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Book Review

ENVIRONMENTAL MODELLING: FINDING SIMPLICITY IN COMPLEXITY

Second Edition

John Wainwright, Mark Mulligan, Editors

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Application of simulation models is an established method used to study processes and solve practical problems in a large variety of disciplines. At present one of the most interesting contexts for environmental modelling is is that related to human-induced climate change. Similarly, numerous works are frequently carried out to evaluate the impacts of land degradation due to the human impact. For most research areas, models can be reliable means of ensuring environmental protection, as long as the results are used properly.

The central concept of this book relies in the idea that environmental systems are complex, open systems. The authors analyses the diversity of possible approaches dealing with environmental complexity and encourage readers to make comparisons between these approaches as well as between different disciplines. The basis of the book is written on the basis provided by the work that authors carried out in the Environmental Monitoring and Modelling Research Group in the Department of Geography, King's College London.

In this second edition additional emphasis and material for those students wishing to specialize in environmental modeling are provided. The book is predominantly suitable for the final year undergraduates and postgraduates in environmental modelling, environmental science, civil engineering and biology, already familiar with the subject, but interested in specialization in the field. It is also appropriate to professionals interested in the environmental sciences, including environmental consultants, government employees, civil engineers, geographers, ecologists, meteorologists, and geochemists.

Environmental Modelling: Finding Simplicity in Complexity 2nd edition is structured into four main sections:
- an overview of methods and approaches to modelling (Part I).
- state of the art for modelling environmental processes (Part II)
- tools used and models for management (Part III)
- current and future developments (Part IV).

The first section (**Part I**) entitled *MODEL BUILDING* provides along eight chapters an introduction to modelling approaches, with a specific focus on issues that commonly arise in dealing with the environment. This part also presents the range of currently available techniques that may be employed in model building and testing. Each chapter ends with conclusions and references.

Chapter 1, *Introduction*, written by John Wainwright and Mark Mulligan is an introductory one and deals with the essential features of environmental modelling. This chapter also gives some information on how to use the book and the book's web site.

Chapter 2, *Modelling and Model Building*, by Mark Mulligan and John Wainwright details: the role of the modelling in the environmental research, the parameters that are required to carry out specific model applications, verification and validation of the models, sensitivity analysis and its role, the implication of errors and uncertainity involved in modelling.

Chapter 3, *Time Series: Analysis and Modelling*, by Bruce D. Malamud and Donald L. Turcotte gives first some examples of environmental time series. It discusses about the frequency-size distribution of time series and the concepts of uncorrelated values in time series, introduces measures of persistence and models that generate persistent time series and ends with some explanations on how complex time series can be generated using physical models.

Chapter 4, *Non-Linear Dynamics, Self-Organization and Cellular Automata Models*, by David Favis-Mortlock has two aims: to summarize the current knowledge of self-organization in complex systems and to show how this knowledge may be used in a practical way to built spatial environmental models.

Chaper 5, *Spatial Modelling and Scaling Issues*, by Xiaoyang Zhang, Nick A. Drake and John Wainwright, discusses the scaling issues facing spatial environmental modelling and the currently used methods reducing the scaling effects on both models and their parameters. To exemplify, a case study is presented on the approaches to scale up a soil-erosion model established at a plot scale to regional or global scales by scaling land-surface parameters.

Chapter 6, *Environmental Applications of Computational Fluid Dynamics*, by N.G. Wright and D.M. Hargreaves focuses on the fundamentals of computational fluid dynamic (CFD) techniques and their applications in environmental modelling. This chapter considers the application of CFD techniques for two scales of atmospheric flows — large scales, greater than 1 km, and small scales, those flows between 10 to 100 m. For the small-scale flows, the discussion is referred to as computational wind engineering (CWE).

Chaper 7, *Data-Based Mechanistic Modelling and the Emulation of Large Environmental System Models*, by Peter C. Young and David Leedal, discusses the problems associated with environmental modelling and the need to develop simple, top-down, stochastic models that match the information content of the data. It introduces the concept of data-based mechanistic (DBM) modelling. The chapter has outlined briefly the major methodological procedures used in DBM modelling and illustrates, through a practical example, how they have been applied in a hydrological context.

The goal of Chapter 8, *Stochastic versus Deterministic Approaches*, by Philippe Renard, Andres Alcolea and David Ginsbourger is to provide a discussion of the strengths and weaknesses of deterministic models and stochastic models and to describe their applicability in environmental sciences.

The differences between deterministic and stochastic modelling are illustrated by means of a real-world application in Oman.

The eleven chapters of **Part II** (*THE STATE OF THE ART IN ENVIRONMENTAL MODELLING*) analyse the state of the art of the environmental models in a number of fields.

Chapter 9, *Climate and Climate-System Modelling*, by L.D. Danny Harvey starts with a brief disccusion about the complexity of the climate systems and the interconnections between their components. In building computer models of the climate system, there are a number of basic considerations to be taken into account, such as: the number of components, the comprehensiveness of the climate model and the role of the simplification used in climate models. It is underlined that the equations used in climate models are a mixture of fundamentals principles that are known to be correct and parameterizations. The chapter also illustrates basic principles governing changes in climate in response to a radiative forcing and the feedbacks that determine the climate sensitiviy. The three-dimensional atmospheric and oceanic general circulation models are presented. Further, the chapter outlines the equilibrium and transient calculations for both climate and the terrestrial biosphere that are performed in the online Excel package.

The goal of Chapter 10, *Soil and Hillslope (Eco)Hydrology*, by Andrew J. Baird, is to argue that an ecohydrological approach is required to improve understanding, and to develop useful models, of hillslope hydrological behaviour. The complex adaptive systems (CAS) and ecohydrological approaches are considered as suitable to conceptualize and investigate hillslope hydrological behaviour.

Chapter 11, *Modelling Catchment and Fluvial Processes and their Interactions*, by Mark Mulligan and John Wainwright provides a landscape view of water movement and examines the complexity of aggregation of hillslope processes into nested catchments connected by stretches of flowing water and the interaction between hillslopes and channels.

Rosie A. Fisher, the author of Chapter 12, *Modelling Plant Ecology*, considers the complexities involved in predicting the response of the global biosphere to climate change. Different methods for modeling plant functions are presented, such as: Gap models, soil-vegetation-atmosphere-transfer (SVAT) models, and dynamic global vegetation models (DGVMs).

Chapter 13, *Spatial Population Models for Animals*, by George L.W. Perry and Nick R. Bond discusses about the importance of ecological modeling and underlines that modeling has become a valuable strategy for increasing ecological understanding at both small and large spatial scales permitting the creation of complex predictive models.

The historical development of ecological modeling is presented as well as more recent approaches (focusing on spatially explicit models, both static and dynamic) drawing examples from the “animal ecology” literature.

Chapter 14, *Vegetation and Disturbance*, by Stefano Mazzoleni, Francisco Rego, Francesco Giannino, Christian Ernest Vincenot, Gian Boris Pezzatti and Colin Legg, starts with a disscusion about the typical causes of disturbance which are grazing, cutting, fire, and frost. The disturbance is defined as an event that causes a significant change from the normal pattern in an ecological system. This paper focuses only on fire and grazing with an emphasis on work in Mediterranean environments. The main models used to simulate of plant growth under grazing and after fire are presented. An experiment to study the interactions of fire and cutting with grazing in the Mediterranean shrubland was established based on modeling approach. The modelling exercises show the power of existing modelling tools to examine some of the complex interactions of ecological processes, such as the combined effects of grazing, fire and dispersal processes, on patterns of plant competition.

In Chapter 15, *Erosion and Sediment Transport: Finding Simplicity in a Complicated Erosion Model*, by Richard E. Brazier, the potential of a simplified version of a complicated soil erosion model to predict and map hillslope soil erosion for a wide variety of scenarios throught England and Wales has been demonstrated. It was shown that hillslopes within catchments, regions or ultimately the whole of the UK can be modeled to identify the potential high erosion risk sites, or those combinations of soil, slope and land-use that should be avoided in the future.

Chapter 16, *Landslides, Rockfalls and Sandpiles*, by Stefan Hergarten, contains a study referring to the main factors that the major natural hazards in many regions of Earth (landslides, earthquakes and forest fires) have in common. It was shown that landslides, earthquakes and forest fires exhibit qualitatively similar size statistics, although quantitatively different. Self-organized criticality (SOC) has become a very popular concept. SOC was discovered in computer simulations of a simple cellular automaton model, the Bak-Tang-Wiesenfeld (BTW) model, sometimes also called the sandpile model. The earliest and still most important models in the context are Drossel-Schwabl forest fire model and the Olami-Feder-Christensen earthquake model. As a case study, the author applied the sandpile model with decreasing threshold to present topography of the Alps. It appears that the statistical data and the recent knowledge on the processes behind mass movements are not sufficient to decide which models are appropriate.

The issue investigated in Chapter 17, *Finding Simplicity in Complexity in Biogeochemical Modelling*, by Hördur V. Haraldsson and Harald Sverdrup, defines the model to be used for any biogeochemical problem. The basic information, classification and recommandation of the models applied in the environmentall modeling are presented. The authors also provide some information about biogeochemical models that describe the connection from biology through chemistry, to geology and back. Three groups of models are defined: models based on process-oriented kinetics, models based on equilibrium principles and empirical models. The authors concluded that the best model to choose is the model that answers the question asked with the necessary amount of accuracy with the smallest cost or effort.

The authors James D.A. Millington, John Wainwright and Mark Mulligan of Chapter 18, *Representing Human Decision-Making in Environmental Modelling*, outline several approaches for the representation and integration of human activity and human decision-making in environmental modelling. They present these approaches in three broad categories: scenarios and integrated assessment modelling, economic modelling, and agent-based modelling. The chapter also discusses some of the wider issues of modelling humans and highlights some of the key issues that modellers will need to consider.

Chapter 19, *Modelling Landscape Evolution*, by Peter van der Beek, reviews the development, application and validity of landscape-evolution or surface-process models. It discusses the construction of landscape-evolution models and the philosophy underlying them, as well as the prime ingredients of such models. The coupling of surface process models to other numerical models, in particular those predicting tectonic motions in the crust and lithosphere, as well as a number of studies applying landscape-evolution models to specific geomorphic/tectonic contexts are also discussed. The author suggests a brief perspective of where the field stands today and what directions might be taken in the future.

The focus of the **Part III** entitled *MODELS FOR MANAGEMENT* moves to model applications. The six chapters of this part bring to light the different needs of models in a policy or management context and demonstrate how these needs might be different from those in a pure research context.

The role of policy-support systems (PSS) and decision-support systems (DSS) in environmental science is briefly disscused by Mark Mulligan, in Chapter 20, *Models Supporting Decision-Making and Policy Evaluation*. The role of PSS is to provide scientific support and to help bridge scientific developments in the understanding of change in land-scapes with operational decision-making in the policy domain. The WaterWorld spatial policy-support is applied in this study focusing on the hydrological baseline of an area and the impact of land use, land management, and climate change. The authors showed that simple climate change, land-cover change and land management interventios applied singularly but, in reality, they will occur concurrently.

Chapter 21, *Models in Policy Formulation and Assessment: The WadBOS Decision-Support System*, by Guy Engelen, contains a large study referring to design and implementation phases of the decision-support systems. In particular, the author focuses on the development of the WadBOS policy support system applied to the Dutch Wadden Sea to facilitate the policymaking process. Finally, the chapter concluded that a policy-support tool can be developed within very reasonable constrains relative to budget, human resources and development time.

Chapter 22, *Soil Erosion and Conservation*, by Mark A. Nearing, reviews the models of soil erosion, with particular focus on soil erosion by water. Erosion models used in applications for conservation planning fall into two basic categories: empirical and process-based. The prime example of an empirically based model is the Universal Soil Loss Equation (USLE), which was developed in the United States. Various process-based erosion models have been developed since the mid-1990s, including EUROSEM, GUEST and WEPP model. The accuracy of USLE, RUSLE and WEPP models has been tested using measured soil loss data form plots. The author concluded that choosing which model to use becomes a matter of what type of information we would like to know and what information we have for the particular site of application.

The objective of Chapter 23, *Forest-Management Modelling*, by Mark J. Twery and Aaron R. Weiskitte, is to explore various modelling approaches used for forest management, provide a brief description of some example models and to explore the ways that they have been used to aid the decision-making process. The modelling approaches used in forest management differ widely in their frameworks and they are: empirical models, mechanistic models, hybrid models, and knowledge-based models. The chapter also treats the components of empirical models, validation, calibration, visualization, integration with other software.

The primary objective of Chapter 24, *Stability and Instability in the Management of Mediterranean Desertification*, by John B. Thornes, was to introduce the problems of Mediterranean desertification and to develop some ideas based on the complexity of response. Another objective was to examine the interaction between soil erosion and vegetation cover. The third part of the chapter attempts to demonstrate how change in climatic gradients cand lead to critical instabilities at different places along the gradient, and how to conceptualize the recovery trajectories both in space and time. At the end, the chapter emphasizes that the emergence of instability in the plant cover itself results not only from climatic and anthropic variation but also from genetic drift among the hillside plant communities.

Chapter 25, *Operational European Flood Forecasting*, by Hannah Cloke, Florian Pappenberger, Jutta Thielen and Vera Thiemig, provides a brief overview on the modelling approaches used in the European Flood Alert System (EFAS) and how they address the challenges of operational early flood forecasting at the European scale.

Chapter 26, *Assessing Model Adequacy*, by Michael Goldstein, Allan Seheult and Ian Vernon, provides an introduction to some basic general techniques for assessing the adequacy of a computer model for its intended purpose. The authors outline the basic methods for assessing the degree of uncertainty that it would be reasonable to associate with model outcomes. The basic tools for making order of magnitude quatification for uncertainties are also provided. Further, the study describes how the methods for assessing the adequacy of a computer model can be used in practice, by applying them to a rainfall-runoff model.

Part IV entitled *CURRENT AND FUTURE DEVELOPMENTS* deals with the current approaches and future developments that are considered to be fundamental for developing strong models. The above information is presented in Chapter 27, *Pointers for the Future*, by John Wainwright and Mark Mulligan. This conclusory chapter summarizes the content discussed in different chapters of the book. The brief points on the modelling methodology are discussed along to the developments that may be productive in the modelling methodology and on technological directions of environmental modelling.

To conclude, the book offers important information on how to use models to develop our understanding of the processes that form the environment around us. In this sense, the book:

- focuses on simplifying complex environmental systems.
- reviews current software, tools and techniques for modelling.
- gives practical examples from a wide variety of disciplines, e.g. climatology, ecology, hydrology, geomorphology and engineering.

It is important to underline that the book has an associated website to provide more information, links, examples and illustrations that were difficult to incorporate in the book. The structure of the site follows that of the book, and allows easy access to the materials relating to each of the specific chapters. The URL for the site is www.kcl.ac.uk/envmod.

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