Hydrogeological Techniques

Integrated assessment models

National Centre for Groundwater Research and Training

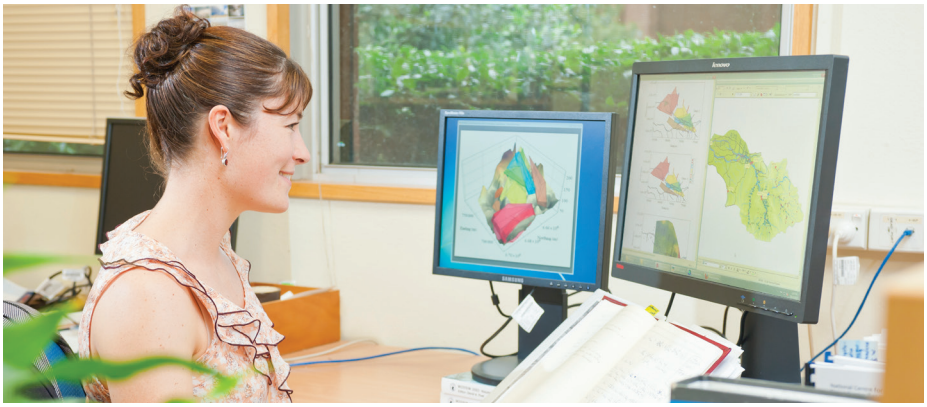
This resource introduces integrated assessment models, which combine knowledge across a broad range of fields to help environmental managers better understand the issues that they are facing, and to make more informed decisions.

Effective environmental management requires an understanding of the interactions between policy choice and complex social, economic, technical and environmental processes. The predicted outcomes then need to be assessed with regard to feedbacks, side effects and, where possible, trade-offs among various, often conflicting, objectives.

Integrated assessment models or tools systematically combine knowledge developed across a broad range of fields (such as economics, ecology, psychology, sociology, hydrology and agronomy) into a unified framework. They are useful in helping to analyse alternatives with stakeholders, quantitatively assess their outcomes, and communicate results.

Integration in the modelling process may refer to:

- **integrated treatment of issues** by examining the various parts of the system as a whole
- **integration with stakeholders**, which can vary from simple updates of research to community groups to large-scale inclusion of stakeholder views and knowledge at all stages in a project
- **integration of disciplines**, by considering two or more disciplinary views of a management problem and its associated system boundaries
- **integration of processes and models**, which requires combining two or more models of different systems or processes in a system



- **integration of scales of consideration**, as resource and environmental issues may often be considered at a variety of temporal and spatial scales, and components of a system may operate on different scales.

Several modelling approaches are used for integrated assessment. In this fact sheet we outline five broad modelling approaches and provide a guide to selecting the appropriate approach.

APPROACHES TO INTEGRATED MODELLING

System dynamics modelling

System dynamics modelling represents a set of conceptual and numerical methods that are used to understand the structure and behaviour of complex systems. System dynamics has the capacity to model feedbacks, delays and non-linear effects, and is useful for improving system understanding and fostering system thinking skills and knowledge integration for modellers and end users. The approach is often applied to investigate complex interactions between humans and ecosystems.

Bayesian networks

Bayesian networks are most commonly used in modelling for decision-making and management applications in which uncertainty is a key consideration.

Variables are represented by nodes connected by arrows which represent causal dependences or an aggregate summary of complex associations, and probabilistic relationships are used to describe the connections among variables. They are able to explicitly incorporate both quantitative and qualitative information to specify the model and thus are particularly useful when historical data are lacking, but other types of knowledge, including expert opinion and survey data, are available.

Want to know more?

Jakeman, AJ, Letcher, RA 2003, 'Integrated assessment and modelling: features, principles and examples for catchment management', *Environmental Modelling and Software*, vol. 18.6, pp. 491–501.

Kelly (Letcher), RA, Jakeman, AJ, Barreteau, O, Borsuk, ME, El Sawah, S, Hamilton, SH, Henriksen, HJ, Kuikka, S, Maier, H, Rizzoli, AE, van Delden, H, Voinov, A.A 2013, 'Selecting among five common modelling approaches for integrated environmental assessment and management' *Environmental Modelling and Software*, vol. 47, pp. 159–181.

Letcher, RA, Jakeman, AJ, Croke, BFW, 2004, 'Model development for integrated assessment of water allocation options', *Water Resources Research* vol. 40, W05502.

Coupled component models

Coupled component models combine two or more complex models from different disciplines to come up with an integrated outcome. Coupling may be loose, where outputs from models are linked together manually or tight where the component models are engineered to work together to share inputs and outputs. Coupled component models inherit the features of the component models that comprise them.

Agent-based models

Agent-based models simulate autonomous groups like population settlements or individuals as 'agents' and their (preferential/behavioural) interactions with each other and their environment. A key focus of the approach is the discovery of 'emergent behaviour' of the system as a result of simple interactions and learning among individual entities.

They are primarily used for policy and institutional analysis, and for simulating socioeconomic or socioecological processes to improve understanding of the dynamic interactions between agents and their settings.

Knowledge-based models

Knowledge-based models can be divided into rule-based models, where the models are formalised by a set of 'if-then-else' rules, and logic-based models, where the models are expressed as a series of logic statements, called facts, formalised according to a logic system. Knowledge elicited from the expert is explicitly encoded in facts and rules. The operation of knowledge-based models by expert systems is useful for all purposes but they are most commonly used for management and decision-making applications. They can be also used to explain deductions based on chains of rule applications.

CONSIDERATIONS FOR MODEL CHOICE

		System dynamics modelling	Bayesian networks	Coupled component models	Agent based models	Expert systems
Reason for modelling/type of application	Prediction	*	x	x	*	x
	Forecasting			x		x
	Decision-making under uncertainty	*	x	*	*	x
	System understanding	x	x	x	x	
	Social learning	x	x		x	
Type of data available to populate model	Qualitative and quantitative data	*	x	*	*	x
	Quantitative data mainly	x		x	x	
Model focus on a complex description of specific processes or greater breadth of coverage of interactions in system?	Depth of specific processes	*		x	x	x
	Breadth of system	x	x	x	*	x
Model to provide explicit information about uncertainty caused by model assumptions?	Yes		x			
	No	x		x	x	x
Interest in investigating the interactions between individuals and their impact on the system, or only the aggregated effects of behaviour?	Interactions between individuals				x	
	Aggregated effects	x	x	x	*	x

This table is a guiding framework for modellers and model users in selecting an appropriate approach for new applications, where x indicates standard features and * indicates possible features of the approach.

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