

## SUSTAINABILITY SCIENCE

Sustainable development is becoming the guiding principle for the 21st century. It is about quality of life: how to develop it and how to sustain it within planetary boundaries. 'Sustainability science' has emerged recently as a new academic discipline and is a growing area of both research and teaching. Sustainability science seeks to:

- advance basic understanding of the dynamics of human-environment systems and forge bridges between the natural and social sciences and between science and policy;
- appreciate the variety of perspectives on sustainable development and the variety of contexts for its design, implementation, and evaluation in particular situations.

Bert J. M. de Vries has taught a course on sustainability science at Utrecht University for many years, in connection to his research at the Netherlands Environmental Assessment Agency (PBL). This textbook is based on that course. The contents have been rigorously class-tested by his students. The book provides a historical introduction into patterns of past (un)sustainable development and into the emergence of the notion of sustainable development. It systematically surveys the key concepts, models and findings of the various scientific disciplines with respect to the major sustainability issues: energy, nature, agro-food systems, renewable and non-renewable resource systems and economic growth. System analysis and modelling are introduced and used as integrating tools. Stories and worldviews are used throughout the text to connect the quantitative and the qualitative and to offer the reader an understanding of relevant trends and events in context. The reader is explicitly invited to engage at a personal level into the interpretation of what sustainable development means and what implications this has for ideas and actions.

*Sustainability Science* is an ideal textbook for advanced undergraduate- and graduate-level courses in sustainable development, environmental science and policy, ecology, conservation, natural resources and geopolitics.

Bert J. M. de Vries is co-founder of the Institute for Energy and Environment (IVEM) at the University of Groningen in the Netherlands, where he received his Ph.D. on sustainable resource use. Since 1990, he has been a senior scientist at the Netherlands Environmental Assessment Agency (PBL, formerly MNP and RIVM). He has been actively involved in modelling and scenario construction for the Intergovernmental Panel on Climate Change (IPCC). Since 2003, he has also been a Professor of Global Change and Energy at Utrecht University in the Netherlands. His research expertise and publications are in resource and energy analysis, modelling and policy; climate and global change modelling; and complex systems modelling for sustainable development. He has co-edited several books, including *Perspectives on Global Change: The TARGETS Approach* (Cambridge University Press, 1997) and *Mappae Mundi: Humans and Their Habitats in a Long-Term Socio-Ecological Perspective* (2002).

## Advance Praise for *Sustainability Science*

“Achieving some sort of sustainability will be THE focus of global societies in the 21st century. To be successful, our leaders will need a perspective of centuries, the full breadth of scientific insights, system thinking skills, great cultural sensitivity and an awareness of spiritual values. All of these are offered in this wonderful, unique text, which will be useful for decades.”

– *Dennis Meadows, co-author of The Limits to Growth*

“This textbook is one of the first truly all-encompassing introductions to sustainability science. It is methodical, clearly written and well-illustrated, truly a pleasure to handle and to read. It sets a standard for the discipline and solidly educates the generation of students that will most directly have to deal with the challenges of creating a sustainable Earth system.”

– *Sander van der Leeuw, Dean, School of Sustainability, Arizona State University*

“In this important new book Bert de Vries has adopted a systems approach to examining all the issues that collectively amount to the determinants of sustainability. It is an excellent, comprehensive and up-to-date text dealing with not only the underlying biophysical science but also human behaviour. His use of interesting examples throughout makes it both instructive and enjoyable to read. I highly recommend it.”

– *Brian Walker, CSIRO Ecosystem Sciences, Australia*

“Bert de Vries’ *Sustainability Science* is particularly welcome as it breaks ground in a new field, which so far lacks a proper systematic treatment. No wonder! The challenge is overwhelming: the book covers a series of disciplines and fields – geography, social and economic sciences, physics, chemistry and biology – using a systems description and system dynamics as the main tool. De Vries not only succeeds in this overwhelming task but spices up the text with multiple excursions into history, philosophy, literature, not to forget the key issue of ethics. Justice and how we would like a future world to look is always present. Bert’s book is impressive, rich and inspiring.”

– *Lars Rydén, Centre for Sustainable Development, Uppsala University*

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**Bert J. M. de Vries**  
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*“In bytsje minder as men lêst,  
Dat bikomt jin fierwei ’t bêst.”  
(A little bit less than you crave for,  
Makes you enjoy so much more.)  
Fries spreekwoord*

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## Preface

This book is the outcome of eight years of teaching the course Sustainability Science for students of the M.Sc. in Sustainable Development at Utrecht University. Its aim is to give a broad overview of what the sciences have to say about sustainable development. To this purpose, it offers a mixture of concepts, theories, models and facts and an invitation to the student to become a critical, independent thinker and to act accordingly.

The book can be used at the B.Sc. level as part of an introductory course or at the M.Sc. level as context for other courses and M.Sc. theses. For most chapters, a high school or college background should be sufficient, but some capacity for abstract thinking is needed. As an introduction into the concept of sustainability and sustainable development issues, it is useful for people in NGOs, government agencies and business who are interested in framing the discourse from multiple perspectives and different scientific disciplines. It can help them to make better decisions for life on a finite planet.

The content is based on three personal convictions. The first one is that humanity faces a transition period in which many ideas, habits and expectations will be challenged and scientists should, therefore, offer an integrated perspective on how developments are connected and may unfold. I follow others in using the term *sustainability science* to summarise this effort. The second conviction is that all scientific disciplines can and should contribute to the content of sustainability science. The conceptualisation of sustainable development as a guiding principle for the 21st century is still fragmented, and this should change. We need a new science, one that uncovers the unity of science and mobilises understanding and offers context. One that uses the novel ways to access information (Internet, Wikipedia, etc.) and to engage in the real world (stories, simulation games, etc.). A third conviction is that sustainable development can best be defined in terms of *quality of life* and that the pluralism in people's values and ideas about what quality of life is and in their circumstances should be acknowledged explicitly. It implies the framing of sustainable development as a global challenge within local diversity, capacity and contingency.

How to realise this ambitious goal is not self-evident. The first part of the challenge is to find observations, concepts, theories and models that are relevant in context. I first introduce system dynamics and influence diagrams and simulation models as an inherently integrating language and toolbox. Next, I summarise history

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insofar as it is relevant for understanding sustainable development: rise and decline of past civilisations, the transition to the industrial era and the emergence of the idea of sustainable development. Subsequently, I introduce worldviews, as combinations of values and beliefs, in order to communicate and appreciate the diversity in the notions of sustainable development and quality of life. I offer epistemological reflections on the nature of scientific knowledge in order to appreciate the inherent complexity and uncertainty of the issues being dealt with. Some basic natural science, notably on energy, is introduced in [Chapter 7](#).

In the second part of the book, I discuss the subsystems in which the concerns about (un)sustainable development are most pressing: natural ecosystems, agro-food systems, renewable and non-renewable resources and the economy-technology system. Each chapter covers what I consider important concepts, theories and models and their link with the observations in the real world. Each chapter has a natural connection with specific scientific disciplines, but ecology and geography are core disciplines. There are a few stories in each chapter to illustrate and complement the theory and the models and invite the student to engage with real-world experiences and situations. At the end of each chapter, five statements about the subsystem are offered to the reader in order to practice worldview pluralism. A few quotes are given to provoke ‘out-of-the-box’ thinking.

There are many different angles from which one can look at development, quality of life and sustainability. Moreover, the flood of data, theories and models keeps growing. Therefore, I can and do claim neither completeness nor representativeness. No doubt, the treatment of some topics is biased because I was trained in physics and chemistry and because I know certain persons and books and do not know others. I am aware that the treatment of some topics is incomplete or inadequate. Ethics, psychology, political science and subdisciplines in geography and economics, for instance, remain underexposed. Besides my limited knowledge, it reflects the inherent complexity of these disciplines and their still limited input in the sustainability discourse. Also, engineering details and legal aspects are hardly addressed. As to the narratives, I do not yet offer a balanced mix of stories. In particular, stories about the many social, economic and technological initiatives and innovations for a more sustainable world are missing. I hope that the book is a start for a more comprehensive, web-based ‘atlas for a sustainable world’, in which the latest scientific insights merge with relevant stories from all over the world and, together, point at the right actions. The website [www.sustainabilityscience.eu](http://www.sustainabilityscience.eu) is a first, simple start towards this goal.

This book could, of course, only be written by building on the thoughts, feelings and intuitions of many other people. Some of them are voices from a distant past or from people I never met, but much of it is easily traced. My promoter Jan Kommandeur offered the inspiration and courage that helped me to follow my own path. With my colleagues at the University of Groningen, I spent many years in the 1970s and 1980s in an atmosphere of great intellectual curiosity and freedom. In those years, I also joined the Balaton Group, founded by Donella and Dennis Meadows. Ever since, the annual meetings have been a source of inspiration, friendship and joy. A considerable part of the ideas in this book have taken shape during exchanges with Balaton Group members. Donella Meadows taught me the virtue of combining clear systems thinking and compassionate engagement. From Dennis



Meadows, I learned the usefulness and fun of communicating insights in the form of games. Aromar Revi nurtured my search for cosmic dimension and wisdom. I refrain from mentioning the many other members of the group – but they know.

In the 1990s, I had the privilege to work in a rather unique group of Global Change Modelling pioneers: the TARGETS and IMAGE teams at RIVM (later MNP and still later PBL – the English name turned out to be more sustainable: Netherlands Environmental Assessment Agency). I thank Klaas van Egmond and Fred Langeweg for the opportunities to follow uncharted paths, and the many colleagues for the instructive and pleasant collaboration. Another source of inspiration and insight were the meetings and discussions as part of writing the book *Map-pae Mundi*, with Joop Goudsblom, on the 250th anniversary of the Hollandsche Maatschappij der Wetenschappen. Since 2003, I occupy for one and later two days a week the chair Global Change and Energy at the Copernicus Institute for Sustainable Development and Innovation at Utrecht University. The chair is financed by PBL, and I am most grateful for the permission I got to spend time on the teaching and writing that has led to this book.

As to the actual writing of the book, I received useful and constructive input from many people: Hans Deuss, Tom Fiddaman, Peter Janssen, Eric Lambin, Sander van der Leeuw, Erik Lysen, Evert Nieuwlaar, Martin Patel, Charles Redman, Max Rietkerk, Lars Ryden, Mark Sanders, Isak Stoddard, Yoshi Wada and Bob Wilkinson. I would also like to acknowledge a few persons in particular. The constructive and humorous criticisms of Jodi de Greef on anything I wrote about complexity and sustainability have protected me from an overdose of sincerity. The chapter on worldviews got a major boost from the inspiring discussions with Klaas van Egmond, my colleague at Utrecht University since 2008. The cooperation with Markus Brede since 2006 brought an intellectual depth to parts of the book that would otherwise have been absent. Cristina Apetrei has been of tremendous help with comments and layout, and her practicality and determination kept me afloat in times of despair. My brother Joop gave with great precision the right books at the right moment, my son Tom applied his management skills for me to figure out what the message of the book is and my daughter Marieke assisted with cover design. I owe much inspiration to the silence and darkness, the skies and clouds, and the mountains, trees and humans of the Vallespir. Finalement, Annelize, sans toi j'avais eu ni le courage ni l'espace de persévérer dans un monde où, comme Proust l'a dit, 'les forts, . . . ont seuls cette douceur que le vulgaire prend pour de la faiblesse'.

I suffer from the injustice and violence in the world, the destructiveness of the relentless pursuit of 'stuff', the lack of awareness among large numbers of people and the cynicism and hypocrisy among many members of the powerful and wealthy. But I also discern and enjoy the germs of rejuvenation, the search for meaning, the genuine compassion that can be seen all over the world. I am grateful that I had the opportunity to work on this book. I am grateful to share with my students and others what I have learned up to now about the road forward.