22 Information and Knowledge Management for Sustainable Forestry

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Abstract

Institutional information and knowledge management often involves a range of systems and technologies to aid decisions and produce reports. Construction of a knowledge system organizing hierarchy facilitates exploration of the interrelationships among knowledge management, inventory and monitoring, statistics and modelling, and policy. Two case studies illustrate these interrelationships in institutional settings: (i) the FAO National Forest Assessment process; and (ii) knowledge management in supply chains. The development and adoption of knowledge management systems in institutions can be improved by considering the principles and studies generated by the social sciences, e.g. innovation diffusion, escalation of commitment and agency theory. Still, many of these principles and practices – as they relate to sustainability – have evolved primarily in the context of the developed world. Broader, more inclusive perspectives are needed as we mesh traditional Western thinking with the insights, cultures, practices and limitations of the developing world.

Introduction

Policies, established by governments and other organizations, both implicitly prioritize those problems that warrant societal (or organizational) attention and provide a broad agenda for the issues involved. This dynamic landscape constrains and focuses the ecological and environmental phenomena we measure and the analyses we perform with those data. Knowledge management (KM) activities, on the other hand, remain relatively invariant with respect to any specific policy direction, but provide the tools and techniques for creating, conserving and sharing knowledge, whatever that knowledge may be. The four thematic areas of this book – inventory and monitoring, statistics and modelling, knowledge management and policy – are interrelated in this very general way.

With ever-greater frequency, the keyword 'sustainability' enters into policy discussions, often as part of an objective or criterion, e.g. 'sustainable forest management' or 'sustainable development'. Because sustainable forest management can be evaluated at many scales and involves social, economic and environmental aspects, each of the four thematic areas comes into play in important ways. But how do they work together in a sustainable forestry context? In this chapter, we explore the interrelationships among these thematic areas by creating a knowledge system organizing hierarchy. Two case studies illustrate the range and interaction of such systems in operational settings: (i) the National Forest Assessment process of the Food and Agriculture Organization (FAO); and (ii) forestry supply chains. Several prevailing theories in the social sciences – innovation diffusion, escalation of commitment and agency theory – are used to illustrate knowledge management system development and adoption in institutions. This will provide guidance for managers who wish to use knowledge management tools in attaining sustainability to successfully integrate these tools into their operations. It will also guide knowledge management researchers in achieving successful integration of their products into existing processes. Vignettes illustrate the relationship of other chapters in this section of the book to particular points in the present chapter.

Interrelationships among Knowledge Management, Inventory and Monitoring, Statistics and Modelling, and Policy

People working in KM, inventory and monitoring, statistics and modelling, and policy tend to write for different journals, attend separate scientific conferences and regard themselves as belonging to different peer groups, as delineated by disciplinary boundaries. But it appears to us that all of these scientific disciplines have something in common. They each offer theory and tools to help identify, understand and solve problems. Therefore, it should be possible to reorganize these four thematic areas in order to highlight their interrelationships, using 'problem solving' as a common theme.

An organizing hierarchy

For the sake of this discussion, we shall assume that there are three broad classes of knowledge systems useful in problem solving: descriptive, predictive and prescriptive systems (Rauscher and Reynolds, 2003). Within each class are subclasses that represent different approaches to providing each class's tools – either descriptive, predictive or prescriptive. In some cases, more specific approaches (e.g. participatory decision making as one type of decision analysis method) could be nested further within these classes. Using these classes as an organizing framework, we might agree to the relational hierarchy below. With this cognitive map as a guide, we can more readily discuss how each theme supports the problem-solving process and how the themes might be interrelated and mutually supportive.

Descriptive tools
- Declarative knowledge management tools – know-what
- Inventory and monitoring
- Descriptive statistics

Predictive tools
- Procedural knowledge management tools – know-how
- Predictive statistics
- Expert-based heuristics
- Spatially aware and non-spatially aware modelling
  - Analytical models
  - Quantitative simulation models
  - Qualitative simulation models
  - Expert system models

Prescriptive tools
- Causal knowledge management tools – know-why
- Decision analysis methods
  - Single-criteria optimization
  - Multiple-criteria decision making (see Vignette 1)
  - Satisficing
  - Participatory (group) decision making
- Decision-support systems
  - Landscape scale
  - Forest scale
  - Project scale
- Policy science and forest management planning
  - Adaptive management
  - Options forestry

Descriptive tools

Descriptive tools focus on the management of declarative data, information and knowledge. The focus here is on what we know. The purpose is to create a shared, explicit and accessible understanding of concepts, ideas, relationships and categories that enables effective communication and understanding of a common societal knowledge base (Heinrichs *et al.*, 2003). It is important that all stakeholders of a particular issue be able to agree on a common descriptive set of knowledge. Such a common understanding of the descriptive, factual knowledge provides a sound basis for reasonable disagreement concerning interpretations, courses of action and values. Successful group decision making can only be based on an explicit identification and discussion of legitimate and factually based differences of opinion when they occur. The various methods and approaches used in KM, inventory and monitoring, and descriptive statistics should be viewed as complementary. We have typically concerned ourselves with intrinsic data quality, which deals with data bias, precision and accuracy. A KM focus on descriptive data also calls attention to how accessible the data is, how secure it is, how ethically it is treated (e.g. Thomson and Schmoldt, 2001), how understandable it is within a given context and how well it is presented to enhance its interpretation (Ribeiro *et al.*, 2004). In fact, improving the organization and accessibility of already existing data and information could achieve considerable technology transfer gains.

Predictive tools

Predictive tools focus on the management of procedural knowledge. The focus is on how activities occur, how things are changing in the real world, how specific problems are solved and how we predict the results of alternative courses of action (Heinrichs *et al.*, 2003). The organization and sharing of procedural knowledge, such as best management practices or how-to processes, creates better understanding and leads to more effective problem solving.

KM methods help us organize and share accepted 'nuggets' of procedural knowledge. This procedural knowledge can be associated with descriptive knowledge to improve understanding. This helps avoid the mindless application of how-to recipes in situations for which they are not appropriate. In fact, situational analysis and guidance should be required as an explicit component of every how-to, best management practice and predictive tool.

Predictive statistics are immensely useful to reduce the noise in information recorded about the natural world and to find the signal that can guide our current actions and help us predict future consequences. Expert-based heuristics, such as rules of thumb, are equally powerful guides when quantitative, predictive statistics are unavailable but when human expertise exists (Schmoldt and Rauscher, 1996; Gigerenzer and Todd, 1999). In the case of predictive statistics, uncertainty is inherent in this class of tool. For heuristic methods, there may be no estimate of reliability or uncertainty, in which case, modelling or decision science tools may help reduce uncertainty.

These tools can be combined into models that provide users with a structured, problem-solving environment. Some models focus on current conditions, such as the estimation of site index or the evaluation of habitat quality. Others, such as growth-and-yield models, use the past as a guide to predict the future. Thinking of this class of predictive tools as having a common purpose aids in organizing them, placing them into their correct context of use and making them more readily available and understandable to a broad variety of clients.

Prescriptive tools

Prescriptive tools deal with causality, judgement, values and choices. Causal knowledge and the prescriptive tools that manage it create the assumptions and theory and drive the choices and actions that directly affect the lives of individuals, organizations and nations (Heinrichs *et al.*, 2003). Although knowledge management researchers have a role to play in organizing causal knowledge and making it more accessible, they are not the prime players. Researchers in policy science should be thought of as organizing the assumptions, creating the theory and identifying the values, emotions and power positions of interested stakeholders. Decision-support systems (DSSs) are in many ways the ultimate integrating tools that bring together what we know in order to assist decision makers in making wise and supportable choices. Holsapple (2003) describes a DSS as 'a computer-based system composed of a language system, a presentation system, a knowledge system, and a problem-processing system whose collective purpose is the support of decision-making activities'. It is absolutely not the function of DSSs to serve up answers to managers (Holsapple, 2003). Although managers in many cases are attracted to apparent turnkey solutions to complex problems, DSSs are primarily communication and organizing tools: the computer model

> forces us to see the implications, true or false, wise or foolish, of the assumptions we have made. It is not so much that we want to believe everything the computer tells us, but that we want a tool to confront us with the implications of what we think we know.
>
> (Botkin, 1977, p. 217)

Many dimensions influence the decision process. The type of decision analysis, whether optimization, multi-criteria decision making or satisficing, represents just one dimension. The political and power dimension as well as the emotional and ethical dimension must also be considered (Rauscher, 1996, p. 265). But DSSs have primarily been constructed to support the technical dimension. It is unclear how the technical, power and value dimensions of the decision process interact with each other. Neither is it clear how to bring support tools for the power and value dimensions explicitly into a DSS framework. This is an important issue, because it is quite possible to have components of the power and value dimensions entirely dominate the technical/factual dimension. Policy science has the potential to teach us by helping to clarify these issues and suggesting ways to publicly clarify sometimes influential, but hidden, elements of the decision process.

Interrelationships

The function of a DSS is to organize the decision process and provide flexible, on-demand access to the full array of prescriptive, predictive and descriptive tools applicable to a particular problem situation. Ideally, a DSS should satisfy the user's need to know what society knows, to know how to use that knowledge and to know why different courses of action produce different expected outcomes. It should also help managers to understand and to explain that understanding to stakeholders.

There is an extremely important feedback loop from DSSs to predictive and descriptive tools. There is no easier way to dramatically demonstrate the limits of our descriptive knowledge base and our capability to use it for predictive purposes than to build and field-test a DSS. For example, in the southern Appalachian Mountain region in the USA, the ability to forecast established overstorey forest conditions over a 30–50 year time frame is quite good (Rauscher *et al.*, 2000). We are beginning to be able to understand and predict tree seedling regeneration following a stand-replacement disturbance (Kim *et al.*, 2000). However, we do not understand, nor can we predict, understorey tree and other woody species' dynamics in the presence of a significant overstorey canopy. What do we do? We assume a constant understorey over the life of a 50–100-year planning horizon. What else can we do? We know that our growth-and-yield predictions for overstorey growth start to seriously degrade after 30–50 years of simulation time from the present. What do we do? We use the models to predict further than 50 years because, once again, there is no other choice.

There are also logical relationships between inventory operations and predictive modelling capabilities. The tension between eco-physiological models and their need for non-standard inventory data is well known. A similar tension exists between DSSs and inventory data. For a goal to be operationally useful, it must have a measurement criterion that can be inventoried in a real forest somewhere. It is not unusual for a client to want goals with measurement criteria that are not available in the current inventory of the property. It may not even be possible to forecast the future value of those measurement criteria by using currently available prediction systems. Such examples are numerous and provide great opportunity to focus new research efforts to fill these major knowledge gaps.

In very general terms, determining exactly what data are inventoried, stored and made accessible is often driven by all four discipline areas. First, land-management policy questions often direct significant changes in data needs, including both variables measured and the scale of measurement. Secondly, the statistics needed by an organization and the models accepted for use, or being developed, also have an impact on data choices. Thirdly, internal organizational policies and cultures can have a significant bearing on knowledge management adoption, methods and successes. It is readily apparent, then, that, without some joint interaction among these disciplinary areas, it will be difficult to ensure that the proper information is available for problem solving (Reynolds *et al.*, 2005).

As with descriptive knowledge, land-management policies and organizational cultures can play a significant role in determining how and which predictive tools are used. Certain mathematical models may be acceptable for land-management planning purposes, but others are not. Conversely, well-grounded procedural knowledge and predictive statistics can inform – and change, in some cases – management policies and procedures. For example, predicted habitat loss for an endangered species can dramatically alter management guidelines for a broad geographical area, as illustrated by the Northwest Forest Plan (USDA Forest Service, 1994), where quantitative science (including inventory and analysis) drives policy.

Policy often determines what causal predictive knowledge we have available to us through the funding streams of science R & D investments. Furthermore, it partially defines the values that hold sway at any point in time, helps to establish the suite of choices that we are presented with and legitimizes certain trade-offs and compromises while effectively dismissing others. Many policy impacts are subtle and poorly understood and yet far-reaching and powerful.

Adaptive management is a way to explicitly acknowledge risk and uncertainty in the forest management process and deal with them logically (Walters and Holling, 1990). However, as Bormann and Kiester (2004) noted, many laws and policies governing natural resource management constrain efforts to properly implement an adaptive management approach. Furthermore, there is an unwillingness by individual managers, management organizations and the public to be wrong – which makes a no-action alternative unusually attractive. But no action has its own set of consequences. 'Nature, never having been constant, does not provide a simple answer as to what is right, proper, and best for our environment. There is no single condition that is best for all life' (Botkin, 1995). Policy scientists have an important role to play in helping scientists and managers deal with the socio-economic realities of sustainable forest management.

New tools face technological and institutional challenges for successful operational deployment. The two case studies, below, illustrate the complex information technology environments within which new tools must be deployed. The first case study illustrates the many issues to be considered in assembling a suite of systems to perform a complex analysis, i.e. a national forest resource assessment. The second case study illustrates issues in linking the system-related activities of multiple organizations, i.e. forestry enterprises interacting in supply chains. Theories that can guide the development and deployment process in institutions are then discussed.

Case Study 1: National Forest Assessment

FAO regularly monitors the world's forests through the Forest Resource Assessment (FRA) Programme, in which countries are required to complete 15 tables of information (Table 22.1) (FAO, 2005). Each item in Table 22.1 has its own policies, monitoring and assessment methods and information-processing approaches.

Countries have a wide range of methods of assessing their resources in order to complete these tables. FAO provides guidance for the process through an online knowledge reference.[1] The organization of the knowledge reference exhibits many similarities to the four themes of the present discussion: an introduction including a policy chapter, an inventory and data collection section, and analyses, outputs and cases sections. The analyses section includes chapters on information management and data registration and modelling for estimation and monitoring.

Information management and data registration

The chapter on information management and data registration (Thomson, 2004) is particularly relevant to the present discussion. The section headings from that chapter illustrate the range of information management considerations (Table 22.2).

The basic Forest Resource Assessment scenario (Table 22.2) is based on the case in which a single institution is conducting the assessment (see Vignette 1). However, real assessments almost always involve many institutions and many computers with complex distributed processing and data registration issues as well as infrastructure and institutional issues. Technical, semantic, political/human, inter-community, legal and international interoperability constraints in particular

Table 22.1. Information required by the FAO Forest Resource Assessment process.

Extent of forest and other wooded land
Ownership of forest and other wooded land
Designated functions of forest and other wooded land
Characteristics of forest and other wooded land
Growing stock
Biomass stock
Carbon stock
Disturbances affecting health and vitality
Diversity of tree species
Growing stock composition
Wood removal
Value of wood removal
Non-wood forest products removal
Value of non-wood forest products removal
Employment in forestry activities

Vignette 1. Indicators and multiple-criteria decision making (Vacik *et al.*, Chapter 23, this volume)

This chapter illustrates the manner in which the knowledge framework adopted by an agency can influence an analysis or assessment approach. For example, indicators have proved to be powerful tools for collecting and reporting information within a management system. Vacik *et al.* use the driving forces–pressure–state–impact–response (DPSIR) approach of the European Environmental Agency (EEA) for the evaluation of alternative management strategies at the forest management unit level. A set of indicators for sustainable forest management (SFM) is arranged according to the DPSIR framework to cover the causal chain of environmental and socio-economic drivers and pressures, to detect changes in the state of the system and to identify impacts on ecosystems and society. The study combines the strengths of tools that enhance system understanding and those of multi-criteria decision making for the purposes of SFM, while keeping the whole concept at least semi-quantitative by integrating ecosystem modelling results. This integration creates new perspectives on the communication of decision making, on the relationship between ecosystem modelling and decision modelling and on the applicability of established approaches per se.

Table 22.2. Information management topics from the FAO knowledge reference for Forest Resource Assessment.

1. Introduction
   - 1.1 What is information management?
   - 1.2 National and international requirements for forest resource assessments
   - 1.3 Current status of information management in national FRAs
2. A basic Forest Resource Assessment scenario
   - 2.1 Data
     - 2.1.1 Data models
     - 2.1.2 Data input
     - 2.1.3 Computer programs for data and information management
     - 2.1.4 Standards, metadata and data quality
       - Standards
       - Metadata and meta-information
       - Verification and validation
       - Backups and archiving
   - 2.2 Information
     - 2.2.1 Information demand and supply
     - 2.2.2 Information aggregation and integration
       - Information transformations
       - Expert opinion
   - 2.3 Information management and change assessment
     - 2.3.1 Data and information sources
     - 2.3.2 Monitoring
   - 2.4 Reporting and communication
     - 2.4.1 Reporting requirements and information management
     - 2.4.2 Maps, graphs and statistics
3. Extending the basic scenario: many institutions and many computers
   - 3.1 The Internet and other computer-related issues
     - 3.1.1 Distributed systems and interoperability
     - 3.1.2 Data registration
     - 3.1.3 Institutional and infrastructure issues
4. Putting a full national forest information system in place
   - 4.1 System design and development
     - 4.1.1 Requirements analysis
     - 4.1.2 System development
     - 4.1.3 Funding and financial mechanisms
5. Discussion

can be limiting factors (Miller, 2000; Thomson, 2005b). Interoperability can be viewed as operating on three levels: strategic (agreements, partnerships and objectives), tactical/operational (who does what?) and technological (information systems and standards – see Vignette 2), and examples of these can be found within the chapters of this book.

Standards, metadata and data registration procedures play a key role in interoperability. The use of standards in supply chains (case study 2 below) can be critical to success (Gopal and McMillan, 2005).

Vignette 2. Standards: Establishment Management Information System (Perks *et al.*, Chapter 24, this volume)

The term 'standards' generally refers to the role of information technology standards in the development of interoperable systems. However, Perks *et al.* illustrate another key role of standards, i.e. the idea that the decision support provided by a system must conform with a set of forest management standards. In addition to supporting a set of interoperable components, the Establishment Management Information System must generate information that is consistent with the UK Forestry Standard, the government's approach to sustainable forestry. The UK standard in turn conforms to the Helsinki Guidelines and Pan-European Criteria, and in the second edition (2004) deals with issues such as the devolution of forestry in Great Britain to England, Scotland and Wales as well as a range of legislation and policy changes.[a] It is critical that systems can easily be kept abreast of such changes.

[a]http://www.forestserviceni.gov.uk/press/2004/14th_may.htm (Accessed 3 August 2005.)

Case Study 2: Knowledge Management in Supply Chains

The following scenario provides one possible view of how wood resources may some day move from timber stand to wood processor.

> The most ambitious predictions indicate that pulp and paper buyers will simply dictate to a wrist-mounted computer (voice recognition enabled, of course) that they need x tons of grade y to be delivered in three days and an order confirmation and delivery time will come straight back at them. That is, of course, if they actually need to place an order at all. After all, with all the data processing technology that is becoming available, the computer will have already decided that it needed x tons of grade y and placed the request automatically.
>
> (Kenny, 1999)

Implicit in this scenario is the idea of a supply chain with a suite of systems operating in concert over a set of enterprises that may contain up to 20 companies (Thony, 2003). The term 'chain' implies a linear flow of products and information and this is reflected in most diagrams of supply chains, in which 'trees' at one end and 'end users' at the other are linked by boxes and arrows, with the directions of the arrows depending on whether the chain is a 'supply-push' or 'demand-pull' situation. The quotation above represents demand-pull, in which a requirement would have the end result of triggering harvest of a specific stand of trees.

In practice, each forest stand contains different product assortments suited for use in several different industries and supply chains, with specific markets requiring specific assortments, and with several forest companies operating in overlapping catchment areas (Forsberg and Rönnqvist, 2003). Key questions for forest management therefore include:

- How should forest inventories be conducted to optimize their use in supply chains?

- To what extent must current forest planning and harvest scheduling systems be modified to fit a supply chain setting?

An end user may have more than one supplier, while the initial supplier may have more than one customer, resulting in 'supply networks' (Fig. 22.1) rather than supply chains. Using this perspective:

> The conventional wisdom is that competition in the future will not be company vs. company but supply chain vs. supply chain. But the reality is that instances of head-to-head supply chain competition will be limited. The more likely scenario will find companies competing – and winning – based on the capabilities they can assemble across their supply networks.
>
> (Rice and Hoppe, 2001)

This leads to development of 'intelligent-webs' that use high-speed and real-time communications to link partners in a networked structure to satisfy consumer demand in a highly responsive manner (Hoppe, 2001). This will provide those well-connected companies with a competitive advantage by supplying products more responsive to customers' needs and time frames.

'Trust' (see Vignette 3) is emphasized as a key consideration for information sharing in supply chains. A key issue, therefore, is the manner in which trust for information sharing operates in a networked situation, not only among participating individuals and corporate entities, but also among software agents (Goel *et al.*, 2005) that negotiate in automated systems. In contrast with the developed world, supply chains in developing countries are tightly linked with long-standing social structures (Woods, 2004). Significant differences in trust development arise in that setting, and systems and processes designed for use in developed countries may not be appropriate for the developing world, especially where software agents are used.

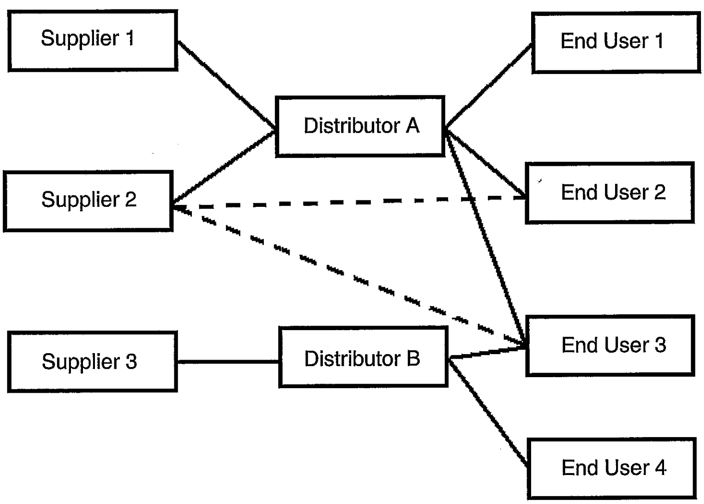

Fig. 22.1. A supply network. Connections may be either 'supply-push' or 'demand-pull' so directional arrow heads are omitted. The dashed lines indicate bypassing of steps in the chain or network.

Vignette 3. Trust: the virtual forester (Reinbolz and Hanewinkel, Chapter 25, this volume)

The ability of policymakers and the general public to understand concepts and issues and develop trust in research findings is key to sustainability. Trust has emotional and personalization aspects. The agent-based virtual forester in the innovative system described by Reinbolz and Hanewinkel is designed to provide personalized help on navigation through complex websites relating to sustainable forestry, and attempts to build an emotional connection with the system user.

Functions of multi-agent systems include (Frey *et al.*, 2003):

- Negotiations between enterprises
- Integrated process planning and scheduling
- Production planning and controlling (with focus on assembling industries)
- Production planning and controlling (with focus on batch production)
- Operational tracking of orders, including suborders, in supply chains
- Analysis of historical tracking information (tracing)

Software agents performing these functions must perform a range of activities including: negotiation of plans among supply-chain partners, monitoring of orders and related suborders, informing partners and internal planning systems when critical events are triggered, routinely forwarding information to trusted third-party supply-chain communication systems, performing internal rescheduling in reaction to a critical event, and renegotiating a plan of production between supply-chain partners due to a critical event. These activities require bridging not only technical differences between enterprises, but also cultural differences that involve work flows, processes, social expectations and established patterns of doing business with partner enterprises.

An Institutional Perspective on Tools for Sustainable Forestry

Institutional processes and cultures are complex and have generally evolved over many years. Not surprisingly, it is exceedingly difficult to introduce new software products for knowledge management or modelling, new sets of criteria or indicators to inventory and monitor, unfamiliar analysis methods that affect decision making, or novel management policies or fresh interpretations of existing ones. Consequently, institutional change – including transitioning towards sustainable forestry – is subject to great uncertainty, frequent missteps, voluminous debate and generally slow progress. A look at some recent developments in the social science literature can help us understand these problems and find ways to advance change.

Sustainable forest management can be aided by adoption of information technology applications. These include tools to track and enable compliance with regulations, reduce risks and increase ecological efficiency by assessing and reducing product and service life cycle costs (Waage *et al.*, 2003). Innovation diffusion theory (Rogers, 1995) can help guide adoption or explain observed patterns of adoption and abandonment of a particular system (Thomson *et al.*, 2004) or of an idea such as sustainable development (Innes *et al.*, 2005). Under Roger's theory, people exist within social systems and fall into five main categories with regard to adopting innovations. True innovators or pioneers comprise less than 3% of the population. The rest of the population is made up of 13% early adopters, 34% early majority, 34% late majority and the remaining 16% laggards. The adoption of innovations, therefore, follows a characteristic bell-shaped (cumulative S-shaped) curve over time. Adoption rate depends on five attributes of innovations: relative advantage, compatibility, complexity, trialability and observability. Pre-diffusion needs/problem awareness, basic and applied research and development and commercialization decisions can significantly affect the adoption process, leading to testable hypotheses in information systems research, such as in the use of Open Source software (Valier *et al.*, 2004).

Institutional and organizational behaviour often departs from such theoretical optimal paths of adoption and abandonment/replacement, and other concepts must always be considered when approaching the introduction of new tools or processes. One such concept, escalation of commitment, refers to a situation in which a decision maker commits additional resources to a failing course of action rather than adopting a new course or using resources for an alternative unrelated activity. The theory of escalation of commitment can explain the roles of different forms of agency commitment to failing approaches. For example, escalation in the IT sector can be related to an organizational reward structure in which a manager's performance is linked with the success of software process improvement activities (Abrahamsson, 2002). Salter and Sharp (2001) showed that the effect of an apparently small difference in national culture can explain differences in escalation of commitment to failing projects in two countries with significant cross-border investment (USA and Canada). Studies of de-escalation of commitment (Heng *et al.*, 2003; Pan *et al.*, 2004) can provide guidance for both researchers and managers to help avoid inappropriate escalation of commitment.

Organizational reward structures are also central to agency theory. Knowledge exists in both explicit and implicit (tacit) forms (Rauscher *et al.*, Chapter 26, this volume). 'The knowledge management literature specifically addresses the problem of converting the implicit to the explicit, while agency theory directs our attention to the costs of doing so' (Hall *et al.*, 2000). Knowledge management activities can require considerable time and effort for individuals in organizations (see Vignette 4). These are strategic activities for organizations, but can compete significantly with specific project-related activities for an individual's time and effort, and individual benefits can vary among team members. Furthermore, the institutional reward system may not adequately reflect KM contributions. These differences can have a significant impact on KM policies in project-oriented organizations, and can lead to conflict and project failure (Hall *et al.*, 2000). Balance between individual and organizational costs and benefits under the guidance of agency theory leads to different optimal strategies to enhance knowledge capture in different types of organizations (Hall *et al.*, 2000). Performing this balancing will

Vignette 4. Information and knowledge management (Rauscher *et al.*, Chapter 26, this volume)

Without attention to the key task of knowledge management, efforts in sustainable forest management may only have limited long-term success. Rauscher *et al.* make the case that proficient problem solving depends on an adequate foundation of relevant and readily applicable knowledge. Making good decisions can be extremely difficult when problems are not well structured and situations are complex, as they are when managing natural resources for multiple benefits and for users with differing values. It takes a well-coordinated, cooperative approach among people developing methodologies and techniques in the areas of knowledge management, decision-support systems and decision analysis methods to support sustainable forest management.

require some trade-offs between concern for the individual and for the organization. However, without some examination of those trade-offs, KM benefits to the organization may not be fully realized or, alternatively, individual commitment to KM may dissolve, owing to incorrectly perceived rewards.

Other useful theories, not dealt with specifically in this chapter but which can help understand the development and deployment of systems in organizations, include resource-based theory (Caldeira and Ward, 2003), the theory of computation,[2] complexity theory[3] and the theory of constraints.[4] Grounded theory (Orlikowski, 1993) is also commonly used in the information systems research literature as it specifically links data collection and analysis with theory development.

Discussion

The discipline of knowledge management covers not only specific tools, which we have explored through an organizational hierarchy, but also a process fundamental to the activities of individuals, institutions and organizations, which we have explored through theories such as innovation diffusion, escalation of commitment and agency theory. In the same manner that there is no single tool that fits all purposes and tools are made to interact to achieve particular aims, there is no single theory that fits all situations and theories also interact and overlap (Waters, 2004). Knowledge management, innovation and commitment theory and theories of organizational change can each provide valuable insights into the interpretation and application of principles from the others.

The manner in which information and knowledge management are used to meet institutional goals was illustrated in two case studies: (i) the creation of National Forest Assessments by FAO; and (ii) supply chains. Dealing with issues such as standards, metadata and interoperability contributes to successful outcomes. Interoperability includes not only computer system interoperability, but also political/human, inter-community, legal and international interoperability.

Vignette 5. Knowledge ecosystems (Thomson, Chapter 27, this volume)

Knowledge ecosystems can be defined as 'the complex and many-faceted system of people, institutions, organizations, technologies and processes by which knowledge is created, interpreted, distributed, absorbed and utilized.' Analogies with ecosystem processes can be used to guide activities such as design of forest planning processes. Under this concept, adaptive knowledge management (Thomson, 2005c) can be used to experiment with knowledge in the same manner that adaptive management, described elsewhere in this volume, is used to experiment with ecological management.

Vignette 6. Web services: habitat and rare species protection (Ray and Broome, Chapter 28, this volume)

A web service provides information for other applications that send messages to it over the Internet. Ray and Broome describe how one organization uses web services to deliver up-to-date advice on sustainable forest management in relation to habitat and rare species protection under complex and constantly changing biological and legislative constraints.

The concept of knowledge ecosystems (see Vignette 5) can also be helpful in guiding linkages among individuals, institutions and technology.

The conference on which this book is based highlighted many state-of-the-art applications that characterize sustainable forestry decision making in the highly interconnected setting of institutions in the developed world. However, forestry exists within the broader context of social, environmental and economic endeavours, and many of the drivers of forest-related decisions in less-developed parts of the world have their basis in these broader issues. The top three major social issues of global concern identified in the United Nations Millennium Declaration[5] are peace, security and disarmament; development and poverty eradication; and protecting our common environment. All three of these have consequences for forestry. Information and communication technology (ICT) will play a significant role in addressing these issues, with social and cultural drivers being paralleled by technological drivers (Thomson and Colfer, 2005). Agenda 21 has also been a driver of system development, particularly in relation to sustainability and enhanced participation (Thomson, 2005c). Service transformation (see Vignette 6), delivery of services in a way that meets the changing wants and needs of clients, is also a significant driver of system development, especially in government services (Thomson, 2005a).

Differences between developed and developing countries in their approach to information technology and knowledge management are often related to 'divides'. Differences in access to knowledge in the 'digital divide' concept are well recognized. However, other less-known ICT-related divides, such as democratic, gender, racial, knowledge (see Vignette 7), strategy and nanotechnology divides, may be more significant in the future, as may failures to address the

Vignette 7. The rational DSS model and the fact/value divide (Ekbia and Reynolds, Chapter 29, this volume)

Rational DSSs work well for situations in which there are well-defined, agreed-upon goals, all alternatives are known, preferences are clear and stable and there are no time and cost constraints. These conditions rarely apply in forestry, and Ekbia and Reynolds describe a range of alternative approaches for these types of more complex situations. These alternatives lie along a divide characterized by emphasis on facts, on one side, and on values, on the other.

issue of 'information literacy' (Thomson and Colfer, 2005). Institutions in developed and developing countries therefore face different challenges in creating and using systems to aid decision making and produce mandated reports.

Definitions of 'sustainability' have evolved with time and vary considerably (Innes *et al.*, 2005). However, many of the practical applications of the concept focus on certification processes for sustainability. Chain of custody is central to the process and is closely linked with supply-chain development:

> If the industry being certified has a fairly disintegrated supply chain, then certification can be used as a means to improve communication and information management, ultimately streamlining and integrating the supply chain. The result is a comprehensive plan that, prior to certification, did not exist and is one of 'the most valuable reasons for becoming certified' according to many interviewees.
>
> (CCIF, 2002)

Such examples demonstrate clear and tangible benefits from the interaction of policy setting (certification) and information and knowledge management.

Sustainable forestry is practised within a policy and planning hierarchy, ranging from national levels, for which Montreal process-type criteria and indicators[6] are developed, reported and compared, to local levels, at which a forest manager is trying to determine an appropriate silvicultural regime for a particular stand of trees. As described earlier in this chapter, there exists a hierarchy of descriptive, predictive and prescriptive tools to assist in these activities. However, adoption of a particular tool, integrating it with existing institutional processes and ensuring that its performance complies with current and changing policies must be carefully orchestrated. Fortunately, a range of organizational theories exists to avoid failure (Fortune and Peters, 2005) and increase the likelihood of success.

Notes

1. http://www.fao.org/forestry/site/7817/en
2. http://en.wikipedia.org/wiki/Theory_of_computation
3. http://en.wikipedia.org/wiki/Computational_complexity_theory
4. http://en.wikipedia.org/wiki/Theory_of_constraints
5. http://www.un.org/millennium/declaration/ares552e.htm (last accessed on 6 July 2005)
6. http://www.iisd.ca/forestry/mont.html

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