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■ *Research Paper*

Getting the Big Picture in Natural Resource Management—Systems Thinking as 'Method' for Scientists, Policy Makers and Other Stakeholders

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This paper discusses the benefits of applying Systems Thinking to solving natural resource management problems. It first explains the Systems Thinking concept and briefly outlines its history and emergence in agriculture and natural resource management. A series of case studies are then presented which illustrate practical examples of how Systems Thinking has been used to address real life natural resource management issues. The case studies build on the conclusions of each other by adding additional ways (lessons learnt) of incorporating Systems Thinking into practice to address issues more systemically. The first case study deals with examples of how Systems Thinking facilitated the sharing and integration of disparate sources and forms of knowledge, and making sense of the factors influencing tree density in the tropical savanna region of northern Queensland. The second case study deals with how Systems Thinking has been imbedded in the design and implementation of a research project investigating how to improve financial returns to smallholder tree farmers in the Philippines. The third case study illustrates how Systems Thinking was used to design and facilitate an adaptive rodent management project in Cambodia based on participatory research, development and extension. From these experiences, the authors' highlight a variety of key points that lead to the proposition that Systems Thinking should be 'absorbed' into scientific research, in the same way that statistics, is today an integral part of all sciences. A framework for the application of Systems Thinking is presented to help improve sustainable land management. Copyright © 2007 John Wiley & Sons, Ltd.

Keywords Systems Thinking; problem solving; integrating information and knowledge; knowledge building; collaborative learning

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INTRODUCTION

Land managers are regularly faced with the prospect of having to anticipate the consequences of their actions, and avoid unintended consequences, without comprehensive information about the system surrounding their management activities (Bosch *et al*., 2003). This is due to a number of reasons. First, natural systems are complex and while information may be available to assist managers in decision-making, it is often uncertain. Second, relevant information is often fragmented and scattered throughout scientific publications, reports, databases and in people's heads, making it difficult for managers to utilize. Third, divergent views about management can appear because of different management objectives (conservation vs. production) and different people hold different opinions and values about how management systems operate. Information in scientific publications tends to reflect information about reduced scenarios, not the whole system situation which the real decision maker confronts. Finally, this uncertain, fragmented and conflicting picture of natural resource management can result in managers continually dealing with symptoms (empirical observations) rather than the underlying causes of management problems. There appears to be no easy solution to improving information access, utilization and management. The authors propose, however, that progress may be found in the application of Systems Thinking to understand and manage the 'natural' and 'people' systems associated with natural resource problems and solutions.

SYSTEMS THINKING

It is not surprising that recent literature has suggested that 'new ways of thinking' are required (if not essential) to manage the complex problems associated with sustaining and enhancing land condition. Although this range of new methods and methodologies are extensive, many of these new ways of thinking have emerged from or embrace the concepts inherent in Systems Thinking. Taking on a systems approach to land management involves exploring the complexity of interactions within the 'hard' system (the biophysical components that can be modelled, particularly by simulation) and within the 'soft' system (the interactions between the biophysical components, technology and the farm family or village community). It also acknowledges that these systems or whole entities as we might view (or construct) them are embedded in larger systems that provide context and meaning for decisions made at the farm level (an area often neglected in the information supplied to land managers). A systems approach has been shown to be useful because it takes on a holistic view of the world and allows for interactions to be discovered (Röling and Jiggins, 1998).

Systems Thinking has come a long way since the 1950s and Checkland (1985) compares the 'hard' (1950s and 1960s) and 'soft' (1980s) traditions of Systems Thinking, from an approach orientated to goal seeking to that of learning, both having advantages and disadvantages. Ison *et al*. (1997) draws on the work of Checkland and Scholes (1990) suggesting that soft Systems Thinking views systems as (i) constructs, devices or holons that are articulated for the purposes of understanding and change; (ii) a shorthand for a system-sub-system-environment relationship; and (iii) brought forth by an observer who has a unique experiential or cognitive history. A popular methodology to enact this has been Checkland's soft systems methodology (SSM) which takes a set of actors through a process of shared problem appreciation, learning about the problem and taking collective action to improve it (Checkland, 1981). Checkland began developing this tool from 1979, largely in relation to bounded problems in the corporate sector. Since then, this methodology has been used by many researchers and extension agents in the agriculture and resource management domain.

As Systems Thinking developed, the 1990s saw an array of changes in how (some) researchers, development practitioners and extension agents went about their practice. There was a shift away from single disciplinary projects toward multi-disciplinary and inter-disciplinary research, and

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approaches that allow for the recognized complexity of and uncertainty within systems. During this time, there was also recognition that new approaches were needed that would allow knowledge and understanding to emerge from processes involving stakeholders. This led to the application of learning and action based participatory approaches such as action learning, action research, participatory action research and adaptive management (AM). The success of these in agriculture and resource management is well-documented through the 1990s (Hamilton, 1995; Bosch *et al*., 1996; King, 1997; King, 2000).

Today, the current trend in agriculture and natural resource management is for practitioners (and researchers) to facilitate multi-stakeholder participatory methodologies that allow for uncertainty and surprise (Röling and Wagemakers, 1998). Following are three case studies illustrating how Systems Thinking has been used in this context to address real life natural resource management issues with a range of stakeholders. The paper also demonstrates how the learnings from studying different issues, in different localities and using a variety of approaches could be integrated to help develop a framework for the application of Systems Thinking for improved sustainable land management.

CASE STUDY 1: TREE-DENSITY MANAGEMENT IN THE TROPICAL SAVANNA REGION IN AUSTRALIA

Computer-based modelling systems can be useful tools to explore and formulate problems, and subsequently make decisions about land management issues with a range of stakeholders—which can then be followed by action. This case study focuses on using a Bayesian belief network (BBN) (Cain *et al*., 1999) to facilitate the sharing and integration of disparate sources and forms of knowledge, making sense of the factors influencing tree density in the tropical savanna region of northern Queensland, and collaborative learning. A BBN is essentially a cause and effect diagram (flow diagram) in which *nodes* present factors believed (by different stakeholders) to influence particular outcomes. Below are examples of ways in which the tool has been used to achieve Systems Thinking processes for effective multi-stakeholder research in sustainable land management:

Providing a Framework for Knowledge Sharing and Capturing

Using the BBN as a mechanism for Systems Thinking entails effective stakeholder communication and knowledge sharing. The influence diagram (Figure 1) was created with graziers, researchers and extension officers using a BBN which captured their knowledge about the factors believed to influence tree density. Through this process, stakeholders also identified management actions and non-manageable factors that they believed would influence this outcome.

This process provided a mechanism through which stakeholders could express and discuss their understanding of the cause and effect relationships between management actions, controlling factors and resource management outcomes or goals. The tool also provided stakeholders with a mechanism to identify where their knowledge fits into an overall understanding of the management system and to appreciate how other stakeholders understand the links between management actions and outcomes (providing a mechanism for externalizing and internalizing knowledge). Nonaka and Konno (1998) describe this as a process where individual stakeholders socialize and externalize their knowledge within a group, combine this knowledge, and learn from each other (internalization).

Allowing for Different Perspectives and Divergent Views

The mapping process also allows for different perspectives and divergent views, because stakeholders have different implicit and explicit understandings of how ecological processes work (Ross and Abel, 2000). However, in order to communicate with another person, one does not need to think (construe) in the same way, but

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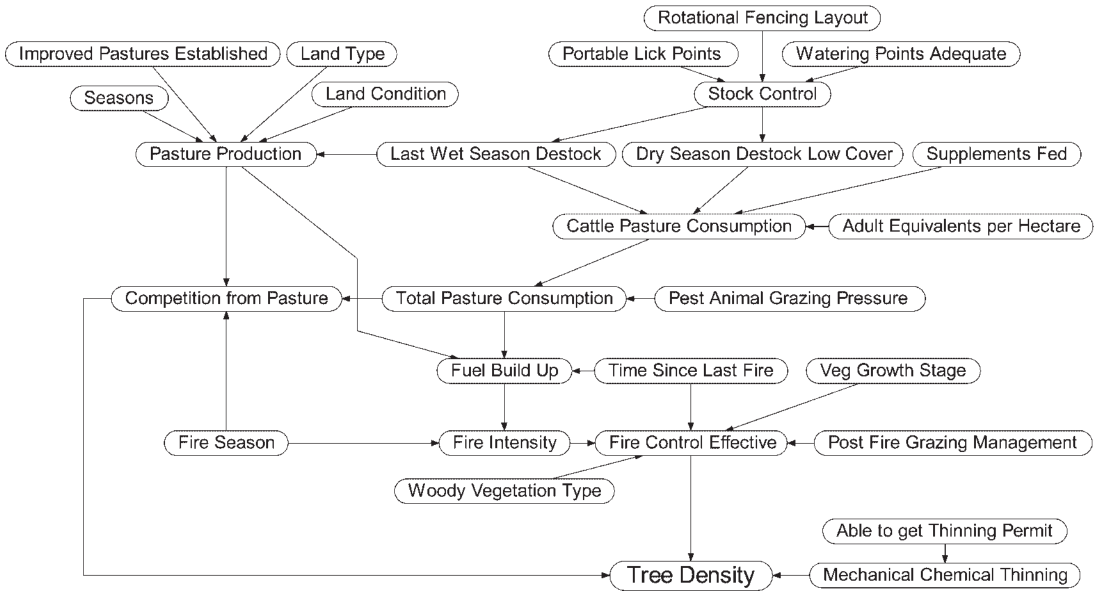

Figure 1. Multi-stakeholder influence diagram for tree density

be able to construe how the other person is construing (Bosch *et al.*, 2003). This means that while divergent views occur, the appreciation of one another's views gained through 'mapping the system' helps stakeholders to converge on a common understanding of the management system.

Incorporating Knowledge from Different Sources and System Levels

Once an influence diagram is constructed it can provide a map on which pieces of knowledge about parts of the management system can be overlaid and integrated (Figure 2). Where appropriate, hard data and models can be used to quantify relationships. In cases where these data and models are not available, the experiential knowledge of land managers and other stakeholders can be used to fill-in the data gaps. This ensures that the full range of existing knowledge is used, where the knowledge that scientists create is integrated with the understanding of systems by land managers.

Figure 3 shows a completed systems model for tree density. Each node has two or more *states* that represent possible outcomes that can occur. Arrows or *links* represent causal relationships between nodes and a *conditional probability table* specifies the relationship among nodes. For example, the highlighted section in Figure 3 shows that fuel build up and fire season influence fire intensity. Table 1 shows the probability table for this relationship. The first row represents the scenario where fuel build up is high (>1800 kg/ha) and the fire season (time of fire) is late dry (October/November). Under this scenario there is a 100% chance that fire intensity will be hot. By completing the probability table for each node in the BBN, available data, information and experiential knowledge are integrated in a systematic way. The result is a knowledge base and a dynamic systems model that can assist stakeholders (particularly managers) in decision-making through analysing different scenarios.

Making Sense and Co-learning

Making sense is an important step in systems analysis. It is done by testing model behaviour with stakeholders through management scenario analysis. Scenario analysis allows the prediction of possible outcomes of management strategies

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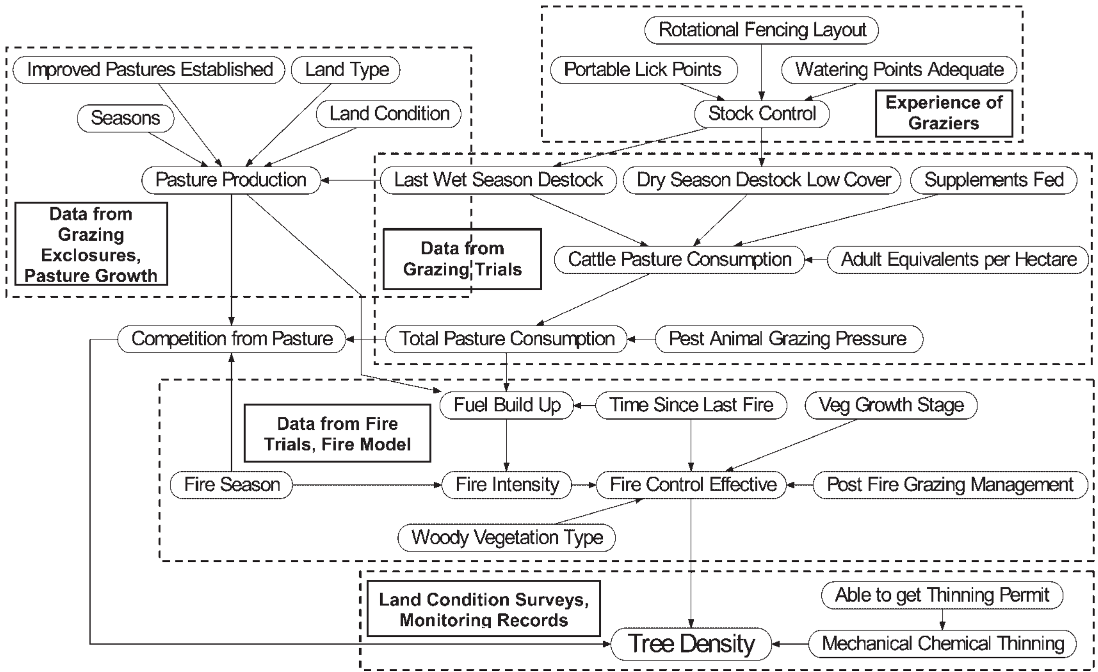

Figure 2. Data and information mapped on the tree density influence diagram

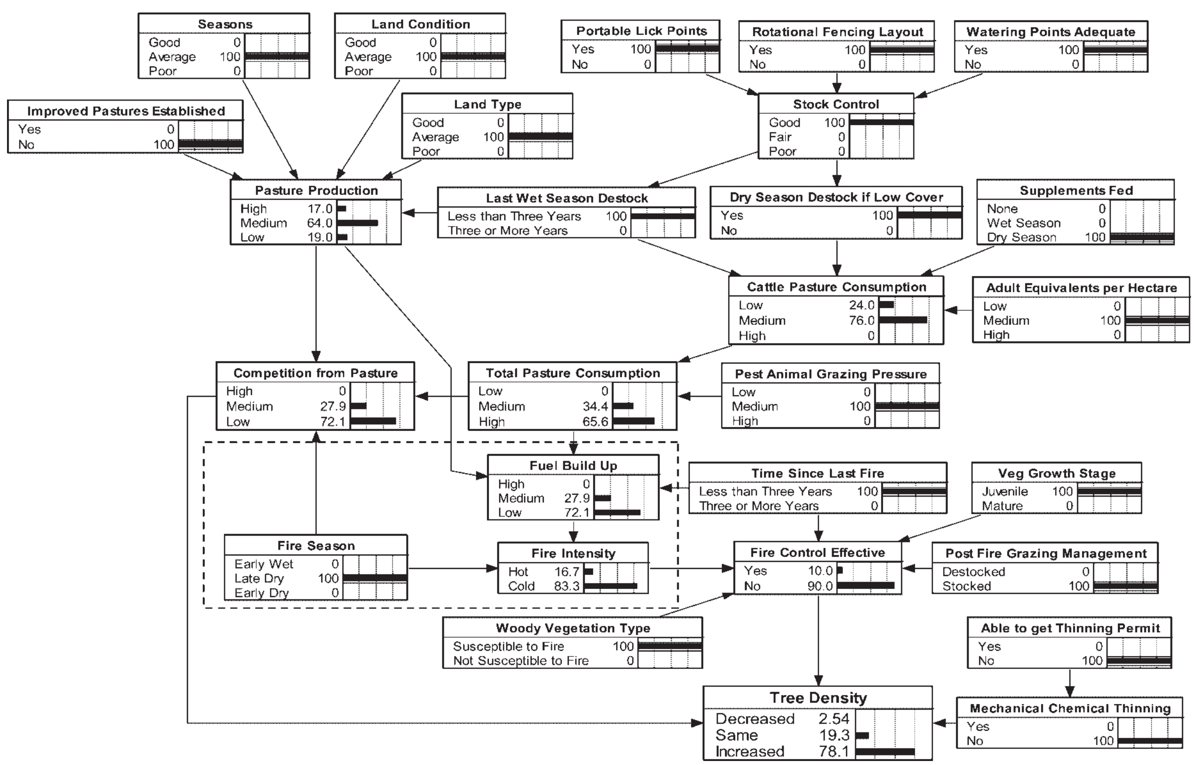

Figure 3. Populated BBN for tree density

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Table 1. *Probability table for fire intensity node in Figure 3*

Fuel build up	Fire season	Fire intensity	
		Hot	Cold
High (>1800 kg/ha)	Late dry (Oct/Nov)	100	0
High (>1800 kg/ha)	Early dry (June/July)	60	40
High (>1800 kg/ha)	Early wet (Dec/Jan)	30	70
Medium (1200–1800 kg/ha)	Late dry (Oct/Nov)	60	40
Medium (1200–1800 kg/ha)	Early dry (June/July)	30	70
Medium (1200–1800 kg/ha)	Early wet (Dec/Jan)	0	100
Low (<1200 kg/ha)	Late dry (Oct/Nov)	0	100
Low (<1200 kg/ha)	Early dry (June/July)	0	100
Low (<1200 kg/ha)	Early wet (Dec/Jan)	0	100

or the chance that a particular management strategy will lead to a desired outcome. This creates a learning environment. BBNs provide a valuable tool for scenario analysis since many scenarios can be examined quickly. Scenarios are entered by selecting particular states for nodes that represent management interventions or controlling factors. A particular scenario has been entered into the BBN in Figure 3 and then changed in Figure 4 (the nodes highlighted with a star are where the scenario has changed). In the first scenario (Figure 3), there is a 78% chance that

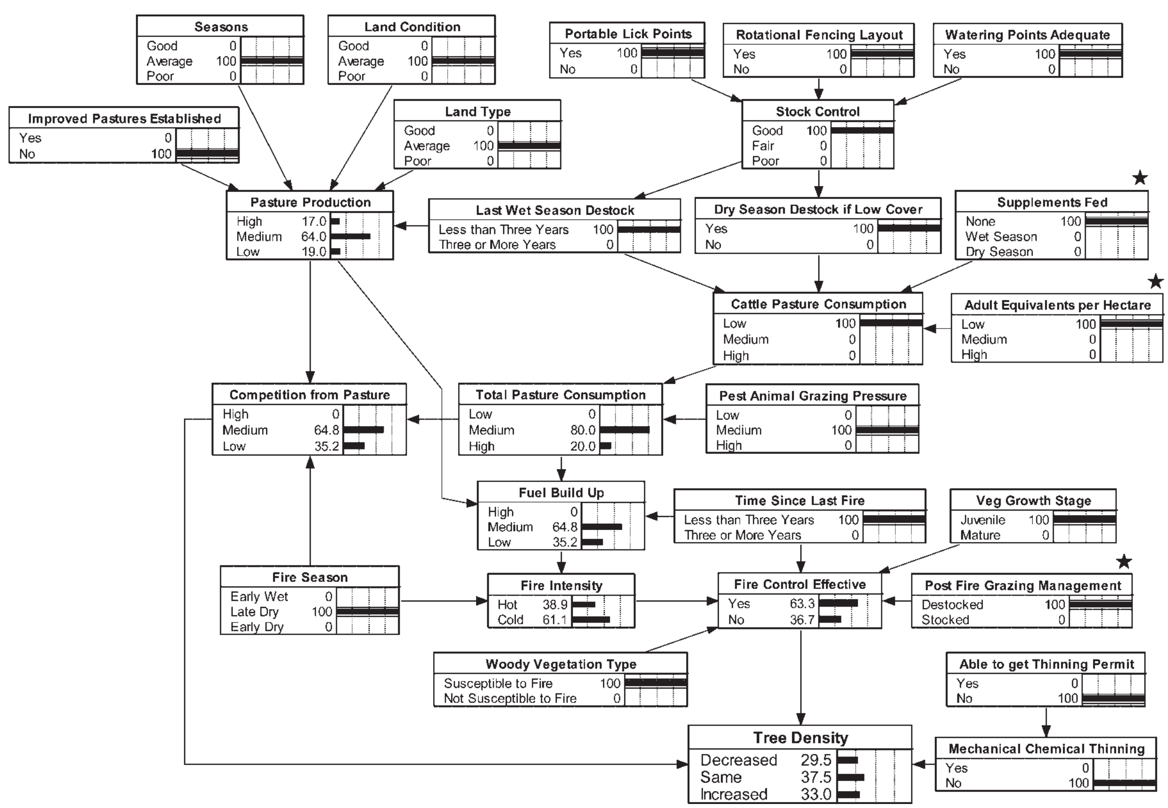

Figure 4. *BBN for tree density containing alternative scenario*

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tree density will increase, which changed to 33% when fire control effectiveness and competition from pasture increased (Figure 4).

Adaptation and Refinement in Context—Adaptive Management

The approach of stakeholder involvement and Systems Thinking described above leads to a model that represents the mutual understanding of stakeholders and their current knowledge base for decision-making. However, this knowledge base is rarely perfect because natural systems are complex, and their management takes place against a background of continuous and unpredictable change in environmental, economic and social conditions. Due to this, the uncertainties in achieving desired resource management outcomes remain high. However, new knowledge about management systems behaviour is continuously generated through observation (monitoring) and the evaluation of outcomes of implemented management strategies. Embedding the BBN model in an AM cycle allows for continuous improvement of the knowledge base, and its usefulness for managing natural resources under uncertain and variable conditions.

Summary and Learnings

Computer-based modelling systems can be useful tools to explore and make decisions about land management issues that are more systemic than traditional approaches—which can then be followed by action. Of particular importance is their ability to be used within a participatory process, to enable multi-stakeholder knowledge capturing, testing and refinement. Used this way, a computer-based modelling system (such as a BBN) can (a) provide a flexible modelling environment, (b) allow uncertainty in knowledge to be expressed using probabilistic relationships, (c) allow biophysical, economic and social variables (either quantitative or qualitative) to be related, (d) enable a graphical (flow chart) interface that is easily understood and facilitates communication between stakeholders and (e) be easily updated as new knowledge emerges without the need for specialist computer skills (i.e. nodes added or removed, links changed and probabilities updated). Figure 5 captures the essence of the ideas in this case study in a conceptual diagram.

CASE STUDY 2: IMPROVING SMALLHOLDER FORESTRY MANAGEMENT IN THE PHILIPPINES

Systems Thinking has been embedded in the 'Tree Farmer Project' in Leyte Province, The Philippines. This project aims to improve the livelihoods of smallholder farmers by improving financial returns from forestry, and promoting improved management methods. Below are the three examples where Systems Thinking has been used to date:

Conceptualizing and Designing the Project

Conceptualization of the project occurred over a period of 1 week during a visit by researchers to

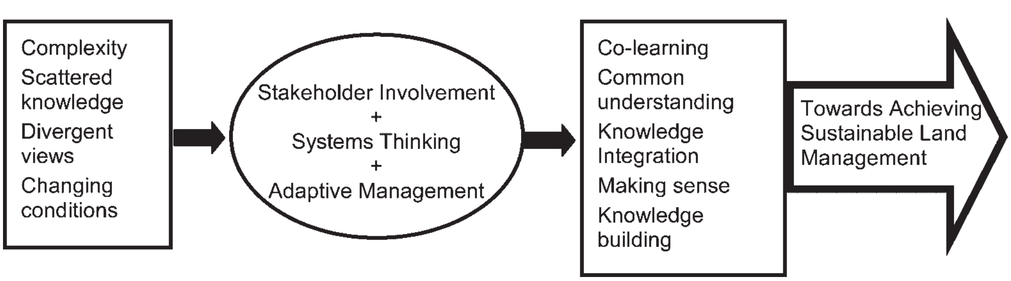

Figure 5. Conceptual diagram summarizing the conclusions of Case Study 1

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the Philippines (to incorporate feedback on the initial project proposal following discussions with the funding body). During this week, a number of visits to smallholder tree farms and communities were undertaken, and discussions held with a variety of stakeholders including tree farmers, officers and researchers from the Department of Environment and Natural Resources (DENR) and Local Government Units (LGU). These discussions, combined with experiences from a precursor 4-year project, suggested a complex range of interacting factors influencing the lack of current uptake of smallholder forestry in Leyte. For example, it became apparent that there exist a large number of tree farms (established about 10 years ago) with trees ready to be harvested and smallholder farmers were asking where they could find a market for their trees.

Following the field visits, a workshop was held where researchers discussed the observations made over previous days and discussions tended to focus on separate studies that could be undertaken to address one or more of the issues identified. In an attempt to integrate the disparate discussions, a brainstorming session was held to create an overall influence diagram that connected different aspects of possible research opportunities. Two observations were represented by boxes placed on a black board, namely, (i) the existence of a large number of tree farms and (ii) the need to improve current poor returns to tree farmers. From this basis, researchers brainstormed the factors that influenced the current poor returns and how these linked back to the existing smallholder tree farmers. The resulting influence diagram that was developed on a black board is shown in Figure 6. The initial starting points are contained in ovals and linked by an arrow.

The construction of the influence diagram provided a shared understanding to all of the researchers in the project of how their particular area of expertise contributed to the broader project objective of improving financial returns to smallholders.

Improving the Flow of Information for Forestry Regulation

In conceptualizing the project, as outlined under the section Conceptualizing and Designing the Project above, it became apparent that tree registration and log transport regulations enforced by DENR appear to be restricting access of smallholder tree farmers to formal timber markets. Rather than the regulation *per se*, this barrier seems to be the result of how regulations are enforced by DENR and the lack of understanding of the regulations by smallholders. If the individuals with the greatest influence on the flow of information are directly involved in recognizing the existing problems and formulat-

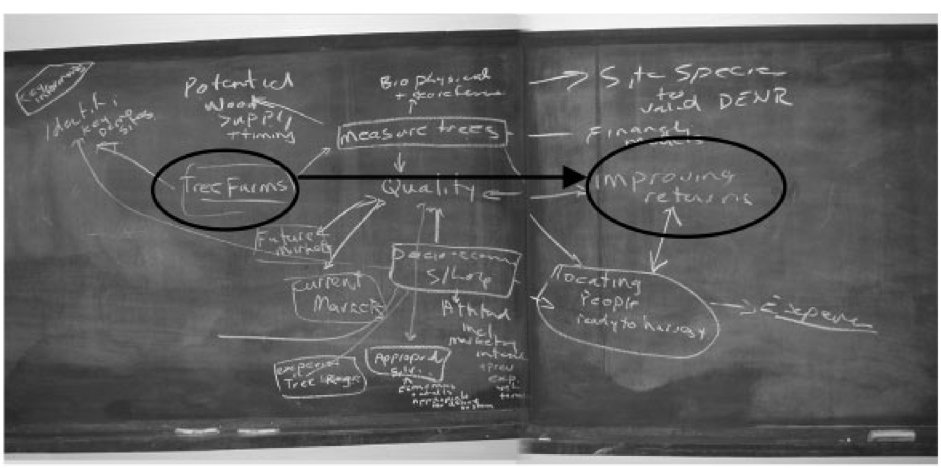

Figure 6. Influence diagram developed for planning the research project

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ing solutions to these problems, there is greater likelihood that strategies will lead to sustainable changes. In order to achieve these changes, the motivations and actions of different stakeholders must be examined in the light of the institutional arrangements governing them. It is also essential that the strategies devised for improving information flow, link closely with other project activities so that the changes occur at three levels (i.e. farm households/community, DENR staff operations, and policy). A systems approach is therefore an implicit component.

Figure 7 shows the relationship between various project activities and the action research workshops which lie at the core of the suggested approach for improving the flow of information concerning tree registration, harvest and transportation regulations and approval mechanisms. The action research workshops provide opportunities to (i) monitor and report via information bulletins, what the tree farmers involved in the project demonstration plots are required to do to get tree registration and (ii) to report and compare this information across the project. The steps involved in bringing the action research teams to life are to (i) confirm the aim with key stakeholders, (ii) secure sponsors' commitment, (iii) identify the participants, (iv) design and schedule regular workshops, including a training workshop, (v) secure the necessary resources, (vi) conduct workshops and implement activities to improve information flow and (vii) reflect on achievements and implement changes.

Making Sense of the Tree Nursery Sector in Leyte

Systems Thinking has also been applied to understand the factors affecting the production of quality tree seedlings and to investigate the

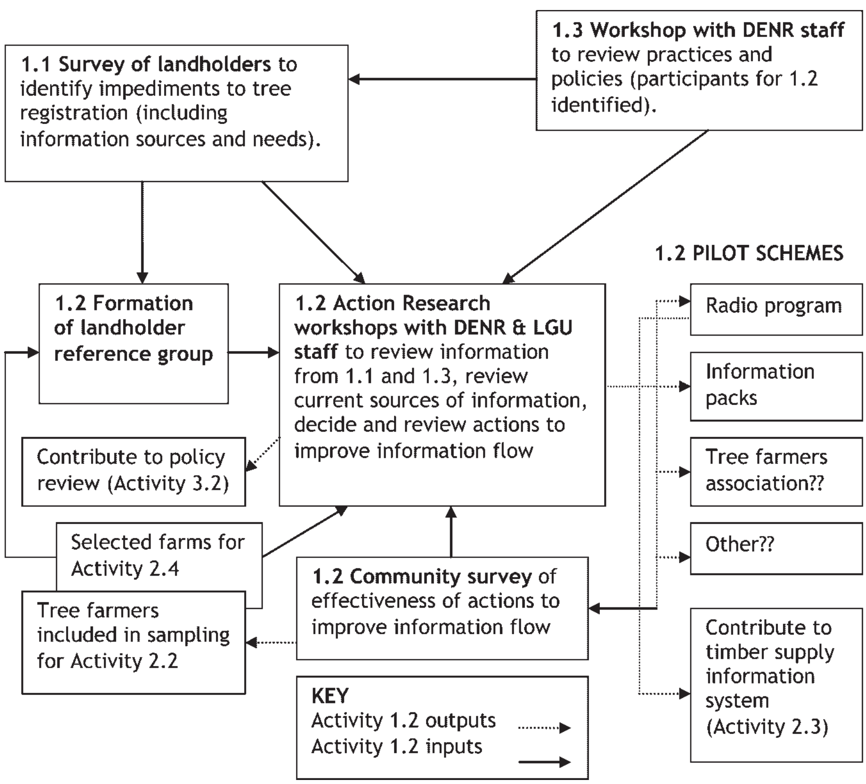

Figure 7. Relationship between activities concerning the development of strategies for improving information flow about tree registration, harvest and transportation regulations and approval mechanisms (1.1, 1.2 and 1.3 refer to specific project objectives)

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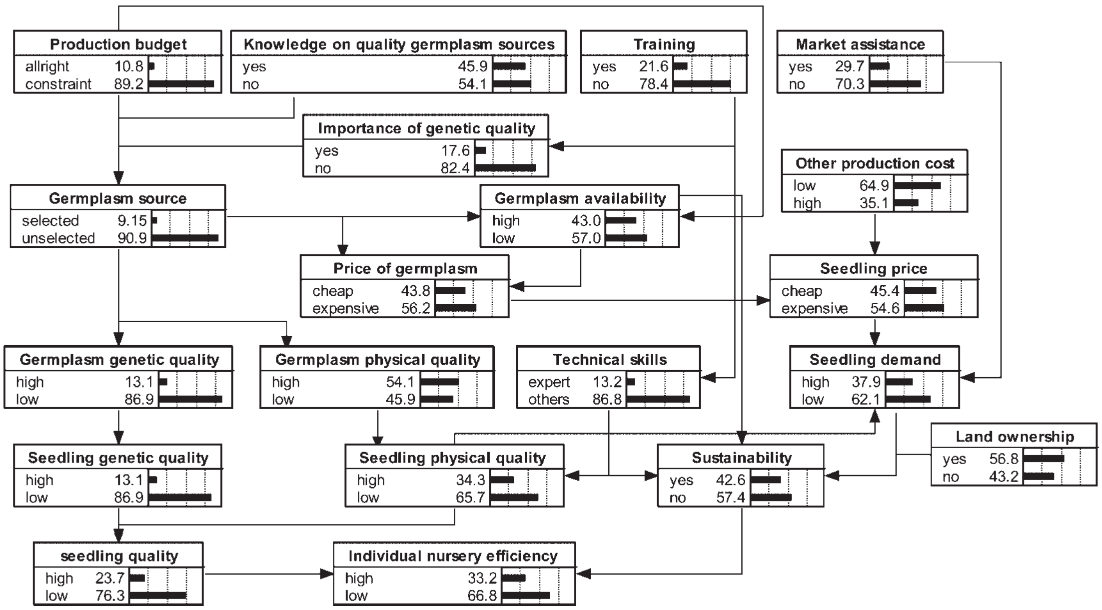

Figure 8. Nursery efficiency BBN for individual nursery group (Source: Gregorio, 2006.)

impact that different policy interventions may have on improving the quality of seedlings available to smallholders.

To conceptualize the nursery sector, an influence diagram was constructed for each of the nursery sector using a BBN. The data to construct the model (Figure 8) was obtained from a combination of quantitative and qualitative methods. For example, surveys were used to collect responses from nursery operators on Leyte, and the nominal group technique, as well as individual discussions, was used to collect expert opinion. This model has provided a good example of a dynamic systems model which can be used to explore the likely impacts of different policy interventions. Unlike the process used with a BBN in Case Study 1 where a range of stakeholders constructed a model using the BBN as a participatory tool, this model was constructed by researchers using data obtained from a range of stakeholders from surveys and other social research methods, including focus group discussions and the nominal group technique. The model has subsequently been used to identify which factors most influence key outcomes such as seedling quality, nursery sustainability and nursery efficiency. In addition, it has been used to explore the likely impact of various policy interventions such as developing training programmes for nursery operators.

Summary and Learnings

Systems Thinking can be aided by a variety of tools, ranging from informal and non-technical to highly structured and technical in their application and form. There are a number of group techniques that have been used in this project that enable Systems Thinking. At the most basic level, brainstorming sessions can be used to develop and conceptualize research problems and projects. More formal group techniques such as Delphi and nominal group technique can be used to access expert opinion where there is a lack of formal data. There are also a multitude of computer-based techniques (e.g. simulation programmes—Simile, Vensim; linear programming; multi-objective decision support systems; BBNs). These tools, used within a systems approach, can help design projects that need to account for a number of system levels. In this project, the issues associated with improving financial returns to smallholders have been conceptualized as being interrelated such that they cannot be addressed in isolation (as would be the case in

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a reductionist approach). This approach leads the way for future project objectives, such as interpreting and integrating project results and developing policy recommendations.

CASE STUDY 3: ADAPTIVE RODENT MANAGEMENT AND PARTICIPATORY RESEARCH IN CAMBODIA

Rice production is the basis of food security in Cambodia. In some areas rodent pests cause chronic and acute damage to rice crops. Rodent damage, therefore, puts at risk food security, particularly impacting on subsistence farmers and their families. A collaborative multi-stakeholder research project (FARMERS—farmer-based adaptive rodent management, extension and research systems) has been conducted in the Kampong Cham Province to increase the capacity of farmers and researchers in choosing rodent management options based on technical, economic and social aspects of rodent management. As such, it had a secondary aim of improving the capacity of extension staff (and the project team) to facilitate multi-stakeholder adaptive research.

The definition of AM within the context of the FARMERS project was based on a participatory action research model and was a systems-based, problem-solving approach. The project operated on continuous learning and action cycles, with community participation in all phases of the planning, implementing, monitoring, interpretation and evaluation of the research. Key aspects to the facilitation of AM in this project that involved Systems Thinking were:

- Participatory planning included farmers of the Samrong Village, scientists, extension agents and managers at the whole project level. This in itself was innovative, as farmers are typically involved in activity level decision-making but excluded from decisions made at the whole project level.
- Research was carried out on-farm and involved the facilitation and co-ordination of a number of stakeholders. The AM cycles also coincided with cropping seasons to better link learning with ecological processes and the project included social, economic and biophysical aspects to optimize learning about eco-systems management.
- Participatory tools were used to (i) bring out stakeholder's different perceptions of reality and (ii) enable stakeholders to conceptualize their environment in a systemic way; and the core project team (including farmers) used, critiqued and adapted methods before using them with the community.
- The AM approach was also used to develop the learning of the project team itself. The AM approach also involved learning about learning to increase people's capacity to deal with uncertainty and surprise. In addition, indicators (to reflect change) were not only developed at the farming systems level (e.g. social, biophysical, economic), but were also developed at the project team and management level.
- The inclusion of management in the core team aided in linking understanding to policy and redefining learning as a valid project outcome. The inclusion of farmers in the core team moved a step closer to ensuring the sustainability of the learning process in communities (beyond project time frames). It also acknowledged the value of farmer process knowledge as well as farmer technical knowledge.

A range of participatory methods were used to enable Systems Thinking. These methods were established in the 1980s, where participation was not only seen as a way of developing better technologies in relation to context (as with traditional farming systems research), but also a right of individuals and communities in shaping and determining their own destiny.

Participatory Maps

Maps can be used for mapping villages, farmers' fields, streets and buildings, etc., and can highlight factors such as access to services and resources, individuals and groups, communication channels, flooding areas, access to

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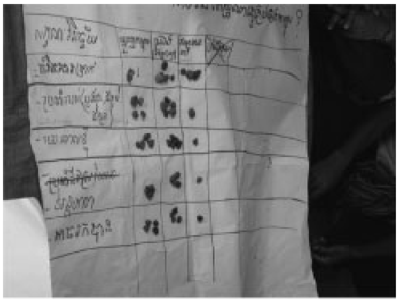
resources and distance between fields. When done in the field, passers by, can stop and contribute to the process. A map has been constructed in an open space on bare soil in Samrong village, Cambodia on which farmers mapped where research trials (in this case, trap barrier systems or TBS) were located in the previous season in relation to the village and farmers' fields.



Photograph 1: matrix scoring using stones.
Score: 1 stone ☺⟶ 5 stones ☹

Participatory Matrix

The matrix method is useful for comparing in relative terms, different options. Used in a participatory forum, the method allows for analysis of why different stakeholders prefer different options to others. When used over time, the matrix enables changes in preferences or perceptions to be monitored. Although results are recorded by scoring, the discussion generated during the process of creating the matrix is extremely valuable and can be recorded as qualitative data. This method was used in Cambodia to assess different approaches to rat control against a variety of criteria (e.g. cost, environmental damage, labour). Photograph 1 and Table 2 illustrate a matrix constructed by farmers using stones on a flat piece of paper to score their satisfaction with each control method against different criteria.

Calendars

Calendars show changes over time for specific factors. When several factors are drawn on one calendar, relationships between these factors can be compared. People can discuss whether there is or is not a cause and effect relationship or pattern. Significant events (e.g. a mouse plague, a festival, a terrible tragedy) can be drawn onto calendars and compared with on-going factors (e.g. rainfall, regular planting times). The seasonal calendar constructed with farmers in Cambodia investigated the relationship between rodent damage and other factors such as cropping seasons. Farmers used local materials (e.g. rice plants in different stages of growth, sticks) to construct the seasonal calendar on bare ground.

Network Diagrams

Network Diagrams help to understand relationships and they can be used over time to assess changes in relationships and to identify any new relationships that need to be fostered. Examples by the Cambodia farmers include (i) exploring the number, type and quality of relationships between different groups or agencies that are important for a group of farmers or a community to achieve a desired activity, (ii) the number and quality of relationships to organizations that can

Table 2. Matrix scoring table on rat control methods in Samrong Commune

Methods	Chemical	Bamboo	Trap	Hoe	Stick	Dog
Labour	5	3	4	4	5	5
Money	1	4	3	2	5	4
Materials	4	4	3	3	4	5
Environment	1	5	5	5	5	5
Effectiveness	5	2	3	3	3	3

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provide different types of resources (e.g. education, funding, equipment) and (iii) identifying similar projects carried out by different science institutions or projects within institutions. The farmers cut different sized circles out to depict the importance of different groups in achieving the project goals and the circles were placed in varying proximity to each other to represent the amount of contact currently occurring between these groups. The farmers then moved the circles to illustrate what they desired in terms of future relationships. This was also carried out with different stakeholder groups, so that each group could see their contribution and importance of enabling the whole system to function.

Photographs

Photographs were also used as tools for Systems Thinking. Photographs were taken over time and then used to assess changes in the 'approach' of the project. Questions such as 'Who is involved?', 'How are people interacting?' and 'What are the underlying assumptions of the approach?' generated valuable discussion. Photographs can also be taken over time and in different locations to aid in understanding rice damage in relation to season, management practices or project goals. Taking photographs that 'zoom in' and 'zoom out' helped to (i) introduce Systems Thinking concepts, (ii) enable a more systemic approach when addressing an issue and (iii) explore emergent properties at different system levels.

Gender Analysis Tools

Gender analysis frameworks are tools for considering the impact that a research or development project may have on women and men, and on the economic and social relationships between them (gender relations). In Cambodia, a pie chart (Photograph 2) was used to explore the differences in men's and women's labour, time and resources for different activities over the farming season. Other components, such as access and control, were surfaced during discussions while the pie chart was being constructed. This pie chart was specifically used as a reflection tool with men (both farmers and researchers) who had not invited women to a project workshop discussing on how to improve their rice farming systems. The aim was to highlight the importance and contribution of women, so that these participants might re-think their assumptions about 'who' should be involved next time (acknowledging steps in a change process). As with most participatory methods, proportion lines are negotiated and renegotiated, providing much discussion about why and how participants have come to the agreement they have. The arguments are captured when small groups share their perceptions with the larger group.

Photograph 2: pie chart drawn on the ground to explore gender issues

Simulation Models

Simulation tools generate enthusiasm and energy because they are often operated in the real environment. These tools also provide rapid cycling (e.g. action learning cycling) and a fast turn over of cause and effect. In multi-stakeholder events (particularly where people have competing interests) situations are often uncomfortable. Simulation tools enable participants to focus on the tools (rather than themselves), providing an environment to share experiences, perceptions and assumptions. The tools are used to explore what might happen and why, rather than 'knowing' what will happen. Simulators mimic common phenomenon (e.g. rainfall) and the experience is only a way of postulating what might happen in the 'real'

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world. The process of critical inquiry and reflection through a simulated process is therefore important, in particular, drawing out the benefits and limitations of the model to make predictions.

Summary and Learnings

The tools presented in this case study were used for participatory planning, monitoring and evaluation and to facilitate learning at both the community and organizational level to (i) learn about farming system options, (ii) learn about learning and (iii) negotiate action amongst stakeholders with different 'perceptions of reality' across system hierarchies. In each of these examples, the discussion generated was just as important as (if not more important than) the outcome. The main point to highlight with this case study is that it is the way in which the tool is used and the process in which it is embedded which is important. That is, the tool needs to be incorporated into a well-facilitated participatory process. Important was also how the process helped the scientists to work outside the conventions of discipline specific research, and to share power with non-scientists by recognizing their knowledge and giving them an active say in all decision-making.

CONCLUSIONS: A FRAMEWORK FOR THE APPLICATION OF SYSTEMS THINKING

The reluctance of science to embrace 'new ways of thinking' to explore the world is well-documented and there are a number of reasons why Systems Thinking as 'method', is not integral to many disciplinary based approaches. We propose that one prominent reason for this reluctance is the entrenchment of the 'reductionist' scientific method. The traditional view is that science involves empirical observation, theory formulation, theory testing, theory revision, prediction, control, the search for lawful relationships and the assumption of determinism; and scientists are the 'experts' in carrying out this process. With this traditional view of science came a range of methods to support these processes and these are carried out by researchers who consider them normal, if not essential, to produce good science. For example, statistical analysis as a tool in research is found in an array of disciplines such as agronomy, medicine, psychology and engineering, and used by scientists from these disciplines as normal practice within research projects. Systems Thinking, in contrast, is not.

Society realizes that we need to think outside of the square to create new forms of community and ecological governance. Wilson (1988) refers to the present time as one where the tensions between economic paradigms and ecological realities are creating major political and practical management issues and states that 'everyone in the rural extension business has to be increasingly skilled in the art of managing the 'bigger picture' issues with the hard realities of managing a business from day to day'. Systems Thinking can no longer be attached onto the end or added as an isolated part of a research project, but rather needs to be an integral mechanism in which to explore and analyze a complex problem in a holistic way.

As Röling and Jiggins (1998) describe, *the essential conditions for sustainable practices at the farm level are increasingly determined at higher eco-system levels*. Applying Systems Thinking at a wider system (or supra) level requires that the suggested processes put forward above, should also be applied within the organizations in which scientists operate. That is, those involved in institutional management will need to take on a more systemic approach in the way they view a science organization and how scientific 'paradigms' influence the way in which science is done. At an organizational level, managers need to understand the need for Systems Thinking as 'method', and support scientists to add new tools to their 'tool box'. In addition, the importance of science organizations understanding the wider system issues that (i) impact on land managers making more sustainable practice decisions and enacting those decisions and (ii) impact on their own organization, is vital. Just as Gunderson and Pritchard (2002) suggest that resource systems that have been sustained over long time periods increase resilience by managing processes at multiple scales, we believe that to sustain a people-based land management system over

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time, requires management processes at multiple scales. This implies Systems Thinking be present within the hierarchies of science organizations.

Figure 9 provides a framework for the application of Systems Thinking for improved sustainable land management. This model builds on the conclusions of the first case study (Figure 5) and has been constructed by adding additional ways (lessons learnt) of incorporating Systems Thinking into practice to address issues more systemically.

Systems Thinking can offer a way in which to construct and explore inter-relationships at a variety of system levels (King, 1998). We highly recommend the use of Systems Thinking as 'method' for scientists in general, and not just systems specialists and practitioners. The case studies above present a range of tools (e.g. computer modelling systems, a range of group processes and participatory methods) to facilitate Systems Thinking, but they are not generally present in the scientist's 'tool box'. How then can we engage scientists from traditional disciplines to use new methods, particularly methods for Systems Thinking? King (2000) illustrates how people change to a new practice when they have 'discovered' for themselves that the new practice is of benefit. As systems specialists, we can put processes in place that enable discovery. The discovery is therefore undetermined and scientists can test different tools for themselves, do their own sense making, come up with their own conclusions and adaptations, and judge for themselves whether or not the tools have value in their own context and endeavour. To do this, Systems Thinking tools are suitably fitting. As scientists, we can challenge ourselves, by questioning the assumptions behind the methods we use and by testing Systems Thinking methods in action.

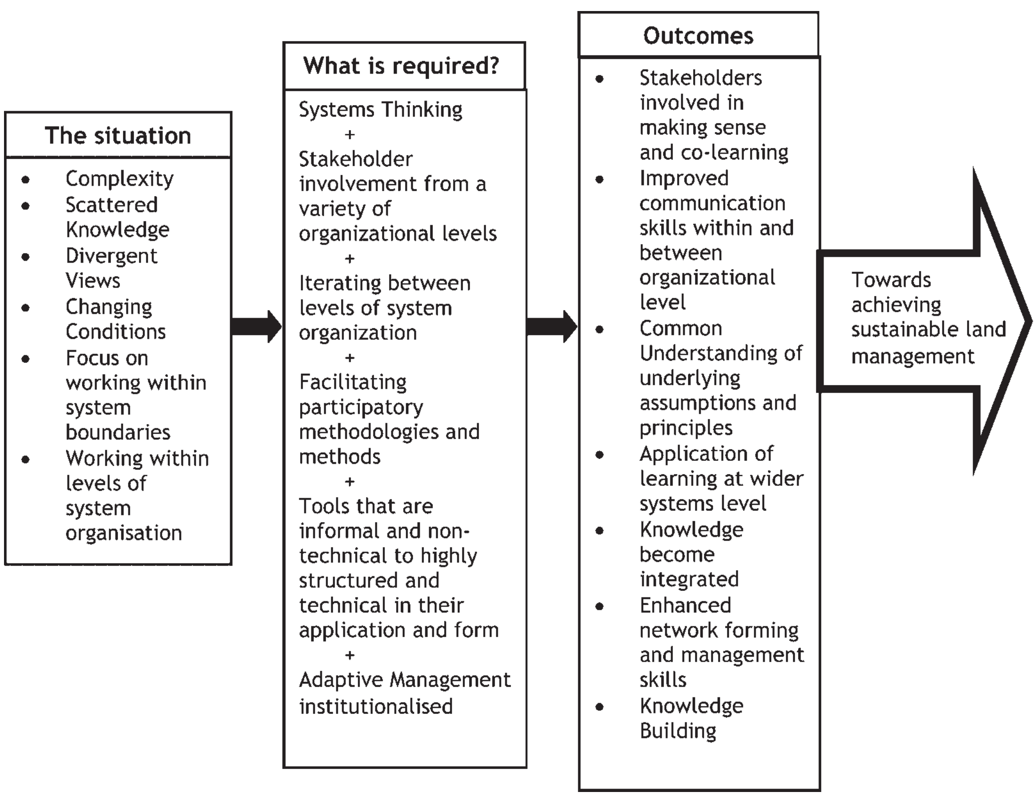

Figure 9. Framework for application of Systems Thinking concepts that would help achieving outcomes that will contribute to sustainable land management

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REFERENCES

Bosch OJH, Allen WJ, Williams JM, Ensor AH. 1996. An integrated approach for maximising local and scientific knowledge for land management community knowledge: integrating community-based monitoring into the adaptive management process in the New Zealand high country. *The Rangeland Journal* **18**(1): 23–32.

Bosch OJH, Ross AH, Beeton RJS. 2003. Integrating science and management through collaborative learning and better information management. *Systems Research and Behavioral Science* **20**: 107–118.

Cain J, Batchelor C, Waughray D. 1999. Belief networks: a framework for the participatory development of natural resource management strategies. *Environment, Development and Sustainability* **1**: 123–133.

Checkland PB. 1981. *Systems Thinking Systems Practice*. John Wiley & Sons: Chichester.

Checkland PB. 1985. From optimising to learning: a development of Systems Thinking for the 1990s. *Journal of Operational Research Society* **30**(9): 757–767.

Checkland PB, Scholes J. 1990. *Soft Systems Methodology in Action*. John Wiley & Sons: Chichester.

Gregorio N. 2006. *Improving the Effectiveness of the Forest Nursery Industry in Leyte Province, the Philippines*. PhD thesis, The University of Queensland, Australia.

Gunderson LH, Pritchard L. (eds). 2002. *Resilience and Behaviour of Large-Scale Systems*. Island Press: Washington.

Hamilton NA. 1995. *Learning to Learn with Farmers*. Published Doctoral Dissertation, Wageningen Agricultural University, Wageningen, The Netherlands.

Ison RL, Maiteny PT, Carr S. 1997. Systems methodologies for sustainable natural resources research and development. *Agricultural Systems* **55**(2): 257–272.

King CA. 1997. Facilitating learning and creating linkages between researchers, farmers and extension agents. In *Proceedings (Volume 2) The Australasian Pacific Network Conference: Managing Change-Building Knowledge and Skills*, Albury.

King CA. 1998. A process-analysis approach for improving multi-disciplinary farming systems research, development and extension. In *Proceedings of the Third European Symposium on Rural and Farming Systems Analysis: Environmental Perspectives*, Germany.

King CA. 2000. *Systemic Processes for Facilitating Social Learning: Challenging the Legacy*. Published Doctoral Thesis, The Swedish University of Agricultural Sciences, Uppsala.

Nonaka I, Konno N. 1998. The concept of 'Ba': building a foundation for knowledge creation. *California Management Review* **40**(3): 40–54.

Röling NG, Jiggins J. 1998. The ecological knowledge system. In *Facilitating Sustainable Agriculture: Participatory Learning and Adaptive Management in Times of Environmental Uncertainty*, Roling NG, Wagemakers MAE. (eds). Cambridge University Press, UK.

Röling NG, Wagemakers MAE. 1998. A new practice: facilitating sustainable agriculture. In *Facilitating Sustainable Agriculture: Participatory Learning and Adaptive Management in Times of Environmental Uncertainty*, Röling NG, Wagemakers MAE. (eds). Cambridge University Press, UK.

Ross H, Abel N. 2000. Eliciting mental models of landscape processes: the transect method. In *Environment-Behaviour Research on the Pacific Rim: Proceedings of People and Physical Environment Research Conference*, Moore GT, Hunt J, Trevillion L. (eds). Faculty of Architecture, University of Sydney.

Wilson J. 1988. *An Introduction to Systems Thinking: Changing Agriculture*. Kangaroo Press Pty Ltd: Kenthurst.

Syst. Res. **24**, 217–232 (2007)
DOI: 10.1002/sres