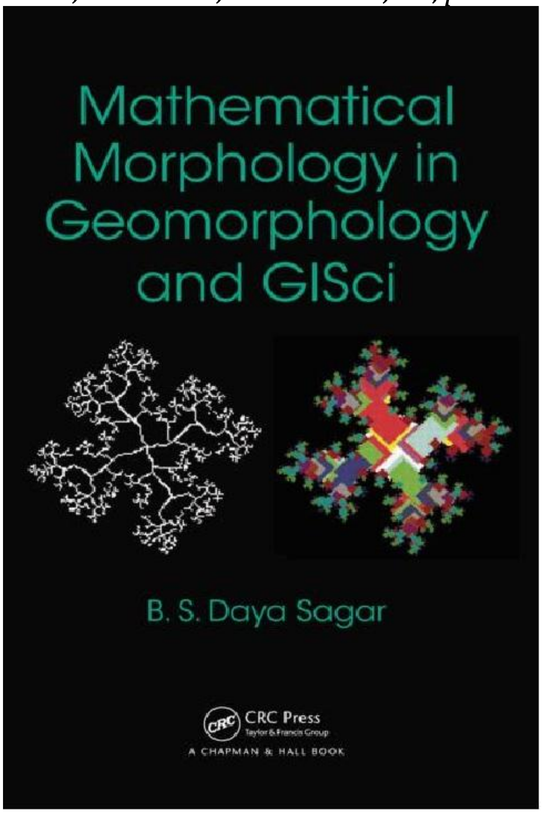
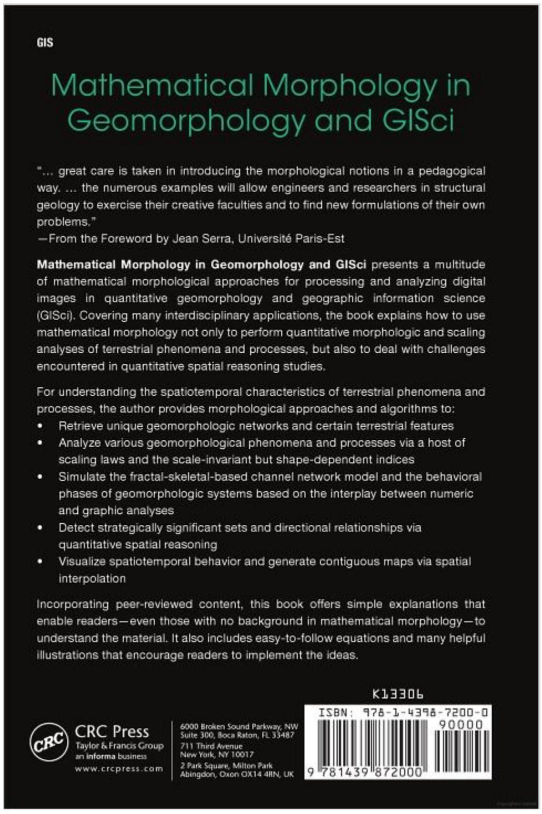
B. S. Daya Sagar (2013) ***Mathematical Morphology in Geomorphology and GISci****, CRC Press, Boca Raton, FL, p. 546.*





What is so appealing about this book is that the author introduces geomorphology using models of mathematical structure that are rooted in new approaches to geometry, particularly fractals and chaos. He adopts a basic model of a fractal river basin from which he extracts skeletal structures, thereby introducing ideas about networks in the landscape in an entirely natural way. He uses this as a basis for developing many other aspects of mathematical morphology – the use of sets to generate partitions of areas, the use of interpolation to produce surface representations and the identification of spatial clusters. Towards the end of the book, he generalises many of these ideas to more human spatial systems using the regionalisation of India as his exemplar and in so doing, he has produced as comprehensive a treatment of morphology in geographic information science as you will find anywhere. This is an important book that should be explored by all those who profess to be interested in spatial morphologies.
—**Michael Batty**, FRS, University College London

Since the initial birthing of computational geography and GIS over fifty years ago, the field of Geography has been evolving with many contributions from both the academic and research side as well as the application world. I am happy to see the emergence of the book "Mathematical Morphology in Geomorphology and GISci". This text further extends our understanding of GIScience how fundamental quantitative approaches can extend how we understand geography and our world.
—**Jack Dangermond**, President, Esri

This is a unique book on the analysis of various Geomorphology problems using mathematical morphology. The author is an acknowledged expert on the subject and this specialized book is the outcome of over fifteen years of continued research by him. Spreading over more than 500 pages in fourteen chapters, the book elaborately deals with feature extraction, analysis, reasoning, and modelling of spatio-temporal terrestrial data. The topics are described in a lucid manner with many examples and figures, making them easy to understand. Though primarily aimed for geo-morphologists, this book will be helpful for researchers working in problems of geography, cartography, geology, remote sensing and pattern recognition.
—**Bidyut B Chaudhuri**, FIEEE, Indian Statistical Institute

The monograph provides, in a consolidated manner, an application of mathematical morphology to structural geology, particularly addressing the issues like quantitative, morphologic and scaling analyses to terrestrial phenomena and processes. Texts on retrieval, modelling and reasoning, for example, are also useful to other application domains related to machine learning and pattern analysis.
—**Sankar K Pal**, FIEEE, Indian Statistical Institute

"... book on “Mathematical Morphology in Geomorphology and GISci” by Daya Sagar considers various topics—like pattern retrieval, pattern analysis, spatial reasoning, and simulation and modelling—of geoscientific interest. ... these intertwined topics which are useful for understanding the spatiotemporal behaviour of many terrestrial phenomena and processes, various original algorithms and modelling techniques that are mainly based on mathematical morphology, fractal geometry, and chaos theory have been presented in this book of 14 chapters. ... the journey through this book should provide geomorphologists and GISci specialists a new experience and exposition, and a host of new ideas to explore further in the contexts of quantitative geomorphology and spatial reasoning. ... book should be of immense value to the postgraduates, doctoral and post-doctoral students who would like to venture into applications of mathematical morphology in geomorphology and GISci."
—From the Afterword by **Arthur P Cracknell**, FRSE, University of Dundee

Prof Daya Sagar is a leading authority who has made major research contributions in most aspects of the applications of mathematical morphology and fractal geometry in terrestrial geomorphology and spatial informatics. This unique book on “Mathematical Morphology in Geomorphology and GISci”—highlighted numerous cases, imminent for those interested in venturing into developing physics-based models useful in geocomputation, and spatial informatics—takes an algorithmic approach to efficiently handle with topics related to (i) retrieval of complex terrestrial phenomena, (ii) analysis and reasoning of such retrieved phenomena, (iii) modeling and visualization of various terrestrial processes, and (iv) spatial informatics. The choice of the author, in this book, to combine mathematical morphology and fractal geometry, being the most powerful ideas in geometric sense, is perfectly right and appropriate for quantitative characterization of terrestrial phenomena and processes that exhibit plethora of geometric features and processes ranging from ‘simple’ to ‘strange’.
—**B. L. Deekshatulu**, FIEEE, Institute for Development and Research in Banking Technology

This enticing book introduces mathematical morphology to GI scientists in way that is persuasive and accessible using ideas that the author himself has pioneered in the last 20 years. It should be read by all those with an interest in how we represent surfaces in the environmental and urban domain.
—**Michael Batty**, FRS, University College London

“…great care is taken in introducing the morphological notions in a pedagogical way. … the numerous examples will allow engineers and researchers in structural geology to exercise their creative faculties and to find new formulations of their own problems.”
—From the Foreword by **Jean Serra**, Co-Founder of Mathematical Morphology, Université Paris-Est

"A wide-ranging treatise by an erudite scholar"
—**Jayanth Banavar**, Dean, College of Computer, Mathematical, and Natural Sciences, University of Maryland

"This book attacks the deep problem of analyzing mathematically the form of landscapes by mathematical tools, in particular by involving the discipline founded by geoscientists Matheron and Serra, Mathematical Morphology. The approach is original and pedagogic. It combines systematically experiments on numerical synthetic landscape models with experiments on real digital elevation models. Some chapters are very original, as they aim at the explanation of complex geomorphological phenomena. For example the formation of dunes is explored by its underlying bifurcation theory."
—**Jean-Michel Morel**, Editor-In-Chief of *SIAM Imaging Science*, Ecole Normale Supérieure de Cachan, Department of Mathematics, CMLA, France

"The book describes several techniques of mathematical morphology to address problems of image processing and data analysis with applications in geophysical information retrieval, analysis, reasoning, and modeling. Some of the specific topics presented include functions, sets, and skeletons as terrestrial surfaces; threshold-decomposed features; and geophysical networks. The aims of the methods described in the book are to extract information about the geometrical structure of an object, such as a water body, basin, channel network, and section of a water body, using concepts of mathematical morphology. The book provides not only details of various techniques of mathematical morphology, but also several illustrations of application. In some of the interesting illustrations in the book, specific geomorphological features are subjected to transformations by using various of structuring elements to achieve multiple effects and different results. Examples are provided to demonstrate how the main characteristics of a structuring template, such as shape, size, origin, and orientation, affect the results in different ways. It is shown how the topological characteristics of a water body, such as spatial distribution, morphology, connectivity, convexity, smoothness, and orientation, can be characterized by different structuring templates. One of the several novel aspects of the book is the integration of mathematical morphology and fractal analysis. Various examples are provided on the generation of fractal landscapes and fractal digital elevation models as well as the extraction of flow direction networks. Illustrations are provided to demonstrate the derivation of simulated fractal digital elevation models through morphological decomposition procedures. The book shows how physiographic and geomorphologic processes can be analyzed by quantitative representations of concavities and convexities. Valley and ridge connectivity networks are shown as abstract structures of concave and convex zones of terrestrial surfaces. Applications of the methods to extract features of terrestrial significance are provided. The features include unique ridge and channel networks, physiographic features such as mountains, hierarchically decomposed subwatersheds, and topologically significant regions of cloud fields. Methods are presented for the extraction of valley connectivity, ridge connectivity, and drainage networks from digital elevation models.

Grayscale skeletonization methods are described to derive ridge and valley connectivity networks. Particularly interesting illustrations are provided of automatically extracted channel networks, ridge networks, and subwatershed maps. The book contains extensive discussion and illustration of many more applications of image and data analysis in geomorphology and geographic information science. Coming from a different background in biomedical signal and image analysis, I find the illustrations and examples provided in the book to be not only interesting but also attractive and intriguing. The detailed procedures described in the book along with the large number of illustrations of application should assist researchers and practitioners in geographic information science and other areas of application of image processing and data analysis."
—**Rangaraj M Rangayyan**, FIEEE, University of Calgary

"This book represents an interesting application of approaches of mathematical morphology to digital terrain modelling."
—**Igor Florinsky**, Russian Academy of Sciences

"Professor Daya Sagar's book is a tour-de-force. He approaches mathematical morphology in depth from a variety of perspectives and practitioners and researchers from many fields will find much to learn. His linking of pattern retrieval, pattern analysis and modelling is innovative and powerful."
—**Sir Alan Wilson**, FRS, University College London

"The 546-page book "Mathematical Morphology in Geomorphology and GISci" by B. S. Daya Sagar published by Chapman and Hall/CRC is a welcome addition to the literature. It fills a gap that has existed for some time in the field of image analysis by providing a comprehensive mathematically-based overview of methods to systematically analyze the great variety of features observed at the surface of the Earth. The study of shapes and sizes of objects and their mutual interrelationships is paramount in Geoinformation Science (GISci) which has become a new flourishing field of scientific endeavor. The author has included numerous instructive examples of application with a substantial number of them related to the analysis of fractal patterns. Overall, the treatment of the subjects is thorough and the book can be regarded as a follow-up to the original approach to mathematical morphology commenced by Georges Matheron in the 1970s and 1980s. These fathers of the field had introduced the use of Minkowski operations such as dilation, erosion and the opening or closing of sets by means of iterative processes. Since then, there has been significant progress both from an observational and a theoretical point of view. Important new high-precision products that have become available include digital elevation models (DEMs). With respect to underwater topography, there now are the digital bathymetric maps (DBMs). Many of the examples in the book use DEMs or DBMs. During the past 25 years we also have witnessed important new developments in the fields of fractal modeling and chaos theory. The author offers excellent explanations and examples of application of non-linear process modelling; for example, he uses the logistic equation to study fold dynamics and applies spatiotemporal dynamical modeling to understand geomorphological processes. At the annual conference of the International Association for Mathematical Geosciences held in Salzburg, Austria, September 5-9, 2011, Professor Sagar delivered the Georges Matheron Lecture providing the audience in this plenary session with an overview of his contributions to mathematical morphology. I am happy to see that this material now has been expanded in book-form, so that it can be studied by scientists working in the field all over the world. I also highly recommend the new book to all teachers engaged in presenting courses on geomorphology and GISci to university students."
—**Frits Agterberg**, Emeritus Scientist, Geological Survey of Canada

Geomorphology is practiced in many earth science disciplines in the study of shape and form and their changes over time. Increasingly the challenges of climate change, population growth and shifts, and conflicting uses of resources have brought geomorphology to the forefront of scientific investigation. The new book addressing the application of mathematical morphology to problems in geomorphology by Dr. B.S. Daya Sagar is timely and fills a needed gap. Dr. Sagar is one of the worlds's leading experts on mathematical morphology. This book is large (515 pages) but well organized and clearly written. It is accessible to those with no knowledge of mathematical morphology, as early chapters introduce the basic structuring elements and provides numerous examples. There are practical examples throughout the book and the theoretical underpinnings are tied to examples. As a statistician, I found the quantitative spatial relationships and reasoning especially interesting. Many of us educated in North America perhaps may have had limited exposure to this subject but it merits serious consideration, given the importance of spatial-temporal relationships and clustering.
—**John H.(Jack) Schuenemeyer**, President, Southwest Statistical Consulting, LLC, USA. Professor Emeritus, Mathematical Sciences, University of Delaware. Fellow, American Statistical Association

"Professor Daya Sagar's book is a triumph in the literature on morphology. It provides rich, comprehensive insight into the mathematics of morphology, using problems and examples from the geographic sciences. In addition, scholars of image processing, computer vision, and medical imagery will also find useful material in shape analysis and recognition."
—**Kentaro Toyama**, Visiting Scientists, School of Information Science, University California Berkeley

"This work was written by a well-known geomorphology expert, Daya Sagar, for other geomorphology experts. Therefore, if you are not a part of that group, then this book is probably not for you. Knowledge in geomorphology and geographic information systems (GIS) is required to be able to follow the material. Chapter 1 summarizes the

content of the book. Chapter 2 introduces all the formulas for the mathematical morphology. The author describes every operator in detail, with many examples. Some readers might find the structure of this chapter confusing, but the explanations and descriptions are of very high quality. A general description of the datasets used in the book is given in chapter 3, and several different real-world geographic environments are discussed in detail. In the following chapters, the author shows how mathematical morphological operators can be used to obtain several different geomorphologic and geographic features, such as mountains, basins, and ridges. The author assumes that the reader is an experienced geomorphologist, familiar with this subject (GIS), who might want to learn more about using mathematical morphology for related tasks. However, I found these chapters very dense and hard to follow. Furthermore, the structure of these chapters is not always clear and sometimes the author seems to go back and forth between concepts, which can make the reading somewhat uncomfortable for any reader. The book does include extensive documentation and numerous references for further reading. I note that many of the references are by the author of this book and his colleagues. While this provides evidence that Sagar is really an expert in the field, it seems that including references from other researchers might broaden the scope for further reading to resources with different points of view. Unfortunately, the book has been published in grayscale. In this type of book, color images are almost mandatory. Color illustrations would have helped me better comprehend the material. The geographic images introduced in chapter 3 and used throughout the book should have appeared in color for improved understanding. Overall, this book provides solid information about using mathematical morphology for geographic imaging from a real expert in the field. Because of the level of expertise required, the book is suitable only for proficient geomorphologists. Novices in this field should not start with this book."
—**Jose Manuel Palomares Munoz**, ACM Computing Reviews

Jean Serra in the Foreword to this book states that it is intended for an audience of "geomorphologists" while Arthur Cracknell in the Afterword suggests that it will be of "immense value" to postgraduates, doctoral and postdoctoral students. But if this is so, the intended readers will have to be exceptionally, mathematically erudite and adept at programming as well, for although Sagar provides an introduction to his version of mathematical morphology, no computer code, pseudo or otherwise, is included in the text. Sagar's audience may well be geomorphologists but he frequently cites the work of human geographers. Consequently, this text will be of great interest to all scientists who believe that space can be utilized as a powerful explanatory variable. Chapter 1 describes the general organization of the book and includes a synopsis of each of the 13 remaining chapters. Chapter 2 explains the various concepts behind mathematical morphology, both binary and mulitiscale operations, that were originally introduced by Georges Matheron in 1975 and then further developed by Jean Serra and others. The third chapter describes the diverse data sets amenable to investigation using the techniques of mathematical morphology. These include simulated and actual Digital Elevation Models, Digital Bathymetric Maps, fractal basins that exhibit self-similarity and indeed any remotely sensed image displayed as a numerical array. Fractal basins can be decomposed into topologically prominent regions but, as usual, William Warntz' seminal contributions to the determination of the critical points, lines and areas of a surface are overlooked (Waters, 2009). Feature extraction, covered in Chapter 4, is a topic of interest to physical and human geographers, for the feature concerned might be a watershed or a commuting district, a river or a road. The segmentation algorithm described on p.80 does reference Warntz' concept of peaks and pits but not the passes and pales and other critical features that are equally useful in surface segmentation. Sagar's primary focus on geomorphological applications is asserted in Chapter 5 where he demonstrates the use of the techniques of mathematical morphology for terrestrial surface characterization. Here he builds upon the pioneering research of Horton and Strahler. The stream order models developed by Horton and revised by Strahler are shown to have a fractal structure and therefore to be scale invariant. In addition, Sagar references Shreve's 1967 paper but Shreve's iconoclastic article (Shreve, 1966) from a year earlier demonstrated that "the law of stream numbers is indeed largely a consequence of random development of channel networks according to the laws of chance". Thus, by and of themselves, these "laws" yield little geomorphological insight. Scaling Laws are the focus of Chapter 6 (and also Chapter 7) but these too have been shown to have little explanatory power unless they are supported by other lines of evidence (see the literature reviewed in Waters, 2013). Sagar does an excellent job of reviewing research from the early days right up until the most recent contributions including his own extensive oeuvre and thus it was pleasant to see both Mike Kirkby and Adrian Scheidegger's work being cited (even if the Scheidegger reference has a few errors). References to the work of Mark Melton and Richard Chorley on morphological systems are, unfortunately, conspicuous by their absence. Particularly, innovative is the discussion of spatial-temporal dynamics in Chapter 9, where Sagar has made extensive and seminal contributions. It would have been reassuring to see an in depth account of the limitations of these approaches, especially the concepts of equifinality, or convergence, where different system trajectories may result in the same end state or the converse of this, multifinality or divergence, where the same initial conditions can result in a variety of end states (Skyttner, 2005, p.54). The methodologies introduced here are illustrated with applications to sand dune avalanches and flood water dynamics. The final chapters of the book discuss Spatial Relationships and Spatial Reasoning (Chapter 10), Derivation of Spatially Significant Zones from a Cluster (Chapter 11), Directional Spatial Relationships (Chapter 12), the intriguing concept of Between Space (Chapter 13) and Spatial Interpolation (Chapter 14). As these chapters cite the work of Mike Batty, Mike Goodchild, Bob McMaster and Alan Wilson, among others, they are likely to be of considerable interest to the community of human geographers. A small quibble: Sagar provides a list of symbols and notations, three pages long, but no such summary of the acronyms used in the book. My overall assessment is that this book is a truly remarkable contribution that is likely to make a significant impact in the GISci community far beyond its primary target audience of geomorphologists. Mathematical Morphology in Geomorphology and GISci is also a celebration of the remarkably innovative contributions of Daya Sagar over the last two decades.

References
Shreve, R. L. 1966. Statistical Law of Stream Numbers. The Journal of Geology, 74 (1), 17-37.
Skyttner, L. 2005. General Systems Theory: Ideas and Applications (Second Edition). World Scientific Publishing, Singapore.
Waters, N.M. 2009. Representing Surfaces in the Natural Environment: Implications for Research and Geographical Education. Ch. 3, pp. 21-39, in Mount, N. J., Harvey, G. L., Aplin, P. and Priestnall, G., Eds., Representing, Modeling and Visualizing the Natural Environment: Innovations in GIS 13, CRC Press, Florida.
Waters, N. 2013. Social Network Analysis. In Fischer M.M., Nijkamp P. (Eds) Handbook of Regional Science, Ch. 38, pp. 725-740. Springer: Heidelberg, New York, Dordrecht, London.
—Nigel Waters, *Geomatica*, v. 67, no. 4, p. 283-284, 2013

"As hydrologists, we are permanently confronted with problems where the geometrical vision of realty is of paramount importance for quantifying the flow. This is the case, for instance, of river networks, when their geometry is characterised by a fractal dimension, as well as in the case where the estimates of the contaminant concentration in a river water has to be made using Random Functions on a non-Euclidian graph with successive branching. Mathematical morphology tools are required to describe these graphs and to explain why, for instance, the spreading of infectious diseases, like cholera, differs between two different river systems, due to their geometrical properties. The automatic extraction of these river networks from Digital Elevation Models, or those of other surface-water bodies, is also a great challenge. Similarly, for porous media, when the flow is analysed at the pore scale, the governing equations are those of Navier-Stokes, and not Darcy's law, which only applies at the macroscopic scale. With modern tools, e.g. X-ray tomography, 3-D images of the pore space can be obtained, which need to be described by morphological tools to extract from these images the relevant microscopic properties that govern the flow, at both the pore scale and the macroscopic scale. For all these problems, the book Mathematical Morphology in Geomorphology and GISci by Professor Daya Sagar is invaluable. All the basic concepts of mathematical morphology, as originally defined by Matheron and Serra in the 1970s and later extended by many authors, are clearly presented with many practical examples of how to use them. As Professor Sagar has himself largely contributed to the modern theory of geomorphology, his book is rich in new concepts and methods. Hydrologists will be happy to find that many of the examples given in the book deal with rivers, water bodies, and the morphology of drainage basins."
—**Ghislain de Marsily**, Membre French Académie des Sciences, Université Paris 6, France.

I am sure that this very dense and useful work will appeal to geomorphologists, structural geologists and geographers open to new research ideas and approaches. They will find in this book a rich source of inspiration for their own research that, I expect, will foster their desire to deepen their knowledge of mathematical morphology. As a mathematical morphologist myself, I found themany case studies presented stimulating; they have aroused my thinking on morphological tools and approaches that would further refine the solutions proposed. As such, this book can also be considered as an efficient instrument of dialogue, a bridge between image processing and geosciences, giving rise to fruitful discussions and exchanges about emerging issues and possible solutions, thereby contributing to disseminate mathematical morphology. Thanks to Daya Sagar!
—Serge Beucher, Center for Mathematical Morphology, Mines ParisTech, Paris, France, *Mathematical Geosciences*, DOI 10.1007/s11004-014-9569-3, 2014

What do Mathematical Geoscientists Do? I've commented on this issue before, but it remains a valid issue. Many are engaged in "geostatistical" applications. At the international meeting of the IAMG in 2009 held at Stanford, most of the presentations involved geostatistics. However looking back on my own career, involving successive generations of students in my group at Stanford, we focused mostly on simulating sedimentary geological processes. Some thought we were crazy, but others applauded. This went on for 35 years, from 1964 until 1999. So, there are other fields of application, and in fact many different fields. Today in the hinterlands, there are some mathematical geoscientists doing very original work involving applications that we'd barely thought about earlier. I'll mention one of today's pioneers, whose focus is on mathematical morphology of geological features, Daya Sagar of the Indian Statistical Institute at the Bangalore Centre. Notably he's been at it for two decades and has published a lot, including a seminal 546-page book in 2013 entitled "Mathematical Morphology in Geomorphology and GISci" that spans much of the field. Let's face it, the shapes or forms of geological objects are tantalizing, and some can be astoundingly complex. Landscapes, for example, often exhibit complex forms. Trying to describe their shapes alone can be challenging, but the greater challenge is to explain the processes and morphological forms that affect each other. Everyday features, such as stream meanders on broad floodplains, or lakes on floodplains with short lives, may be common, but they are not simple to categorize or analyze. All the while we're dealing with interdependencies between features and processes. Interdependencies are invariably accompanied by complex cyclic and chaotic behavior. So do you still want to make predictions? Take heart, though, because there are some new tools to help you, and that's where Daya's work is relevant.
—John W Harbaugh, Stanford University, IAMG Newsletter, No. 89, p. 5, 2014.