An Integrated Decision Support Toolbox (DST) for the Management of Mountain Protected Areas

Authors: Bajracharya, Birendra, Pradhan, Sudip, Shrestha, Basanta, and Salerno, Franco

Source: Mountain Research and Development, 30(2) : 94-102

Published By: International Mountain Society

URL: https://doi.org/10.1659/MRD-JOURNAL-D-09-00048.1

Mountain Research and Development (MRD)
An international, peer-reviewed open access journal
published by the International Mountain Society (IMS)
www.mrd-journal.org

MountainDevelopment
Transformation knowledge

An Integrated Decision Support Toolbox (DST) for the Management of Mountain Protected Areas

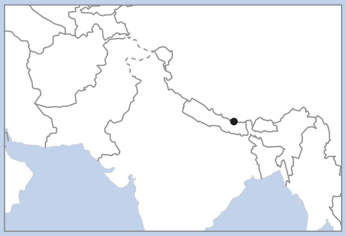
Birendra Bajracharya[1]*, Sudip Pradhan[1], Basanta Shrestha[1], and Franco Salerno[2,3]

** Corresponding author: bbajracharya@icimod.org; birendra.bajracharya@gmail.com*

[1] International Centre for Integrated Mountain Development (ICIMOD), Khumaltar, Lalitpur, PO Box 3226, Kathmandu, Nepal

[2] Ev-K2-CNR Committee, Via San Bernardino 145, 24126 Bergamo, Italy

[3] Water Research Institute–National Research Council (IRSA–CNR), Via del Mulino 19, 20047 Brugherio (MB), Italy



New tools and methodologies are required in systemic planning and management of mountain protected areas. Among others we propose here a decision support toolbox (DST) conceived as an integrated collection of both soft and hard system methodologies, consisting of participatory and computer-based modules to provide a set of integrated, self-contained tools and approaches to support decision-making processes in the management of mountain protected areas. The Sagarmatha National Park and Buffer Zone (SNPBZ) in Nepal was taken as a pilot case. A number of participatory exercises such as participatory 3-dimensional modeling, scenario planning, and qualitative modeling were carried out to understand social-ecological processes and generate a systemic view over space and time. The qualitative models were then converted into computer-based system dynamics models. The design and development of DST software were carried out with an incremental and modular approach. This process involved stakeholder analysis and decision-making processes through a series of consultations. The software was developed with the main modules including scenario analysis, spatial analysis, and knowledge base. The scenario analysis module runs system dynamics models built in Simile software and provides functions to link them with spatial data for model inputs and outputs. The spatial analysis module provides the basic geographic information system functions to explore, edit, analyze, and visualize spatial information. The knowledge base module was developed as a metadata management system for different categories of information such as spatial data, bibliography, research data, and models. The development of DST software, especially system dynamics modeling and its linkage with spatial components, provided an important methodological approach for spatial and temporal integration. Furthermore, training and interactions with park managers and concerned stakeholders showed that DST is a useful platform for integrating data and information and better understanding ecosystem behavior as a basis for management decisions.

Keywords: *Decision support systems (DSS); system dynamics; spatial analysis; protected area management; ecosystem management; Nepal.*

Peer-reviewed: *September 2009* ***Accepted:*** *January 2010*

Introduction

Conservation planning is commonly targeted towards the goals of protecting and restoring viable populations of native plants and animals and protecting habitats, ecological and evolutionary processes, and functional connectivity for a conservation network that is more resilient to environmental change (Jones et al 2006). Protected area systems are seen as one of the most common strategies adopted to achieve conservation goals (Mulongoy and Chape 2004). While protected areas represent a form of effective in situ conservation, many of them are located in remote parts of countries inhabited by marginal and economically least developed communities. These local communities largely depend on natural resources and are likely to support protected areas as long as they continue to get the benefits (Mulongoy and Chape 2004; Zhaoli and Jianchu 2008).

The often contradicting demands of nature conservation and livelihood support make the management of protected areas especially challenging. The evolving concepts of landscape approach and ecosystem-based conservation and community participation involve much larger spatial scales that go beyond species and habitat conservation (Chettri et al 2008). The problems facing protected areas are closely related to socioeconomic factors including poverty, land tenure, and equity while they also involve national-level concerns such as tourism, energy, natural resources, and ecosystem services (McNeely 2008). In simple terms, protected areas represent complex systems with closely interacting social and ecological processes.

Amatya et al (2008) have specified that new tools and methodologies such as a decision support system (DSS) are required in systemic planning and management of mountain protected areas. However, the concept of DSS has evolved since the early 1960s in parallel with the development of computer technologies (Ekbia 2004; Ekbia and Reynolds 2007) and is often defined as interactive computer-based systems to assist complex decision-making processes that utilize data and models to solve unstructured problems. The emphasis in early DSS was on databases and data models, which later on extended to knowledge bases and knowledge management. Thousands of DSSs have been developed for diverse applications, with variations in terms of scope, functionalities, computational methods, spatial capabilities, and system performance (Mowrer et al 1997; Johnson and Lachman 2001). DSSs designed for natural resource management have evolved to encompass a broad range of tools including databases, growth and yield models, wildlife models, financial models, geographical information systems, and simulation and visualization tools (Nute et al 2003). In the present context, the development of a DSS was seen as part of an institutional consolidation process that will provide a framework for monitoring the social-ecological dynamics of mountain protected areas.

The concept of a decision support toolbox

As a first step, an assessment of existing DSS packages oriented to ecosystem management was carried out in order to benefit from the experiences of other similar initiatives and assess the possibility of using existing software tools for implementation of a decision support toolbox (DST). Assessments by Mowrer et al (1997) and Johnson and Lachman (2001) provided a good comparison of different DSSs targeted to ecosystem management. A majority were either in the realm of research or addressed very specific applications, while very few were relevant for supporting the objectives of the project. No single DSS has been capable of fully addressing the broad range of issues involved in protected area management.

The concept of the DST was initiated as a collection of tools and methods to address the needs of different stakeholders to support key components of the decision-making process. It included hard- and soft-system methodologies, such as computer-based and participatory tools. Efforts were made to link these in order to ensure a smooth flow of information between the conceptualization phase of the system and its quantitative analysis and between the people's needs and the development of solutions (Salerno et al 2008). Studies in diverse regions all over the world suggest that natural and social systems behave in nonlinear ways, exhibiting marked thresholds in their dynamics, and that social-ecological systems act as strongly coupled, integrated systems (Folke et al 2002). Managing social-ecological systems requires understanding and managing feedback and interrelations among ecological, social, and economic components of systems across temporal and spatial scales (Holling 2001; Gunderson and Holling 2002). The system dynamics approach was considered appropriate for DST development, as it combines theory, methods, and philosophy to analyze the behavior of systems and uses concepts from the field of feedback control to organize information into a computer simulation model (Ford 1991; Forrester 1994, 1998).

Sagarmatha National Park and Buffer Zone (SNPBZ) was taken as a pilot case for the development of the DST. The management of SNPBZ is a complex task involving the conservation goals of the park and livelihood options of the people living within it. With many settlements located inside the park and having a management structure with the well-established role of the buffer zone council in decision-making, a higher level of coordination is required between the park authority and the local communities. Participatory approaches have been used as an effective way to develop shared understanding of issues and decision-making processes. Besides involving local stakeholders and park authorities in a number of consultative meetings, the participatory research included scenario planning (Daconto and Sherpa 2010), participatory 3-dimensional (3D) modeling, and qualitative systems analysis (Salerno et al 2008). Similarly, as hard system methodology, the DST software was designed and developed to provide a set of integrated but self-contained computer-based tools to support the decision-making process. This article focuses on the approaches and methods adopted for developing the DST software tool.

Development of the DST software

A modular approach was followed for development of DST software; this was an evolving process, with the functionalities of components being defined or modified during the course of development. User analysis and review of existing tools and contemporary technologies were carried out for system design.

User analysis

Analysis in SNPBZ identified the main stakeholders as government agencies at central and local levels, community-based organizations (CBOs), business organizations, national and international nongovernmental organizations (I/NGOs), research and academic institutions, and cultural and religious institutions (CESVI 2006). Each household in SNPBZ is represented in the Buffer Zone User Group, from which the Buffer Zone User Committees (BZUCs) are formed. These stakeholder groups are involved at different levels in influencing management decisions, and each has its own primary values and concerns. While some of the local-level stakeholders—such as BZUCs, cultural and religious groups, CBOs, and business organizations—were involved during the participatory processes, the most likely users of the DST software were, and are, the government agencies at central and local levels, I/NGOs, and research and academic institutions. An additional group includes external users such as research students and visitors who are not direct stakeholders but who will interact with the software to explore the available information resources.

During interaction with the DST software, these stakeholders will play different roles—with 1 stakeholder potentially playing many roles and conversely, many stakeholders playing 1 role. The different roles played by the stakeholders are identified as *decision maker*, *thematic expert*, *technical user*, *researcher*, and *external user*. For example, during the modeling exercises, park officials played the role of thematic expert and collaborators from the universities were researchers, whereas project staff involved in database development were technical users.

Defining the system components

The project promoted a systemic approach as an appropriate frame of reference for conservation and management of protected areas. The fundamental assumption behind systemic thinking is that everything interacts with, affects, and is affected by the things around it (Checkland 1981; Leleur 2005). The choice of system dynamics as a tool to investigate the interconnected issues of protected area management is based on its capability to provide a holistic view of the system. The system behavior can be sketched at the operational level and visually represented using available software (Muetzelfeldt and Massheder 2003). The system dynamic models constitute the central component of the DST software. Models were developed to address the different issues related to management of SNPBZ, such as tourism, population dynamics, solid waste management, energy management, indoor air pollution, forestry, and water pollution.

Being home to the world's highest peak, Mount Everest, and a World Heritage Site, SNPBZ has tourism as its driving force for all its socioeconomic and environmental dynamics. The discussions with local and national stakeholders identified overcrowding during tourist seasons as a key management problem. Another issue related to tourism was population dynamics. There is a growing trend of inmigration of non-Sherpa people who pursue economic opportunities. On the other hand, with their growing economic status, many Sherpa residents are moving to Kathmandu and abroad to expand their business and escape harsh climatic conditions (outmigration). With overcrowding resulting from tourism, the park needs an effective waste management plan to address the problem of increasing solid waste and environmental pollution. Energy demand is another management issue that affects the natural resources, as fuelwood is still a major source of energy in SNPBZ. Related to the type of energy use are the issue of indoor air pollution, which affects the health of the local population, and the problem of forest degradation due to fuelwood collection. Tourism is also impacting the water quality of the region, and pollutants are increasing, in the form of both organic waste and solid waste that find its way to natural streams. Individual system dynamics submodels were developed to address these different issues. While these submodels can be run individually, a composite model was built by linking all of them in order to have a complete picture.

Another important aspect of protected area management is area-based planning and monitoring. Hence, geographic information system (GIS) functions were also considered an important component of DST design. The system was designed to allow the system dynamics models to read and write the model inputs and outputs from and to GIS layers, so that the user can visualize both temporal and spatial behavior.

A component for a knowledge base was considered, with a view to address the need expressed by stakeholders for a systematic platform to access and share the existing data and research work carried out in SNPBZ over many years. The different components of DST and interaction among the users in different roles are shown in Figure 1.

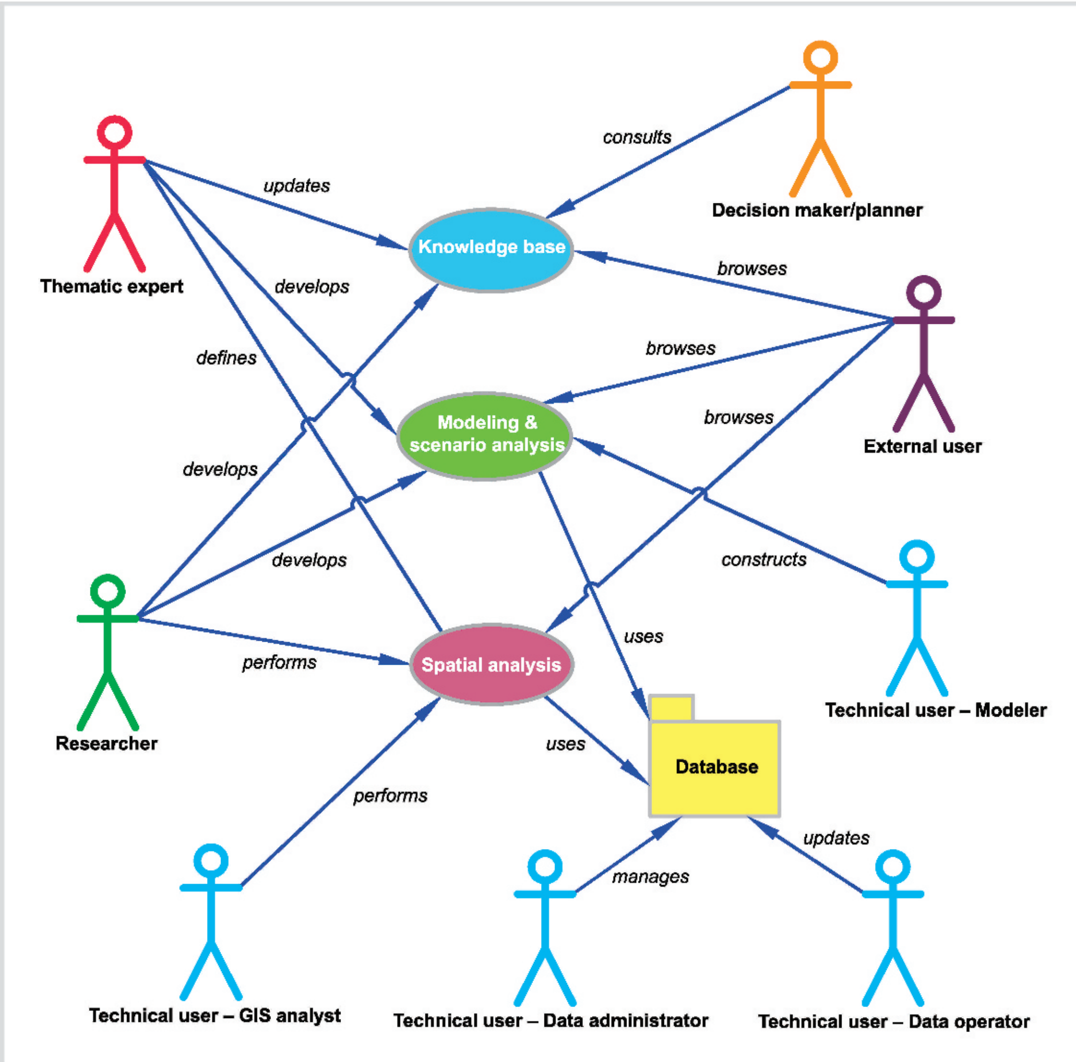
System architecture

The DST was developed using a modular architecture, which allowed for the progressive development and delivery of self-contained, complementary modules. The modular architecture of DST integrates multiple technologies and applications. DST software was designed with the 3 functional modules: scenario analysis, spatial analysis, and knowledge base. While the DST provides basic GIS functions and makes it possible to run system dynamics models, it is assumed that the users will employ external commercial software for more advanced processing such as model building and neighborhood analysis. The system architecture of DST is presented in Figure 2. The details of these modules are presented in the following sections.

DST modules

One objective of DST development is to initiate the understanding of the biophysical and socioeconomic dynamics of the area. The first step is to translate the real-world scenario into qualitative models; this helps to get a clear picture of the linkages between different players in the system and a grasp of the entire complexity of the environment. The key tool used for qualitative modeling is the concept map, which allows information flow to be managed in a participatory process. Concept maps are qualitative diagrams that facilitate the development and sharing of a common understanding among participants coming from different disciplines with different worldviews. Concept maps were developed using specific

FIGURE 1 User analysis.



notations in order to ensure that they would be of greater use for subsequent qualitative and quantitative modeling. Figure 3A shows a concept map of population dynamics in SNPBZ. A group of experts in system dynamics then developed the quantitative models based on these concept maps. The system dynamics model of population dynamics is shown in Figure 3B.

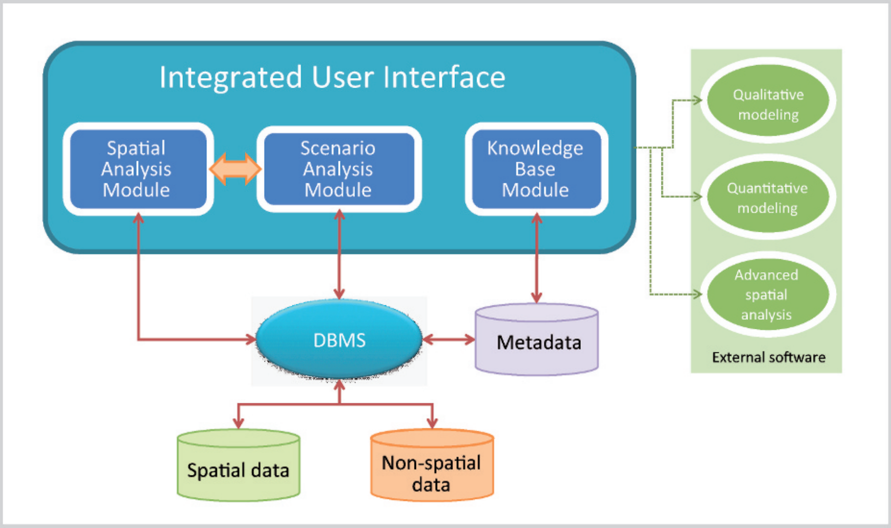
Scenario analysis module

The scenario analysis module was designed with 2 submodules. The first submodule allows the user to browse and view qualitative models in the form of qualitative diagrams developed using CMapTools® (http://cmapspublic3.ihmc.us) software by thematic experts. These qualitative diagrams are exported as HTML files from CMapTools® for use in the DST.

The second submodule allows users to run the system dynamics models created in Simile® software (Simulistics Ltd) by translating the qualitative models. Interfaces are provided to adjust model parameters and policy levers to run the simulations. Different scenarios are generated by changing the policy levers. The functionality to link with GIS makes it possible to view the model behavior in both space and time. The DST runs the models using the Simile engine, while the results are obtained in various forms of outputs such as tables, charts, and diagrams. These tables and charts display the values of performance indicators at specific time intervals defined during the model run. The pattern of these variables describes the behavior of the

http://dx.doi.org/10.1659/MRD-JOURNAL-D-09-00048.1

FIGURE 2 The system architecture of the DST.



system over time. For example, the output of the tourism model shows the overcrowding index for each settlement on a daily basis. This scenario is also displayed on a map showing the settlements with different overcrowding indices with different color symbols (Figure 4).

Spatial analysis module

The spatial analysis module provides basic GIS functions and geoprocessing tools for viewing, creating, editing, and analyzing spatial data. The module allows the users to query and attribute spatial data and prepare maps for

FIGURE 3 (A) Qualitative model (concept map) of population dynamics in SNPBZ; (B) quantitative (system dynamic) model of population dynamics.

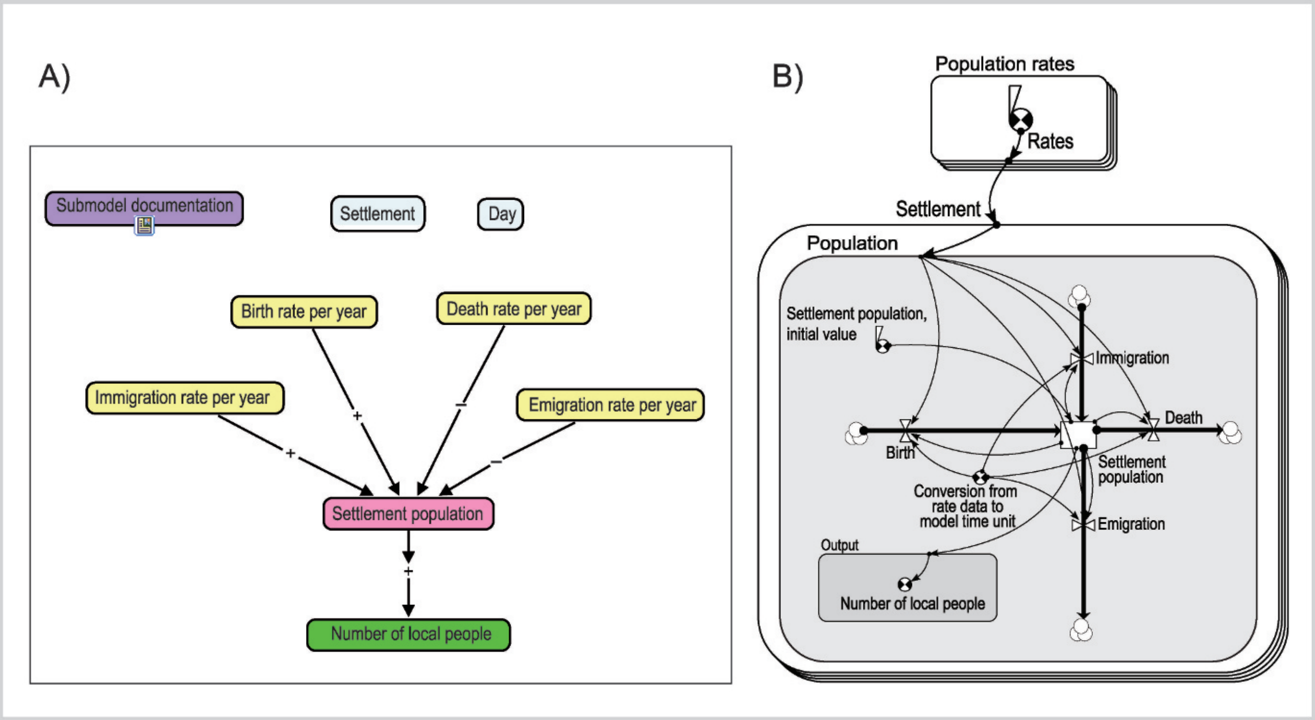
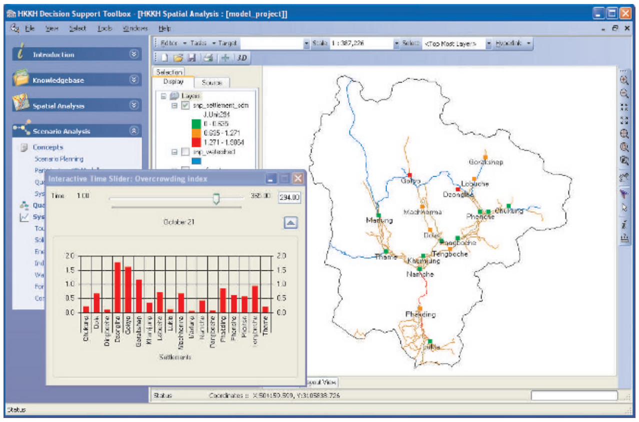


FIGURE 4 Tourism model showing the overcrowding indices of settlements.



display and printing. The data developed and compiled by the project are packaged along with the software so that the user is able to access them through the menu provided under the spatial analysis module. It also provides a slidebar tool to visualize or map the spatial pattern of system dynamics model outputs over time. A 3D viewer is provided for interactive and dynamic 3-dimensional visualization of landscape terrain with associated spatial data. The spatial analysis module was developed using MapWinGIS, an open source ActiveX control from MapWindow. The module uses .shp (shape) and .img (ERDAS Imagine®) file formats for vector and raster layers.

Knowledge base module

The knowledge base module was designed as a metadata management system that allows storage of metadata for various kinds of information such as bibliographies, spatial data, satellite images, models, etc. The metadata are a structured set of information about the content, purpose, quality, and location of the data set. By looking at the accompanying metadata, users can find information on what is available and how, when, and where the data were collected and validated. The spatial metadata are based on an ISO 19115 geospatial metadata standard of the International Organization for Standardization (ISO), and the bibliographical metadata are based on modified Dublin Core. The module provides functions to query the metadata using simple and advanced search tools. The system also allows for storing the data, model, or other information for distribution along with the metadata. A similar knowledge base system using the open source GeoNetwork platform has been made available at the project's Integrated Web Portal (www.hkkhpartnership.org). Currently, it contains more than 1500 metadata records in different information categories.

User interface

In terms of system design, the scenario analysis and spatial analysis modules are integrated with each other, allowing communication of data and model outputs between them, whereas the knowledge base module functions independently. However, the different modules are made available to the user through an integrated user interface with a contextual menu and toolbars customized for each module. A comprehensive help system and tutorial are also included in the DST to guide the users. The user interfaces for different modules are shown in Figure 5A–C.

Operationalizing the toolbox

Iterative development and stakeholder participation

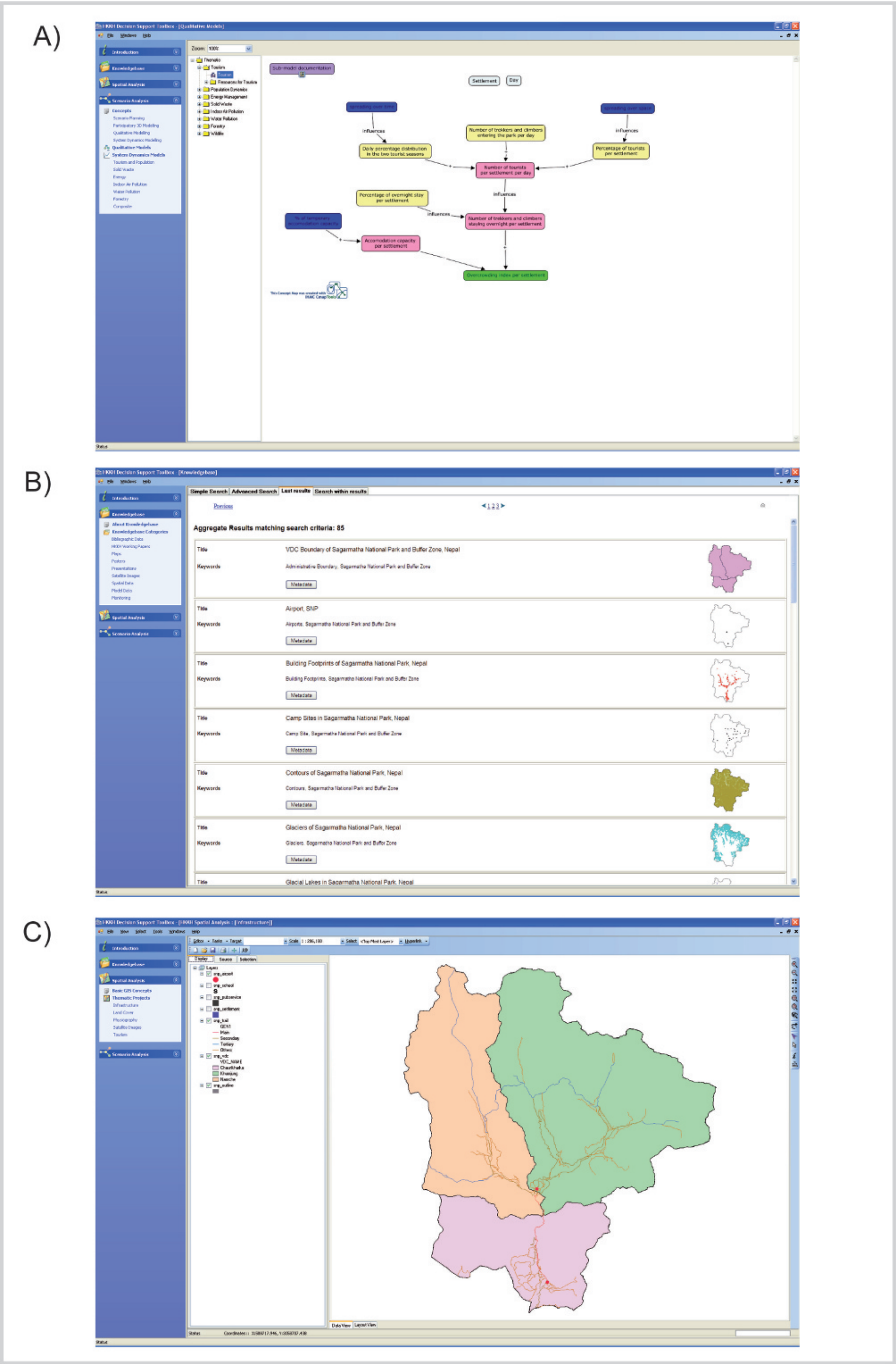
The development of tools with practical applications in SNPBZ itself was an iterative and learning process, which helped to refine the tools during the implementation of the Hindu Kush–Karakoram–Himalaya (HKKH) project. To begin with, a gap analysis was carried out on the existing capacities of the stakeholders to use spatial data and scientific methodologies in their decision-making process. The scenario planning exercise in SNPBZ provided a useful indication of possible future actions to address the problems affecting the park. These interactions helped to identify the key issues to be addressed by DST. It emerged quite clearly that the livelihoods of the people and the issues related to natural resource use and environmental conditions in the park revolved around tourism.

Workshops were then organized with key stakeholders and thematic experts to create qualitative models of the system. They worked on the identification of spatial boundaries, ecosystem services, institutional and legal factors, and power relations that influence patterns of decisions by stakeholders. They evaluated the implications of different sets of policy levers. The qualitative diagrams were translated into quantitative model structures. A data gap analysis was carried out looking at the data demanded by the model structures and existing data. Field missions were conducted to collect the missing data. The models were further refined and then sent to stakeholders for review and feedback. A number of training programs were also organized to familiarize the users with DST and to get their input on practical aspects of the software. The evolving model constructs and the stakeholders' feedback helped in the development process of DST interfaces and functionalities.

A number of interactions with the park managers and concerned stakeholders have shown that DST is a useful platform for integrating data and information and better understanding ecosystem behavior as a basis for management decisions. The data collected during the modeling process will also serve as baseline information for longer-term monitoring.

http://dx.doi.org/10.1659/MRD-JOURNAL-D-09-00048.1

FIGURE 5 Interfaces of the DST software: (A) scenario analysis module; (B) knowledge base module; (C) spatial analysis module.



Innovative tools for protected area management

Ecosystems in reality are a combination of multiple subsystems linked by complex interactions. System dynamics models make it possible to interlink the subsystems and get a systemic view of the issues in protected area management. Simulations are attractive tools for ecosystem modeling and provide an opportunity for controlled experimentation with parameters and observation of their impacts, thus generating alternative scenarios, which help in the planning, decision-making, and evaluation processes (Bousquet and Le Page 2004; Ekbia 2004; Ekbia and Reynolds 2007). Although GIS can display and analyze time- series spatial information, it does not provide suitable dynamic modeling tools (Brady and Whysong 1999), and its capability to deal with multidimensional space–time modeling is limited (Maguire 2005; Miller et al 2005). In attempts to integrate GIS and system dynamics, either GIS is used as the main interface with extended modeling functions (GIS-centric approach), or the modeling environment is extended with the capability to visualize the map outputs (model-centric approach). In the DST design, an integrated interface has been provided for both GIS and modeling functions, and users can have a simultaneous spatial and temporal view of a system's behavior. The linking of GIS and system dynamics has opened new possibilities for developing models. It is now time for integration of spatial thinking and systems thinking so that temporal and spatial disaggregation can be expressed more explicitly in the model construct.

Institutionalization and replication

Although system dynamics has been in existence for decades, its application to ecosystem analysis and management is recent. The systemic approach demands expertise from many disciplines, as there is a need to view the issues in a holistic manner across many thematic areas and sufficient understanding of the system dynamics is required to construct the model of social-ecological processes. This poses challenges in effective implementation of the DST, as current management frameworks are often sectoral in nature. The institutional challenges basically emanate from weak infrastructure to utilize modern decision-support tools and lack of awareness among policy decision-makers. Introducing systemic thinking in management practice requires awareness generation as well as management training in these concepts, approaches, and tools.

The system dynamics models included in DST are area specific, and they address the conditions and issues pertinent to SNPBZ only. Customized user interfaces have been developed to run these models so that the stakeholders can utilize the DST with minimum guidance. However, these tools and approaches are generic in nature and have been developed with the flexibility to use them either separately or in conjunction, depending upon the user's requirements.

The project has been making efforts to institutionalize these tools and approaches for the stakeholders through capacity building and training activities. These activities also provide opportunities to get users' feedback, which leads to further refinement of the DST. Furthermore, capacity building of both community organizations and government bodies, both at local and national levels, is important for successful implementation of the DST and its replication to a wider network of protected areas.

ACKNOWLEDGMENT

This publication was produced within the framework of the project "Institutional Consolidation for the Coordinated and Integrated Monitoring of Natural Resources towards Sustainable Development and Environmental Conservation in the Hindu Kush–Karakoram–Himalaya" Mountain Complex," financed by the Italian Ministry of Foreign Affairs–DGCS.

REFERENCES

Amatya LK, Salerno F, Panzeri D, Cuccillato E, Bajracharya B. 2008. HKKH Partnership Project: Partnership towards integrated participatory and scientific management of mountain ecosystem. *In:* Bhandari BB, Suh SO, Woo SH, editors. *Water Tower of Asia—Experiences in Wetland Conservation in Nepal*. Changwon, South Korea: Gyeongnam Ramsar Environmental Foundation, pp 13–24.

Bousquet F, Le Page C. 2004. Multi-agent simulations and ecosystem management: A review. *Ecological Modeling* 176(3–4):313–332.

Brady WW, Whysong GL. 1999. Modeling. *In:* Morain S, editor. *GIS Solutions in Natural Resource Management: Balancing the Technical-Political Equation*. Santa Fe, NM: OnWord Press.

CESVI [Cooperazione e Sviluppo]. 2006. *Sagarmatha National Park Situation Analysis: Stakeholders, Management System, Participatory Tools in Use and Preliminary Capacity Building Assessment.* HKKH Partnership Project Working Papers. Kathmandu, Nepal: HKKH Partnership Project. Available at hkkhpartnership.org; accessed on 30 April 2010.

Checkland P. 1981. *Systems Thinking, Systems Practice*. Chichester, United Kingdom: John Wiley.

Chettri N, Sharma E, Shakya B. 2008. Biodiversity conservation beyond boundaries: An initiative on regional cooperation in the Hindu Kush–Himalaya. *In:* Bajracharya SB, Dahal N, editors. *Shifting Paradigms in Protected Area Management*. Kathmandu, Nepal: National Trust for Nature Conservation.

Daconto G, Sherpa LN. 2010. Applying scenario planning to park and tourism management in Sagarmatha National Park, Khumbu, Nepal. *Mountain Research and Development* 30(2):103–112.

Ekbia HR. 2004. *Rethinking DSS: Lessons Learned from Ecosystem Management*. Redlands, CA: University of Redlands.

Ekbia H, Reynolds K. 2007. Decision support for sustainable forestry: Enhancing the basic rational model. *In:* Reynolds K, Thomson A, Köhl M, Shannon S, Ray D, Rennolls K, editors. *Sustainable Forestry: From Monitoring and Modelling to Knowledge Management and Policy Science*. Wallingford, United Kingdom: CABI Publishing, pp 497–514. Available at www.slis.indiana.edu/faculty/hekbia/web/other/EkbiaReynolds_DSS.pdf; accessed on 12 August 2009.

Folke C, Carpenter S, Elmqvist T, Gunderson L, Holling CS, Walker B, Bengtsson J, Berkes F, Colding J, Danell K, Falkenmark M, Gordon L, Kasperson R, Kautsky N, Kinzig A, et al. 2002. *Resilience and Sustainable*

http://dx.doi.org/10.1659/MRD-JOURNAL-D-09-00048.1

Development: Building Adaptive Capacity in a World of Transformations. Scientific Background Paper on Resilience for the Process of The World Summit on Sustainable Development. Stockholm, Sweden: The Environmental Advisory Council. Available at www.unisdr.org/eng/risk-reduction/sustainable-development/resilience-sd.pdf; accessed on 18 June 2008.
Ford A. 1999. *Modeling the Environment*. Washington, DC: Island Press.
Forrester JW. 1994. System dynamics, systems thinking, and soft OR. *System Dynamics Review* 10(2):245–456.
Forrester JW. 1998. *Designing the Future*. Seville, Spain: Universidad de Sevilla.
Gunderson L, Holling CS, editors. 2002. *Panarchy: Understanding Transformations in Human and Natural Systems*. Washington, DC: Island Press.
Holling CS. 2001. Understanding the complexity of ecological, economic and social systems. *Ecosystems* 4:390–405.
Johnson P, Lachman B. 2001. *Rapid Scan of Decision Support System Tools for Land-Use Related Decision Making*. Prepared for Association for Biodiversity Information. Arlington, VA: NatureServe. Available at http://ncseonline.org/NCSSF/DSS/Documents/docs/Johnson2001.pdf; accessed on 6 June 2007.
Jones AL, Daly K, Molvar E, Catlin J. 2006. Conservation planning and assessment of irreplaceability and vulnerability of conservation sites in the "Heart of the West" Region, Middle Rockies. *Journal of Conservation Planning* 2(1):62–97.
Leleur S. 2005. *Systemic Planning: Principles and Methodology for Planning in a Complex World*. Copenhagen, Denmark: Polyteknisk Forlag.
Maguire DJ. 2005. Towards a GIS platform for spatial analysis and modeling. *In:* Maguire DJ, Batty M, Goodchild MF, editors. *GIS, Spatial Analysis, and Modeling*. Redlands, CA: ESRI Press.
McNeely JA. 2008. A new paradigm for managing protected areas in the 21st century. *In:* Bajracharya SB, Dahal N, editors. *Shifting Paradigms in Protected Area Management*. Kathmandu, Nepal: National Trust for Nature Conservation.
Miller I, Knopf S, Kossik R. 2005. Linking general purpose dynamic simulation models with GIS. *In:* Maguire DJ, Batty M, Goodchild MF, editors. *GIS, Spatial Analysis, and Modeling*. Redlands, CA: ESRI Press.
Mowrer T, Barber K, Campbell J, Crookston N, Dahms C, Day J, Laacke J, Merzenich J, Mighton S, Rauscher M, Reynolds K, Sojda R, Thompson J, Trenchi P, Twery M. 1997. *Decision Support Systems for Ecosystem Management: An Evaluation of Existing Systems*. General Technical Report RM-GTR-XXX. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station.
Muetzelfeldt R, Massheder J. 2003. The Simile visual modeling environment. *European Journal of Agronomy* 18(3–4):345–358.
Mulongoy KJ, Chape S, editors. 2004. *Protected Areas and Biodiversity: An Overview of Key Issues*. Montreal, Canada: Secretariat of the Convention on Biological Diversity; and Cambridge, United Kingdom: UNEP–WCMC [United Nations Environment Programme–World Conservation Monitoring Centre].
Nute D, Potter WP, Dass M, Glende A, Maier F, Uchiyama H, Wang J, Twery M, Knopp P, Thomasma S, Rauscher HM. 2003. *An Agent Architecture for an Integrated Forest Ecosystem Management Decision Support System*. Decision Support for Multiple Purpose Forestry, 23–25 April, Vienna, Austria.
Salerno F, Cuccillato E, Muetzelfeldt R, Giannino F, Bajracharya B, Caroli P, Viviano G, Staiano A, Cartenì F, Mazzoleni S, Tartari G. 2008. *Concept Maps for Combining Hard and Soft System Thinking in the Management of Socio-Ecosystems*. Proceedings of the 3rd International Conference on Concept Mapping (CMC2008), 22–25 September. Vol. 1. Tallinn, Estonia, and Helsinki, Finland, pp 298–305. http://cmc.ihmc.us/cmc2008papers/cmc2008-p190.pdf; accessed on 10 March 2008.
Zhaoli Y, Jianchu X. 2008. Climate change impacts on China's biodiversity conservation and their implications to protected area management. *In:* Bajracharya SB, Dahal N, editors. *Shifting Paradigms in Protected Area Management*. Kathmandu, Nepal: National Trust for Nature Conservation.

ONLINE REFERENCES

HKKH Partnership: www.hkkhpartnership.org
IHMC [Institute for Human and Machine Cognition]: http://cmap.ihmc.us/conceptmap.html
Simulistics Ltd: www.simulistics.com

 http://dx.doi.org/10.1659/MRD-JOURNAL-D-09-00048.1