BOOK REVIEW

Mathematics for Sustainability

Reviewed by Eric Marland

Mathematics for Sustainability
by John Roe, Russ deForest, and Sara Jamshidi
Springer, 2018, 490 pages, ISBN 978-3-319-76659-1

"For it seems that these are darker days
Than any others that we've seen
Oh, how we wished that we weren't wide awake
And this was all some kind of dream"
Josh Ritter, from *All Some Kind of Dream* [1]

One of the prevailing challenges of our time is to protect the living Earth from the damage we have caused, to reduce the rate of human-caused change, and to build a healthier ecosystem to live in, for everyone. Around the globe much progress has been made, but we are still a long way from where we need to be. We are not lacking in knowledge or technology, just implementation. To move forward, we need a better educated, interested, and engaged public.

John Roe, Russ deForest, and Sara Jamshidi have created an engaging text aimed at bringing a more informed public to the decision-making table. Aimed at a general audience, the text guides us through understanding complex data, analyzing relationships between systems, and making decisions while incorporating the role of risk and the inevitable uncertainty of measurement and prediction.

For a text with Sustainability in the title, it is essential to define what is meant by *sustainability*. There is some debate over exactly what sustainability means, but the authors of *Mathematics for Sustainability* settle on the 1987 definition of the Brundtland Report.

> *"Sustainability is the ability of a social, economic, or ecological system to meet the needs of the present generation without compromising the ability of future generations to meet their own needs."* [3]

I am not sure I completely agree with the definition (and I wish they had put it in the main part of the text rather than in the note to the student—make sure you cover and discuss this when you use the text) but I think that is ok. Even if we don't agree entirely, we have to pick a common definition to make sure we share the same conversation. Too much confusion comes from mismatched definitions. If we decide to use a different definition later that is fine because what we mean by sustainability may also change over time, perhaps even contradicting an earlier version. As with other definitions and assumptions, we also necessarily define our terminology to clearly delineate the scope of the problems we hope to address.

There are other notable definitions of sustainability, similar in many ways, but different in details (for example, see the statements from the US EPA [5] and my own university [6] to see the similarity). The United Nations pushes farther by identifying 17 Sustainable Development Goals [4]. Adopted in 2015, it "provides a shared blueprint for peace and prosperity for people and the planet." These goals include such topics as Poverty, Education, Gender Equality, Clean Water, Sustainable Cities, and Climate Action. While the Brundtland definition is conveniently vague in order to allow general support, the UN definition provides a specificity and clarity that prevents any misunderstanding. It makes explicit the need to include a number of related areas that are frequently dissociated from sustainability. This reminds us of the interconnectivity of many aspects of moving toward a sustainable world. I would have preferred a more explicit definition like this, but the authors of *Mathematics for Sustainability* choose to focus in on a smaller scale. Some contemplation or discussion on the different perspectives of sustainability might be a worthwhile activity to those using this book.

Eric Marland is a professor and chair of the Department of Mathematical Sciences at Appalachian State University. His email address is `marlandes@appstate.edu`.

Communicated by Notices *Book Review Editor Stephan Ramon Garcia.*

DOI: https://dx.doi.org/10.1090/noti2176

In addition to the global importance of sustainability, students today seem ever more aware and interested in social issues, personal responsibility, and the changing climate. They want access to the best information and want to get involved. At my own university, students voted to self-impose an extra fee to support renewable energy initiatives, and not by a small margin [7]. The students have pushed for a net-zero campus and waste-free events. The students are ready to take on the world, but they don't always have the tools to take advantage of their passion. In a recent vote to become a net-zero campus, the student government association failed to include a description of what it means to be net-zero.

As a classroom exercise this past spring, I asked my modeling class to define what it means to be net-zero as a campus and come up with a formula, a metric, that would allow us to measure our progress toward that goal. The students quickly discovered that the system boundaries are challenging to define. Do you only count electricity production on campus? Do you include housing? Do you include off-campus housing? If you don't include off-campus housing, one way to make strong progress toward becoming net-zero would be to reduce on-campus housing, but that is perhaps not the intent. The students needed more information and more tools to make the full assessment and a better understanding of what data might be available.

When students are asking for, pleading for, more information and action on such an important issue, we need to do our part to give them both the right information and the tools to critically evaluate that information.

The involvement of mathematics in the pursuit of sustainability is much like the role of mathematics elsewhere. It is ubiquitous and foundational, essential to any quantification, prediction, or deeper understanding. In putting together a text outlining mathematics for sustainability, there are at least as many choices as there are for defining sustainability itself. In addition, focusing on a particular audience puts restrictions on what mathematics can be assumed and on what mathematics can be introduced. Inevitably, someone's favorite topic will be skipped or treated with only a light touch. Necessarily, the level of mathematics is determined bijectively with the intended audience. A good author keeps the level in mind throughout the text.

In *Mathematics for Sustainability* John Roe, Russ deForest, and Sara Jamshidi have put together a text aimed at a general audience, keeping the prerequisite hurdles to a minimum and remaining consistent through to the end. As outlined in the beginning of the text, the target audience is students in a general education course in quantitative literacy. This would also be a great 1st year seminar course. Such classes are taught at many colleges and universities with widely varying purposes and directions. Some of these courses make attempts at surveying a broad swath of topics to provide insight into the broader scope of mathematics. Some of these courses focus on the practical mathematics of everyday citizenship by covering consumer statistics and basic financial mathematics. Both of these approaches have their merits. *Mathematics for Sustainability* uses another approach; take a topic of great relevance and interest and present it in a cohesive and comprehensive fashion (using mathematics that is accessible).

Engaging students in a quantitative literacy course is a challenge. We used to require students to use a standard college algebra course to satisfy this requirement and they frequently lost interest quickly. While the students in a liberal arts math course may not have the strongest mathematics background or may not have retained it, these students have likely seen the material in a college algebra course before. The typical four years of mathematics requirements in high school almost guarantee it. Somehow, we convinced ourselves that one additional exposure, with a sufficiently awesome instructor, would be enough to excite students about the wonders of algebraic manipulation and perhaps some witty word problems.

The mistake of this approach is the basis for the Dana Center's Math Pathways project (based at the University of Texas at Austin) [8]. The Dana Center approach is not the only strategy for pushing toward a more appropriate and engaging mathematical experience, but the motivations are similar to other initiatives. We need to find a way to engage students in useful studies of mathematics. But it goes well beyond the idea of using a few well-placed examples in our course materials and beyond the idea of "real world problems." The problems need to be real, but the mathematics also needs to be appropriate to address the problems, not just a made-up problem using some real data. The problems need to be able to be addressed fully with the mathematics and this presents a challenge for the instructor. How can very complex problems be addressed without using the latest innovative methods? How can relatively simple mathematics be used to confront important problems without over-simplifying or marginalizing? The authors of *Mathematics for Sustainability* have done this.

Actually, I think the authors have achieved something even better than finding a way to connect real problems to relevant, appropriate, and accessible mathematics. Roe, deForest, and Jamshidi have presented an approach to sustainability that allows the students to generalize to many similar problems. They learn a basic strategy for studying typical issues in sustainability that can be applied more broadly in problem solving for decision making in general. The skills needed are basic and fundamental mathematics that is accessible to students without a strong background in mathematics.

I will not claim that I agree with everything in the text. I do find that a dynamical systems approach to modeling appeals to me more. I like the conceptual idea that quantities in the future can be determined from previous quantities with an addition of some knowledge of how change occurs (stocks and flows). I feel that the dynamical systems approach more easily meshes with the transition to calculus-based ideas for understanding change and accumulation than matching input and output flows. I typically teach students about interest rates and loans in the same dynamical systems mode. However, I also recognize that few of the students in a class that uses this text are headed for calculus and higher-level maths. I will also note that the difference between a dynamic approach and the flux approach used in the text is more a personal perspective preference and some faculty may prefer the approach used in the text. The mathematics is still sound and may even lower the entrance requirements a bit.

However, the approach of the text is fascinating and I would love to teach from it. The overall format is unusual in that it takes the reader for a ride through the process of collecting, critiquing, and evaluating various pieces of information in order to make a decision. The development is slow and steady, integrating the basic stages of decision making with the appropriate mathematics until enough information is blended together in careful consideration to make a decision. Surprisingly, and wonderfully, it does this without being overly judgmental on what decision should be reached. Embraced as independent adults, the students are given the freedom (and responsibility) to make their own conclusions.

The first few chapters introduce terminology and scope very clearly to make sure the reader understands what the goals are—and what they are not. The book makes the case, albeit indirectly, for an unbiased presentation of information that allows the reader to draw their own conclusions. The authors do not turn "preachy," but rely on the data and their methodical analysis to make the case. Integrated into the first few chapters are some basic calculations and manipulations that are based on the beginning assumptions, easing our way into the mathematics while clearly laying out the shared perspective.

The last two chapters of Section 1 of the text on "Risking" and "Deciding" are particularly of interest to me since it is tempting in the face of uncertainty to delay making a decision. This text reinforces the idea that a delay is also a decision and that we must make crucial decisions of great import, even if there is some level of uncertainty. Evaluating risks and uncertainty in order to make decisions is not a new concept, but perhaps new in this arena [9]. Actuaries earn their livelihood from making judgments like this and understanding the basics of valuing uncertainty and risk is essential to pursuing a sustainable future.

In making decisions, it is wise to consider, "What if I am wrong?" What is the probability I am right and what are the potential consequences of being wrong? Sometimes we might find that the probabilities might be out-weighed by the dire nature of the consequences. Sometimes we make compromises in order to make any progress at all. In the case of the environment, ongoing discussions of tipping points make a challenging estimation process for the consequences of making a mistake [10]. We are forced to confront the idea that some decisions can be revisited while others cannot. The necessity of making a decision remains.

Following this extensive development of a process for critiquing, analyzing, and decision making in Section 1, there is another section of the text on detailed case studies. After having built up the basic knowledge of problem solving in the context of sustainability, Section 2 guides the reader through a series of test cases that show how the methodology can be used in specific cases. While a reasonable course could be constructed without these case studies, a course that includes them would be a much richer experience. By the end of the text, students can then move out into their own disciplines and their communities and help others make researched, analyzed, assessed, and careful decisions.

With addressing climate change there will certainly need to be both elements of mitigating the damage we have caused and adapting to the changes that are already immanent. How we strike the balance between the two is up to us and we face risks of failure whatever the decisions. The success of any efforts we put forth will remain undetermined for many years. However, we also have to think about the consequences of being wrong about our strategies. What if we don't put enough into mitigation? What if we put in more resources than were really needed? Roe, deForest, and Jamshidi provide a template for making these decisions and help us to see a path forward.

While not everyone who reads this book will be tasked with making the crucial decisions ahead of us, developing the process for understanding the science and the trade-offs between different options can help gain support for our continued efforts to become more sustainable.

So while Josh Ritter sees darker days [1], *Mathematics for Sustainability* offers students a path to gain a better understanding of complex systems and to make well-informed decisions. With more efforts like this, perhaps a different and sustainable dream can come true. I look forward to the chance to share this text with my students and to see what lies ahead.

References

[1] Josh Ritter, "All Some Kind of Dream," on *Fever Breaks*, Pytheas Recordings, 2019

[2] A. Baird, S. Nikbakht, E. Marland, K. Palmer, *Revealing the mathematics of sustainability*, in Shifting Contexts, Stable Core: Advancing Quantitative Literacy in Higher Education, MAA Press 2019, ISBN: 9781614443247.

[3] WCED (United Nations World Commission on Environment and Development), *Our Common Future* (Brundtland Report), Oxford University Press, Oxford, 1987. `www.un-documents.net/wced-ocf.htm`. Accessed July 25, 2019.

[4] United Nations, *Sustainable Development Goals*. `https://sustainabledevelopment.un.org`. Accessed July 25, 2019.

[5] US EPA, *Sustainability*. https://www.epa.gov/sustainability/learn-about-sustainability#what. Accessed July 25, 2019.

[6] Appalachian State University, *University Sustainability*. https://sustain.appstate.edu. Accessed July 25, 2019.

[7] Appalachian State University, *Renewable Energy Initiative*. https://rei.appstate.edu. Accessed July 25, 2019.

[8] Charles A. Dana Center, University of Texas at Austin, *Dana Center Mathematics Pathways*. https://www.utdanacenter.org/our-work/higher-education/dana-center-mathematics-pathways. Accessed July 25, 2019.

[9] Michael O'Hare, Richard Plevin, and Derek Lemoine, *Policy should incorporate the cost of error and uncertainty in estimates of fuel carbon intensity*, SSRN Electronic J. (2010), DOI 10.2139/ssrn.1685328.

[10] Sandra van der Hel, Iina Hellsten, and Gerard Steen, *Tipping points and climate change: Metaphor between science and the media*, Environmental Communication **12** (2018), no. 5, 605–620, DOI 10.1080/17524032.2017.1410198.

Eric Marland

Credits

Author photo is courtesy of Appalachian State.