

A Step in the Right Direction: A Critical Review

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Systems Research for Agriculture: Innovative Solutions to Complex Challenges, by Laurie E. Drinkwater with Diana Friedman and Louise Buck. SARE Handbook Series 13. 2016.

My qualifications as a reviewer are as follows. The authors invited Elizabeth Henderson and me to submit initial recommendations to the project as it got under way around ten years ago. I became familiar with Laurie's holistic view of science when she invited me to participate in a graduate seminar devoted to a critical review of the literature of sustainability assessment. I am a long time student of systems ecology and the systems thinking revolution in science and some of its methods, which I have tried to apply in my farm design and in teaching ecological agriculture at an undergraduate level. As a governing council member of NESARE I advocated reserving a significant part of NESARE funding for farming systems research, which the council resisted, then flirted with briefly, funding two research projects. The authors of this manual used one of these, an expansion of an organic dairy research project at the University of New Hampshire, as a case study in the manual. I created and currently teach an online introductory course in systems thinking.

This manual is a welcome step in the direction of a revolution in the way not only agricultural science, but all science, is done. I will focus mainly on the parts of the manual devoted to elaboration of the systems paradigm and resulting research design considerations. A major focus of the manual is on the social organization of systems research, which I think is proper, because that is where many of the obstacles lie in the spread of the systems research paradigm. Because I have little experience with the challenges of collaborative, institutionalized research, I don't feel qualified to comment on those chapters except to say that they seem to address all the concerns that I am aware of.

The systems approach to doing science needs to be viewed as a true paradigm shift away from the reductionism dominant generally in academia and especially in agricultural science where it has penetrated relatively slowly. Hence some of the limitations I will point to in the manual are understandable as cautiousness in the face of institutional penalties for straying far from the reductionist party line. In my interactions with faculty and graduate students I have repeatedly experienced their hesitation to go public with statements which they sometimes offer privately.

A mere tool or a revolution?

The manual contrasts systems and reductionist science this way:

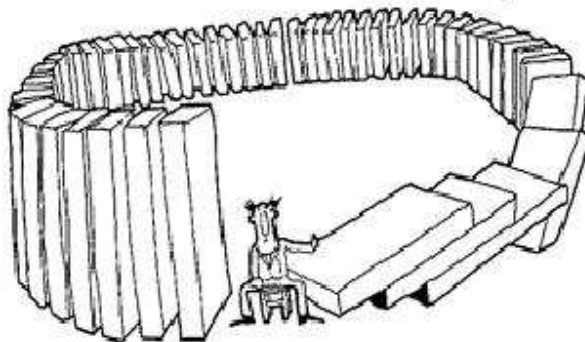
While reductionist science has a place in the research toolbox, systems-based research, and specifically interdisciplinary systems research (discussed further in chapter 2), provides an additional tool for better understanding real-world

complexity while emphasizing the connections between production systems and the associated environmental and social systems.

If the term "paradigm change" in the manual's title is to reflect what the systems revolution in science has come to represent, calling it merely "an additional tool" hardly captures the reality of the situation. Increasingly its practitioners regard the systems way of doing science as a true revolution in the sense that Thomas Kuhn famously introduced the phrase "paradigm shift" nearly 50 years ago in *The Structure of Scientific Revolutions*. That is, it is in an important sense replacing a previous way of doing science that has failed. Like all revolutions it is not a particularly peaceful one; vested interests in the scientific establishment have fought it from day one. It is important for scientists, and indeed all of us, to be aware of the stakes at issue.

In what way has reductionism failed? The reductive method itself has not failed - let me be clear on that. The failure is that the reductionist worldview willfully ignores the limitations of the method - its inability to explain the mostly nonlinear behaviors that arise in an obviously complex, connected world. Worse, its loyalist practitioners have defended it as the only way to do science, rejecting all other methods as not science. Moreover there is the strong pattern of failure of the technologies reductionist science has spawned, a failure hidden from society by cultural conditioning. By focusing on their immediate desired products, we have been taught to regard them as miracles of science, a long line of progress since the Enlightenment. When fully accounting for the negative ripple effects, often downstream in space and time, we can no longer give most of those technologies such high marks. As the unwanted consequences have accumulated, threatening not only modern civilization but the survival of our species and many others, even laymen lacking a systemic view of how things change over time are becoming aware of the damage. The reductionist worldview ignores a cardinal rule of systems science:

In complex systems, cause and effect are often distant in time and space



It should suffice to offer but one example, which should be familiar to any student of agroecology. Early in the 20th century the Haber-Bosch process made possible synthetic nitrogen fixation. Used immediately for the production of both fertilizer and explosives, it greatly magnified the effects of both warfare and the productivity of agriculture.

Synthetic nitrogen fertilizer alone is considered responsible for tripling the global human population, which now consumes 1.5-2 times the resources that the planet can sustainably provide¹. The consequences from agricultural use are multiple:

Immediate consequence: higher crop production and tripling of world population.

Medium term consequences:

- Soil microbe decimation, leading to:
 - Poor plant health
 - Increased pesticide use
- Increased pesticide use, leading to:
 - More soil food web decimation, imbalanced plant nutrition
 - Compacted soil
- Plant diet imbalance, leading to
 - Lower plant health
 - Declining nutritional value of food products
- Soil compaction, leading to
 - Poor plant and soil food web health
 - Increased energy expended in tillage

Long term consequences:

- Depletion of fossil energy, leading to:
 - Rising fertilizer costs
 - Failure of industrial agriculture
 - Declining world population



The famous folktale of the sorcerer's apprentice suggests a realistic view of the era of reductionist science: by exclusive use of the reductive method, modern science at the beck and call of high finance² has created ever more powerful technologies. Trumpeted to the public as a cornucopia of progress, these technologies initially appear true to promise.

But like apprentice magic, they often bring tragic consequences in time. And there is no sorcerer to return, break the spell, and return everything to normal.

The scientific community - as it begins to acknowledge that specialized knowledge is useless and even misleading without a way to gauge the consequences of decisions across broad interconnected wholes and much later in time – is adopting the paradigm and methods of systems thinking.

The question of boundaries

The manual introduces an important principle of systems science:

In agricultural systems research, spatial and temporal boundaries are determined by research goals, the structure of the underlying environment, socioeconomic and political structures and by land-use decisions made by farmers and farm communities.

This question of how to view boundaries is a critical distinction in systems thinking, and needs more emphasis and elaboration, again to counter the cultural conditioning of a worldview that has dominated for several centuries. The new worldview acknowledges the real world as an unbroken sea of connections, some weaker, some stronger. One of the obstacles to the new worldview that needs to be recognized is relics of the old lurking in our language. Because no discrete systems with impermeable boundaries exist in the real world, systems scientists have begun to avoid the noun 'system' due to its implied real boundaries, adopting labels like complexity science or systemic science instead. The distinction is not trivial. What is important is the boundary of inquiry, which properly resides only in the scientist's model. The model boundary is a process of discovery of the 'system of influence' that might explain the nonlinear behaviors that the scientist needs to understand. Thus the following statement in the manual is incorrect:

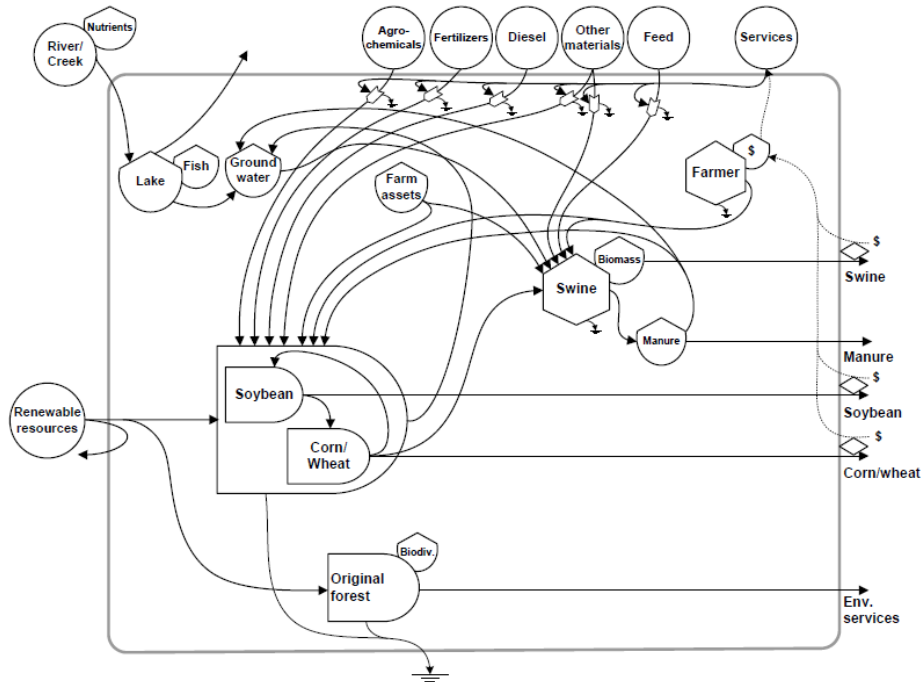
The goal of systems research is to develop knowledge about how a complex system functions as a whole. This goal, with the assumption that the interactions among components must be studied in order to understand the whole system, is the hallmark of systems thinking.

True, in the process the systems scientist acquires important knowledge of the functioning of wholes, but the ultimate goal of system research is to understand how behaviors of concern change over time, not study whole systems. Hence the systems scientist models problems, not whole systems. All science consists of model building; models in systems research are uniquely multivariate and require new methods.

What Methods?

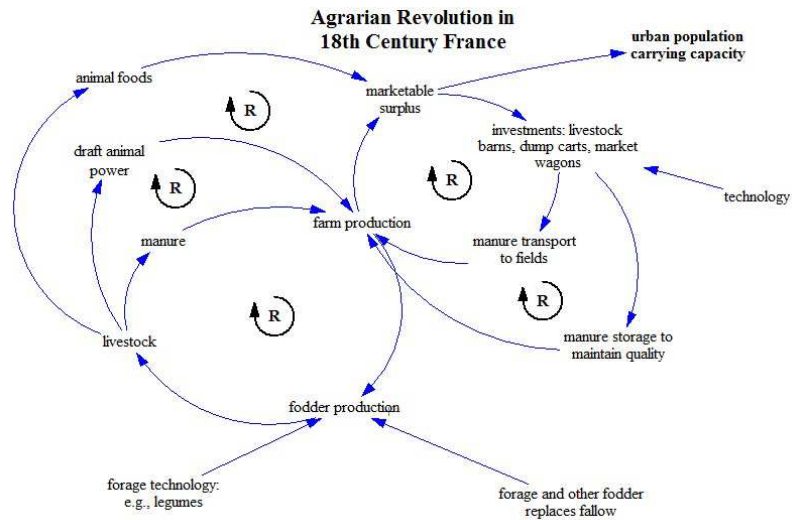
Agricultural systems research is properly both biological and socio-economic in nature. H. T. Odum expanded systems ecology into a general systems methodology, a framework

applicable to all complex systems³. In as much as agricultural systems research needs to encompass both the biological and sociological aspects of the field, Odum's work is an essential disciplinary framework for systems research and design and needs description at length in a research manual.



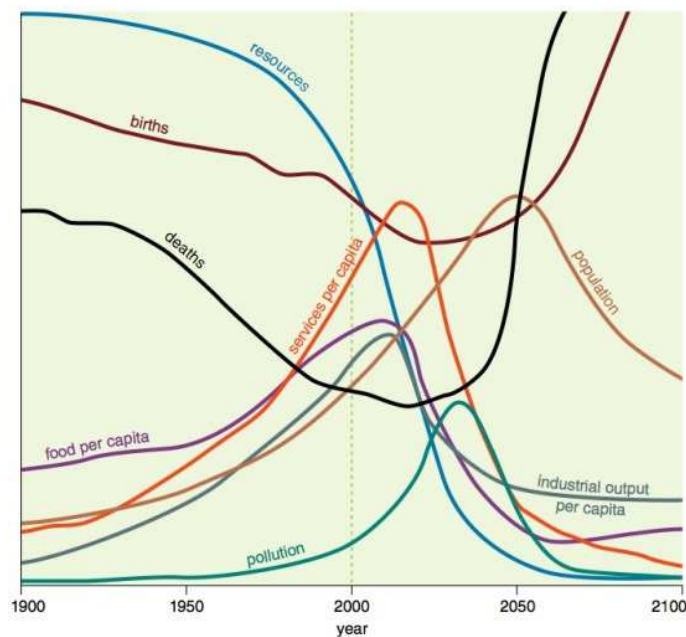
Odum pioneered energy (with an 'm') accounting, which is essential to the analysis of input costs and internal conversion costs in agricultural systems research and design. See for example [Odum's basic description](http://dieoff.org/page232.pdf) (<http://dieoff.org/page232.pdf>) of the method and its importance.⁴

Systems research methods are unique and need more discussion than this manual provides. Modeling of causal feedback structures to explain nonlinear behavior has become a hallmark of systems research. When quantified, computer simulation can test how well causal models explain how things change over time historically, and test scenarios of future change. This simple example of a causal structure provides insights into the leap in agricultural productivity in 18th century Europe, an emergent property of multiple interacting variables. It is a hypothesis that identifies positive/reinforcing feedbacks (R) responsible for the rapid increase of agricultural productivity over that century.



What kind of prediction?

A systems research manual needs to address the confusions and distortions that abound about the kind of prediction that is possible under the two research paradigms. The reductive method achieves accurate prediction under laboratory conditions, *Ceteris paribus* (all other things being equal), as the saying goes. However, it does this by ignoring what might happen in the form of ripple effects when the results of its science are applied in the world outside the laboratory. Systems science achieves a different kind of prediction more in the nature of probabilities. Simulation models of system dynamics, for example, unlike reductive research, can predict the shape of change as long as conditions hold true, but not exactly what will happen at a given point in time. The most well known example, the global Limits to Growth model⁵, demonstrates the probable dynamics that result from four interacting variables, but not in an exact time frame.



The Limits to Growth Project is a good example of resistance to a Kuhnian revolution in how science is done. It was met with a volley of attacks, mostly by economists. The criticisms of its system dynamics modeling method have since been exposed as trivial or untrue. As for its substance, the project simply applied to our species what any good ecologist knows – that a species population that overshoots the carrying capacity of its resource basis encounters limits to growth, which leads to erosion of carrying capacity and ultimately collapse of the population. This exposed the fallacy of one of the fundamental assumptions of mainstream economics. Just as Vatican flat-earthers reacted to Marco Polo's travels to China, for economists the conclusions of the Limits to Growth were heresy.

Because it can simulate probabilities under different policy scenarios, the system dynamics modeling showcased in the Limits to Growth World Model as a transdisciplinary mode of inquiry has proved itself over time and is now widely used in medicine and public health, business management, systems ecology, geopolitical strategy, and increasingly in others, even occasionally in agroecology.

Systems research and sustainability are indelibly linked

Sustainability in its proper ecological sense refers to the ability of populations to persist by holding resource consumption below carrying capacity. It is the structure of the elements that decides how sustainable they are as wholes. The most sustainable structure is one in which the kind of diversity and the way elements hang together and interact as wholes to obey nature's laws and maximize health of ecosystem processes. This means that a scientist who aims for sustainability in an individual farm practice fails to understand the systemic nature of sustainability. As this manual points out,

Sustainability is also considered an emergent property, because it emerges from the multiple social and physical interactions within the system (Chase and Grubinger, 2014; Lengnick, 2015).

A scientist can test a practice for how it *contributes* to the sustainability of a whole, but only in the context of a systemic research framework. Hence the need to focus on these wholes makes systems research essential to any investigation of, or design for, sustainability. As we know, because the self-organization of natural ecosystems has been time tested for several billion years, they are the best templates for sustainable design, in agricultural science or in any other field of study. Thus a manual needs to emphasize the importance of training and operational knowledge of ecosystems as a basis for systems research in agriculture.

In conclusion

The authors of the manual under review did their best under institutional constraints and a paucity of agricultural research to learn from that uses recent advances in systems research theory and techniques. What research of this kind did exist manifested little of

the progress in systems research that was occurring in other fields and in business and government. Hopefully their manual will stimulate agricultural scientists to gain the necessary skills, still rarely taught in agricultural schools but available in other disciplines. The one valiant attempt to teach the worldview and methods of system dynamics in Cornell's agricultural school got no institutional support and was funded privately by an alumnus.

¹ http://www.footprintnetwork.org/pt/index.php/GFN/page/living_planet_report_2014_facts/

² See my paper, **Reductionist Science and the Rise of Capitalism: Implications for a New Educational Program of Agricultural Science** (<http://karlnorth.com/?p=511>)

³ **Environment, Power, and Society for the Twenty-First Century: The Hierarchy of Energy** by Howard T. Odum (https://www.amazon.com/Environment-Power-Society-Twenty-First-Century/dp/0231128878/ref=sr_1_1?ie=UTF8&qid=1481415449&sr=8-1&keywords=Environment%2C+Power%2C+and+Society+for+the+Twenty-First+Century)

⁴ <https://en.wikipedia.org/wiki/Emergy>, <http://www.resilience.org/stories/2013-01-21/emergy-you-spelled-energy-wrong>

⁵ https://www.amazon.com/Limits-Growth-Donella-H-Meadows/dp/193149858X/ref=asap_bc?ie=UTF8