward'. The middle stages of the integrated modelling framework, particularly steps 3 and 4, are where formal quantification or systematic structuring occurs. Clearly, as Figure 1 illustrates, the steps are interactive, cyclic and iterative, but within and among the steps. Participatory modelling is reflected throughout the entire process.

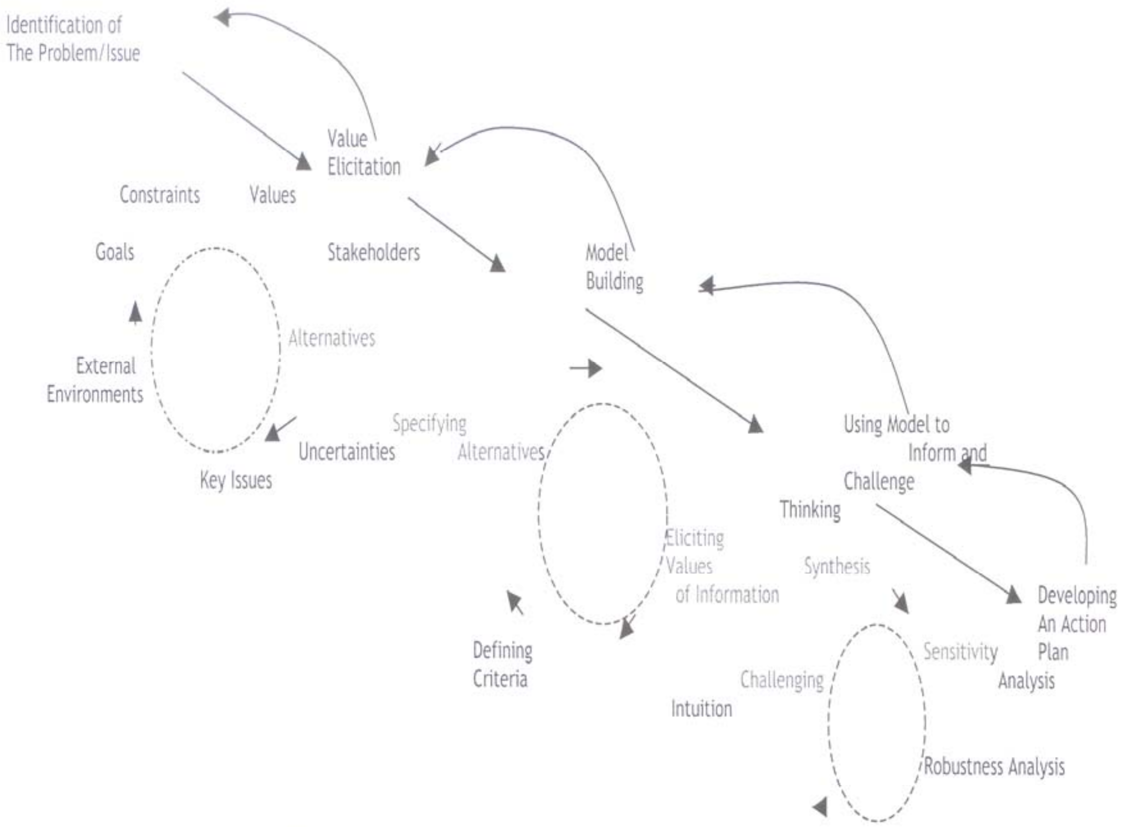

Figure 1: Structuring Framework of Decision Support Systems*

Source: Belton, V. and T. Stewart. 2001. Multiple Criteria Decision Analysis: An Integrated Approach. Kluwer Academic Publishers. Norwell, MA. US.

SOFT SYSTEM-BASED MODELS FOR PARTICIPATORY MODELLING

Many of the issues discussed above revolve around: (1) the difficulties spawned by the inevitability (or necessity) of including local communities and other stakeholders in the planning and decision-making processes, (2) the need to craft a *transdisciplinary* framework that spans the range of expertise and disciplines, including non-scientific management paradigms, and (3) the need to include social and human dimensions and concerns in the planning and decision-making processes. These concerns point to the need for a transdiciplinary modelling framework that is participatory, both systemic and systematic, and capable of accommodating both technical and mechanistic aspects of natural resource management, as well as the non-technical social dimensions. Soft system-based models offer such a modelling framework.

Mendoza and Prabhu (2006) drew attention to the need for participatory modelling. This paper further argues that participatory modelling serves as an appropriate framework for pursuing a transdisciplinary approach to natural resource management. Clearly, natural resource management encompasses many components, as well as many stakeholders, each demanding a voice in the way community-based resources should be managed. In this context, participatory modelling offers a forum by which stakeholders can debate, interact and discuss alternative management regimes, which reflect expert-driven and often technically-oriented alternatives, as well as loosely defined strategies put forth by local communities. Hence, the transdisciplinary approach envisaged in this paper is one that blends traditionally technical disciplines with the informal or less formally defined, perhaps even naïve, ideas of local communities. This presents an obvious problem because the discipline-oriented modelling approach often requires formalized thinking and structures in which the local communities generally find participation difficult or even impossible. These formalized structures often involve theoretical constructs and rational thinking that communities are unaccustomed to, unable to relate to, uncomfortable with, and even find threatening.

The brief discussion outlined above calls for a new modelling paradigm, which is fundamentally inclusive, pluralistic and participatory while at the same time retaining some of the 'analytical' and formal structures of traditional disciplines. Some degree of formalization in participatory modelling is necessary to enable a certain amount of 'critical analysis' so that meaningful and 'justifiable' or 'testable' results can be generated. However, the degree of formalization, and rigour, should be at a level that local communities with less formal training and education are able to relate to, and be engaged with. The depth and degree of model 'structuring' should be commensurate to the local communities' capability to grasp, not to the degree by which experts' tools of traditional models are able to accommodate. The following sections provide an overview of some soft systems modelling approaches developed for community-based forest management. The overview is not meant to be comprehensive; in fact, it is limited to the methods with which the author is familiar. In fact, most of these methods have been developed and applied by the author.

COGNITIVE MAPPING

Cognitive mapping (CM) is a general approach to represent complex decision problems composed of dynamic entities which are interrelated in complex ways, usually including feedback links. These complex entities are represented as nodes and the causal links are represented by edges or arrows with the direction of the arrow representing the direction of influence. CMs therefore are essentially structured ideas laid out purposely for understanding basic relationships and dynamics of a system. The process begins with generation of ideas or concepts with direct and active participation of all stakeholders. This process is very similar to participatory rural appraisal techniques. However, cognitive mapping goes beyond simple listing of essential ideas or concepts. These ideas are organized into a *map* showing the relationships and interactions between and among the ideas. These relationships are organized following a layout of nodes and arrows (i.e. *nodes* represent concepts or ideas and *arrows* denote the interactions or linkages between these ideas). In summary, CM is essentially a graphic representation of how a person perceives a decision problem, organizing the elements of the decision problem as a network of interacting elements. Eden (1988) proposed cognitive mapping as an approach to strategic thinking particularly in exploring values, issues, concerns, perspectives, goals, objectives or 'worldviews as cited by Checkland (1981). Eden (1988) defined a cognitive map as a model amenable to formal analysis that is designed to mimic the way a person defines or perceives an issue. The cognitive map is organized as a set of ideas or concepts framed as a network of nodes, arrows or links to represent the relationships of the concepts or ideas. Mendoza and Prabhu (2003) describe an application of cognitive mapping on a community-managed forest in Zimbabwe. In this case study, three groups representing three villages were convened to assess the sustainable management of the Mafungautsi forest, the boundary of which encompasses the community forests managed by the villages.

QUALITATIVE SYSTEM DYNAMICS

While cognitive mapping provides some rigour and structured analysis beyond the enumerative listing of problem components, it is still lacking in terms of the more formal analysis demanded of most planning and decision-making models. Cognizant of the need for such analysis, Wolstenholme (1990, 1999) and Coyle (2000) proposed the use of *qualitative systems dynamics*. Qualitative systems dynamics was initially proposed to complement the capabilities of cognitive mapping. The development of the concept has since evolved towards adapting and applying the aspects of systems dynamics (Sterman 2000) without the use of quantification and simulation, two key components of traditional system dynamics.

The cognitive map approach described above is essentially a first attempt to structure the essential elements or components of a system. Clearly, the objective of developing a cognitive map is to lay out the overall relationships of factors or elements of a system. For some applications, this may be a sufficient level of analysis given the inherent complexity of the management problem. However, particularly in some situations where there is more information, knowledge or experience about the various factors or elements, it may be possible to structure the cognitive map as an 'influence diagram'. In other words, the relationships are described in terms of causalities between nodes connected by an arrow. In this case, the concept of system dynamics is appropriate (Forrester 1961).

System dynamics is a general term associated with the study of the dynamic behaviour of a variety of complex systems (Coyle 2000). Typically, influence diagrams using nodes and directional arrows are used to denote this dynamic behaviour. In addition, the relationships sometimes referred to as feedback loops or causality diagrams, are either positive or negative. The diagram can serve as a 'sense making' device for the purpose of identifying dynamic causality relationships. Purnomo *et al.* (2004) used a number of influence diagrams to examine the criteria and indicators of a community-managed forest in Indonesia.

Two models developed recently by scientists and researchers at the Centre for International Forestry Research exemplify soft systems models consistent with the principles of qualitative systems dynamics, namely *Co-View* (**C**ollaborative **V**ision **E**xploration **W**orkbench), and *Co-Learn* (Collaborative Learning). Co-View is generally described as 'a tool to help facilitators of natural resource management and stakeholders to articulate and explore a shared vision of the future and to develop strategies to achieve it. It is aimed at strengthening the link between visioning and modelling, by making it easier to use a visioning process as the entry point for modelling, and to use the results of simulation modelling to help to generate strategies for achieving the vision. Co-View has been designed to support social learning, in which the dreams and understanding of the members of the group are brought together leading to new shared insights and joint strategies for action. It has been developed and tested with local communities in Zimbabwe within a program of participatory action research on adaptive resource management strategies (CIFOR, 2000).

Co-learn is a 'software package that facilitates and enables users to navigate around a range of tools and processes. It is intended to be a meta-tool, implemented as a software interface and navigation aid for a suite of computer-based learning support tools. It seeks to support adaptive and collaborative management (ACM) of natural resources by helping people to enjoy learning processes in groups. *Co-Learn* is intended to be used by both participants in group learning processes, as a navigation aid, and by facilitators of such processes for planning, technical support and record keeping. The *Co-Learn* package contains a visioning tool called T*he Bridge Software*. The purpose of '*The Bridge'* is to help people express a vision in a structured way so that it is easy to use as the basis for devising new strategies for action. It is a simple compute-based knowledge management tool. From the users' point of view it involves a series of interactions or dialogues which each elicit a part of their vision, gradually building up the whole picture. After eliciting the vision, a series of steps help users to transform their vision into a conceptual diagram representing their *strategy* for achieving their desired future. The diagram expresses linkages between elements of the vision, and helps with exploration of how the strategy will bring about the changes needed. The visioning tool also helps lessons learned through the diagram to feed back into original vision' (CIFOR 2002).

MULTI-AGENT SIMULATION SYSTEMS

Participatory modelling and participatory management are essentially decision-making environments that involve multiple stakeholders, each demanding a say in the management of the resources. Hence, participatory modeling involves a set of individual agents, each agent making decisions based on what they perceives as a rational choice according to established rules or patterns of behaviour as decided upon by the stakeholders. In this context, understanding a stakeholder's activities and interactions requires a tool that is able to represent the individual's knowledge, beliefs and behaviour. *Multi-agent Systems* (MAS) is one such tool. As its name implies, MAS is a general approach that takes into account the presence of multiple agents (actors or stakeholders), each with their unique views, perspectives and behaviour. Each agent or actor acts or reacts (or makes decisions) as they pursue their objectives rationally, or according to their own rules and behavioural patterns. Bousquet and Le Page (2004) provided an excellent review of MAS particularly its application to ecosystem management.

There are a number of desirable features that makes MAS a suitable framework for analyzing participatory management of natural resources. First, it is an ideal environment for analyzing participatory management because the system recognizes the existence of multiple agents with their own unique style of decision-making. Second, it also recognizes the strong connections and interactions between and among the actors. The MAS system also takes into account the unique ways each agent endowed with cognitive abilities perceives, reflects, constructs, strategizes, acts and reacts to the changing resource environment as it is affected by all the actors or agents.

MAS is a robust approach for analyzing and simulating complex systems involving multiple agents with mechanisms for coordination of independent agents' behaviour. Because of its inherent multi-agent structure, and the inclusion of perceived behavioural patterns of agents, MAS constitutes perhaps the most explicit method for participatory modelling and analysis. Of the three soft systems models described here, MAS is perhaps the one that has been applied most, including for natural resource management. One of the first applications was on common property management regimes that are pervasive among developing nations particularly with agriculture and forestry. In this context, much of the initial development and application of MAS was done by Bousquet (1998). Several authors have since applied MAS to a number of cases and studies: irrigation systems (Barreteau and Bousquet 2000), resource sharing regimes (Thebaud and Locatelli 2001), natural resource management (Rouchier *et al*. 2000), game management (Bousquet *et al*. 2001), economic and social development (Rouchier *et al*. 2001), and environmental management (Bousquet *et al*. 1999, 2002).

Castella *et al*. (2005) reported applications of MAS to lowland-upland interactions in the mountain areas of Vietnam. In addition, Boissau and Castela (2003) described the use of MAS in a gaming simulation environment for constructing a common representation of local institutions and land-use systems in Northern Vietnam. Finally, Castella *et al.* (2005) combined MAS with role-playing games and GIS for simulating land-use changes in Vietnam.

OTHER SOFT SYSTEM MODELS

Lynam *et al.* (2007) wrote an excellent review of the various tools that could be categorized as soft systems models. Their paper surveyed and evaluated selected participatory tools that they considered to be effective in natural resource management based on their experience working with forest communities. These models include: Bayesian Belief Network (BBN), Discourse-based Valuation, the 4R Framework, Participatory Mapping, the Pebble Distribution Method, Future Scenarios, Spidergrams, and Who Counts. The following section briefly describes these approaches as reported in Lynam *et al*. (2007).

BBN (Cain *et al.* 2001), is essentially a modelling environment that provide probabilistic representation of the relationships between 'factors' or input variables and the possible 'states' of a system. *Discourse-based valuation* (Wilson and Howarth 2002) is a method designed for groups to establish agreed upon preference ordering of concepts using different metrics. The *4R Framework* (Dubois 1998) assesses the stakeholders' roles and analyzes the balance of influence among stakeholders in terms of the R's (Rights, Responsibilities, Returns and Relationships). *Participatory Mapping* (Lynam 2002) essentially draws from the principles of rapid rural appraisal (Chambers 2002) by involving communities in developing representations of spatial relationships among real-world objects or elements. The *Pebble Distribution Method* (Colfer *et al.* 1999) is a 'scoring' method that can help understand the priorities of the participants or communities. Future scenarios (Wollenberg 2000) are designed for communities to learn about the future in order to be anticipative and adaptive particularly under conditions of uncertainty and complexity. *Spidergrams* (Lynam *et al.* 2003) can be used to provide a representation of the components and attributes of a system, and also to explore these attributes based on their relative importance or contribution to the goal of management. Finally, *Who Counts* (Colfer 1995) is a model designed to identify the 'key' or important stakeholders.

MODELS AS LEARNING AND COMMUNICATION TOOLS

Traditional system-based models are designed for the purpose of 'mimicking' the behaviour of the real-world system, particularly its biophysical components. Most models tend to be 'predictive', quantitative, rational and objective in its orientation. Consequently, these models are formulated to describe the 'functioning' of a system through an explicit, and often 'functional', description of the interactions and processes within the modelled real world system. These types of models are typical of most 'formal' models.

Despite the elegance, rigour, presumed rationality, objectivity and comprehensiveness of formal models, their acceptance and eventual real-world application by practitioners, particularly among local communities, is rather limited. Critics of these models generally point to the strict assumptions, rigidity, rigour and narrow scope of these models as reasons for their lack of acceptance among practitioners. Moreover, lack of community or stakeholder participation in the design, formulation, and development of these models have also been raised as major shortcomings of traditional models.

In light of the limitations of current models, it may be insightful to examine some fundamental issues that affect the adoption and use of models. For example, a number of scientists have advocated for the use of models not as 'prescriptive, predictive, analytical, rational, and objective models. Instead, models are envisioned as 'learning' tools that fundamentally make no pretence to 'solve problems' or even explain the behaviour of a system.

Recently, there has been a growing emphasis among systems modellers on developing tools and processes that help communities or stakeholders (e.g. decision-makers) 'learn' through the models. Using models as 'learning' tools is really not a new concept because models have always been viewed as tools for planning and decision-support. Hence, models have essentially always been seen as a vehicle or instrument by which insights and other pertinent information can be generated and used in order to make support informed decisions (e.g. learning from model results). However, as pointed out earlier, in response to clamour among practitioners for models to be more 'participatory', less rigorous and 'transdisciplinary, new 'types' of models and new modelling paradigms have been proposed.

The new types of models differ from traditional models in that they are intentionally and inherently robust, flexible and open-ended. Robustness in traditional formal models is often achieved through objective sensitivity analysis by systematically varying levels of model parameters. While this approach expands the scope of models, they nonetheless remain limited and narrow in their ability to embrace the range of complexity and uncertainty typically found in complex systems such as community-based natural resource management. Rosenhead (1989) differentiated these two paradigms succinctly in the following quote:

> In the swampy lowland, messy, confusing problems defy technical solution. The irony of this is that the problems of the high ground tend to be relatively unimportant to individuals or society at large, while in the swamp lie the problems of greatest concern.
> The practitioner must choose. Shall he/she remain on the high ground where he can solve relatively unimportant problems according to prevailing standards of rigor … or shall h/she descend to the swamp of important problems and non-rigorous inquiry.

In the above quote, traditional modelling approaches belong to 'modelling on the high ground' while the new paradigm such as soft system models' are best described as 'modelling in the swamp'. As described in the previous sections, community-based forest management is a classic environment for the use of soft systems models.

THE WAY FORWARD

Wide acceptance and increasing popularity of participatory management place transdisciplinary methods at the centre of suitable approaches to pursue community-based natural resource management. Increasingly, local communities demand more voice and control in the way local resources are managed. To accommodate the voices of local communities and other stakeholders, and at the same time pursue systematic analyses of community-based forests requires an analytical and evaluative framework that accepts qualitative, inexact, raw ideas while still maintaining some rigour that permits structured analysis. Traditional scientific methods often do not provide such a framework or planning and decision-making environment because they generally are less flexible and too structured.

Lynam *et al.* (2007) in reviewing different participatory tools offered the notable conclusion that 'participatory tools are rarely used alone; they are typically part of a series (suite) of methods and procedures. Very often, it is the combination of methods and the robustness of the research and implementation and design that determines if the tool is useful and ultimately effective.' Indeed, there are synergies between and among these models. Complementary and combined use of these models would allow a more robust and flexible 'participatory' modelling environment better suited for the nature of complexity and amount of uncertainty typical of most community-based forest management.

REFERENCES

Barreteau, O. and Bousquet, F. (2000), 'SHADOC: A multi-agent model to tackle variability of irrigated systems, *Annals of Operations Research*, 94 (1–4):139-162.

Belton, V. and Stewart, T. (2001). *Multiple Criteria Decision Analysis: An Integrated Approach*, Kluwer Academic Publishers, Norwell, MA.

Boissau, S. and Castella, J.C. (2003), 'Constructing a common representation of local institutions and and-use systems through simulation gaming and multi-agent modelling in rural areas of Northern Vietnam: the SAMBA-Week methodology', *Simulation and Gaming*, 34(53): 342–347.

Bousquet, F. (1998), 'CORMAS: Common pool resources and multi-agent systems', Lecture Notes in Computer Systems, 14(16): 826–838.

Bousquet, F., Barretaeau, O., Lepage, C. and Mullon, C. (1999), 'An environmental modelling approach: The use of multi-agent simulations', in A*dvances in Environmental and Ecological Modelling*, F. Blasco and A. Weill (eds), Elsevier, Paris.

Bousquet, F., Lepage, C., Bakam, I.and Takforyan, A. (2001), 'Multi-agent simulations of hunting wild meat in a village in eastern Cameroon', *Ecological Modelling*, 138: 331–346.

Bousquet, F., Barreteau, O., d'Aquino, P., Etienne, M., Boissau, S., Aubert, S., Le Page, C., Babin, D. and Castella, J.-C. (2002), 'Multi-agent systems and role games: collective learning processes for ecosystem management', in *Complexity and Ecosystem Management: The Theory and Practice of Multi-agent Approaches*, M. Janssen (ed.), Edward Elgar Publishing, Cheltenham.

Buosquet, F. and Le Page, C. (2004), 'Multi-agent simulations and ecosystem management: a review', *Ecological Modelling*, 176(3–4): 313–332.

Cain, J. (2001), Planning Improvements in Natural Resources Management: Guidelines for using Bayesian Networks to Manage Development Projects, Institute of Hydrology, Wallingford, UK.

Castella, J.C., Trung, T.N. and Boissau, S. (2005), 'Participatory simulation of land-use changes in Northern mountains of Vietnam: The combined use of an agent-based model, a role-playing-game and geographic information system', *Ecology and Society*, 10(1): [Online]: URL http://www.ecologyandsociety.org/vol10/iss/art27, accessed 6 April 2007.

Chambers, R. (1994), 'The origins and practise of participatory rural appraisal', *World Development Report*, 22(7):953–969.

Chambers, R. (1997), *Whose reality counts? Putting the last first*, Intermediate Technology Publications, London.

Chambers, R. (2002), 'Participatory numbers: Experience, questions and the future', in *Proceedings of the Conference on Combining Qualitative and Quantitative Methods in Development Research*, 1–2 July 2002, Centre for Development Studies, University of Wales at Swansea, http://www.swan.ac.uk/cds/research/SDRC/conference_on_combining_qualitat.htm.

Checkland, P.B. (1981), *Systems Thinking Systems Practise*, Wiley, Chichester.

Checkland, P.B. (1984), Systems thinking in management: the development of soft systems methodology and its implications for social science. In: Self-Organization and Management of Social Systems. Eds. H. Ulrich and G.B. Probst). Springer-Verlag. Berlin, pp. 94–104.

Checkland, P.B. (1988), 'Soft systems methodology: overview', *Journal of Applied Systems*, 15(1): 27–30.

CIFOR (2000), Co-View (http://www.cifor.cgiar.org/acm/pub/co-view.html).

CIFOR (2002), Co-Learn (http://www.cifor.cgiar.org/acm/pub/co-learn.html).

Colfer, C.J.P., Brocklesby, M.A., Diaw, C., Etuge, P., Günter, M., Harwell, E., McDougall, C., Porro, N.M., Porro, R., Prabhu, R., Salim, A., Sardjono, M.A., Tchikangwa, B., M.Tiani, A., Wadley, R., Woelfel, J. and Wollenberg, E. (1999), 'The grab bag: supplementary methods for assessing human well-being', *The Criteria and Indicators Toolbox Series*, Number 6, Center for International Forestry Research (CIFOR), Bogor, Indonesia.

Colfer, C.J.P. (1995), Who Counts Most in Sustainable Forest Management?', CIFOR Working Paper 7, Centre for International Forestry Research (CIFOR), Bogor, Indonesia, B. Cooke and U. Kothari (2001), *Participation: The New Tyranny*, Zed Books, London.

Cooke, B. and Kothari, U. (eds) (2001), *Participation: The New Tyranny*, Zed Books, London.

Coyle, G. (2000), 'Qualitative and quantitative modelling in system dynamics: Some research questions', *Systems Dynamics Review*, 16(3): 225–244.

Dubois, O. (1998), Capacity to manage role changes in forestry: introducing the '4Rs' framework', International Institute for Environment and Development (IIED), London.

Eden, C. (1988), 'Cognitive mapping: A review', *European Journal of Operational Research*, 36(1):1–13.

Fals-Borda, O. and Rahman, M. (1991), *Action and Knowledge: Breaking the Monopoly with Participatory Action Research*, Apex Press, New York.

Forrester, J.W. (1961). *Industrial Dynamics*, MIT Press, Boston, MA.

Grant, J.W., Pedersen, E.K. and Marin S.L. (1997), *Ecology and Natural Resource Management: System Analysis and Simulation*, Addison-Wesley Publishing Company, Reading, Massachusetts.

Kapoor, I. (2002), 'The devil's in the theory: A critical assessment of Robert Cambers' work on participatory development' *Third World Quarterly*, 23(1):101–117.

Kumar A. and Kaul R.N. (1997), 'Joint forest management India: Points to ponder', *Wastelands News*, 12(3): 64–67.

Lynam, T., Bousquet, F., Le Page, C., d'Aquino, P., Barreteau, O., Chinembiri, F. and Mombeshora, B. (2002), 'Adapting science to adaptive managers: Spidergrams, belief models and multi-agent systems modelling', *Conservation Ecology*, 5(2): 24 [online] URL: http://www.consecol.org/vol5/iss2/art24, accessed 7 May 2007.

Lynam, T., De Jong, W., Sheil, D., Kusumanto, T. and Evans, K. (2007), 'A review of tools for incorporating community knowledge, preferences and values into decision making in natural resource management', *Ecology and Society*, 12(1): [online] URL: http://www.ecologyandsociety.org/vol12/iss1/Accessed art5/, accessed 7 May 2007.

Mendoza, G.A. and Prabhu, R. (2006), 'Participatory modelling and analysis for sustainable forest management: Overview of soft system dynamics models and applications', *Forest Policy and Economics*, 9(2): 179–196.

Mendoza, G.A. and Prabhu. R. (2003), 'Qualitative multi-criteria approaches to assessing indicators of sustainable forest resource management', *Forest Ecology and Management*, 174 (1–3): 329–343.

Mohan, G. and Stokke, K. (2000), 'Participatory development and empowerment: The dangers of localism', *Third World Quarterly*, 21(2): 247–268.

Misra, P.K. (1997), 'Potentialities of JFM: Some reflections', *Wastelands News*, 12(4): 32–33.

Purnomo, H., Mendoza, G.A. and Prabhu, R. (2004), 'A Model for Collaborative Planning for Community-Managed Resources based on Qualitative Soft Systems Approach', *Journal of Tropical Science*, 16(1):106–131.

Purnomo, H., Mendoza, G.A. and Prabhu, R. (2005), 'Developing multi-stakeholder forest management scenarios: A multi-agent system simulation approach', *Forest Policy and Economics*, 7(4): 475–491.

Rouchier, J., Bousquet, F., Barreteau, O., Le Page, C. and Bonnefoy, J.-L., (2000), 'Multi-agent modelling and renewable resources issues: The relevance of shared representations for interacting agents', Lecture Notes in Artificial Intelligence 1979: 181–197, S. Moss and P. Davidsson (eds), MABS 2000, Springer Verlag, Boston, MA.

Rouchier, J., Bousquet, F., Requier-Dejardins, M. and Antona, M. (2001), 'A multi-agent model for transhumance in North Cameroon', *Journal of Economic Dynamics and Control*, 25(3–4): 527–559.

Rosenhead, J. (ed.) (1989), *Rational Analysis for a Problematic World: Structuring Methods for Complexity, Uncertainty and Conflict*, John Wiley and Sons Ltd. West Sussex, England.

Saxena, K.G., Rao, K.S., Sen, K.K., Maikhuri, R.K. and Semwal, R.L. (2002), 'Integrated natural resource management: Approaches and lessons from the Himalya', *Conservation Ecology*, 5(2): [online] URL: http://www.consecol.org/vol5/iss2/, accessed 7 May 2007.

Selener, D. (1997), *Participatory Action Research and Social Change,* The Cornell Participatory Action Research Network, Cornell University. New York.

Sterman, J.D. (2000), *Business Dynamics: Systems Thinking and Modelling for a Complex World*, McGraw-Hill, Boston.

Thebaud, O, and Locatelli, B. (2001), 'Modelling the emergence of resource sharing conventions: An agent-based approach', *Journal of Societies and Social Simulation*, 4(2): [online] URL: http://jasss.soc.surrey.ac.uk/4/2/contents.html, accessed 7 May 2007.

Wilson, M.A. and Howarth, R.B. (2002), 'Discourse-based valuation of ecosystem services: Establishing fair outcomes through group deliberation', *Ecological Economics*, 41 (3): 431–443.

Wollenberg, E., Edmunds, D. and Buck, L. (2000), 'Anticipating change: Scenarios as a tool for adaptive forest management: A guide', Center for International Forestry Research (CIFOR), Bogor, Indonesia.

Wolstenholme, E.F., (1990), *System enquiry: a system dynamics approach*, Chichester, West Sussex, England.

Wolstenholme, E.F. (1999), 'Qualitative vs. quantitative modelling: the evolving balance', *Journal of Operational Research Society*, 50(4): 422–428.