Post-Normal, Complex Science

"When issue-driven science occurs in the context of policy-making, 'typically facts are uncertain, values in dispute, stakes high and decisions urgent'" (Allen et al., 2003; Funtowicz and Ravetz 1998)

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Using Systems to Clean Up Messes: Complexity, global climate change and soil carbon cycling

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Making a Difference with Systems

My “realist underclothes” often show (Tim again). General theories of everything are cool, but I skim until I get to the part about how I can use them. Tim does the opposite.

Theory←---→ Application

“Narrative”←---→”Reality” and my MS thesis

Making a Difference with Systems

"The point of studying complexity is to make things simple" (Allen et al., 2005)

I want:
Framework->Mapping->Metrics->Results

Today:

- Brief outline of my paper and intro to my system (online)
- Discussion of a struggle

Using Systems

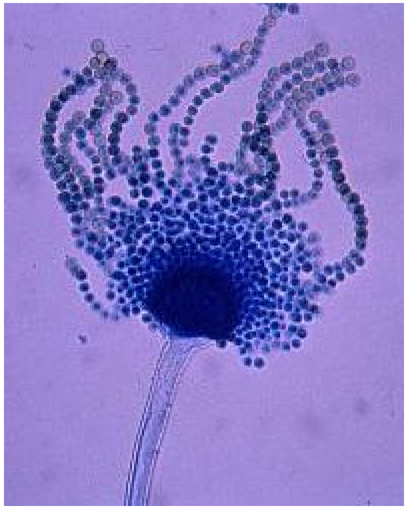
1. Start with a mess. Pick an important, fundable one that might involve a job one day.
2. Try to clean it up.
   In particular, try to model it using multivariate statistics, structural equations modeling, or other such tools
3. Fail

Soil Microbial Communities are Complex

In one gram of soil, approximately:

- Bacteria: 100,000,000 with a size of 0.5 to 1.5 µm
- Protozoa 10,000 that may graze on bacteria
- Actinomycetes: 100,000,000, a filamentous bacteria with a hyphal diameter between 0.5 and 2.0 µm,
- Fungi: 1,000,000, with a larger hyphal diameter of about 8.0

"In short, soil is incredibly, almost indescribably, rich with various forms of microbial life, with their respective enzymatic talents" (Balser et al., 2002)



Aspergillus flavus is a common soil microbe.

Importance

Even a slight change in decomposition rates can result in significant change to the global carbon cycle.

Pool of C stored, in 10^{15} g

VEGETATION 550
ATMOSPHERE 750
SOILS 2400 [top 1M about 1400]
FOSSIL FUEL 5000
OCEANS & LAKES 36,000
CARBONATE ROCKS 75,000,000

A change of total soil organic carbon of only 10% would equal all the anthropogenic CO2 emitted over the last 30 years (Kirschbaum, 2000)

Positive Feedback Loop?

Global climate change ->

↑increased soil respiration (CO_2) ->

↑ global climate change ->....

Positive Feedback Loop?

Wealth of research, few coherent conclusions

- Agree that soil microbial temperature response understanding is essential
- Agree that we don't have a consensus, and that web of interacting, scale-dependent factors is a central problem
- Don't agree on a solution

My question: Why can't we answer the question? What IS the web of interacting factors, and can we make them explicit?

Get a Good Mess

Soil microbes

Meaning of “species”?

Controls, drivers, factors influencing them are also comples (internal, external, etc. – no boundaries implied)

Global climate change
CO_2, Temperature, N deposition, salinity, etc.

Observers are human:
Scales
Values
Perspectives
Goals
Etc.

Tough to “observe” the system:
Teensy
Underground in a dense matrix we can’t see through

More Mess: Scales

The coarsest measure, the source/sink status of a system, can change at scales such as years, seasons, and even day vs. night.

Scales: Time, space, depth, temperature…

It is understood that scales control temperature response….But what are the scales, and what are the controls at which scales?

The“Right” Factors & Scales

Critical challenge:

- Selecting the salient factors that contribute to quantitative model = Framing the question = Bounding the system appropriately
- Consequences seen in the literature include
  - seemingly conflicting results
  - differing conclusions from the same data
  - well-conducted studies with unsatisfactory results

Paper Outline

- Introduction: The problem, the system and complexity

- Steps of SSM
(as modified for environmental applications by Allen and Hoekstra, 1992 and Giampietro, 2003)

- Conclusions

Step 1: Feeling the disequilibrium, recognizing that there is a problem even if it is not clearly expressed

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Step 2: Generate actively as many points of view for the system as possible

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Step 3: Explicit development of abstractions

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Step 4: Building conceptual models

Steps 1-2: Address the material system. Create a wide description of the situation and a "rich picture"

Steps 3-4: Create abstractions and models

Steps 5-8: Return to material system

Help from systems & hierarchy

- Complexity in this context means that “several levels of analysis are required for adequate descriptions” (Brown et al., 1989)
- One aim of complex systems theory is to take seriously the subjectivity and treat it with intellectual rigor.
- Need to organize the factors in a meaningful way.

Accessing Systems

"Making things more complicated does not help when dealing with complexity" (Giampietro, 2003)

Back to … Theory←---→ Application

Audience participation: Do you like the examples or the theory to come first when you're trying to learn something?

"Sending a space shuttle to Mars is complicated. Parenting is complex"
(Dr. Carpenter's definition of complexity for his ecosystem modeling class)

Gettin' Respect

Conference theme: "How can we as a community make systems concepts more **accessible** to decision makers and researchers in the larger global community?" (ISSS website)

I struggle with:

- Dual audience issues
- Dual paradigm issues
- Translating -> Meaning
- Audience participation: Raise your hand if part of what you do is translate Rosen.

Breathing Soils