Applying ecological economics and high and low gain towards a narrative of soil microbial resource shifts with global climate change

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What's the same when everything's different?

Focus on the bigger, theoretical, thermodynamic, epistemological issues with diverse material systems

For example, others not here today: Genya (environmental history), Keith (conservation on military lands), Cassandra (water quality).

Because of, not despite, others' ignorance of our particular system, the lab succeeds.

Overview

- The problem
- We need a narrative
- Quickie ecological economics and high/low gain
- Description of system – key points
- Mapping system as high-low gain using 12 hypotheses
- Using this to make a prediction

Global climate change and microbial resource shifts

Global climate change ->
??↑use of more complex substrates ->
↓ soil carbon storage ->
↑ global climate change… feedback cycle

Temperature-sensitivity of “recalcitrant” (more complex, humified) C in comparison to labile C is a key uncertainty in predicting positive feedback[5]

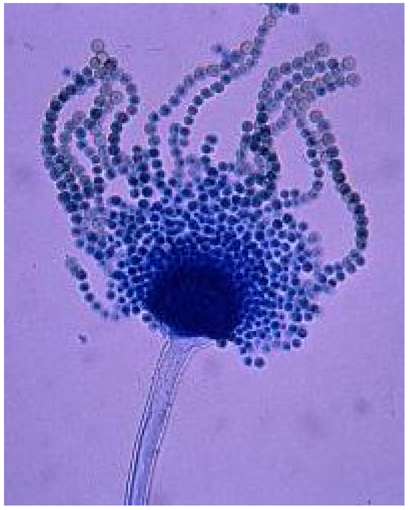
Wealth of studies with no coherent synthesis:
↓,↑,= in use of recalcitrant C

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.

We need a narrative

The literature mentions the need for a "theory" or "story":

"The problem is both with a lack of a 'theory' of respiration that explains how all the driving variables may interact, as well as in obtaining relevant data to test models based on [this] theory." [7]

We use narrative to rise above the local constraints of models, and ultimately to create and interpret them. [1]

Ecological economics and h/l gain

EROI: Energy return on investment= what you get / what you spent to get it

Energy opportunity cost: The diversion of energy from alternative activities to energy production

High-gain: High EROI, low opportunity cost.

Low-gain: Low EROI, expensive to use, organization required

Soil Microbial Fuels

	Labile/Active	Recalcitrant/Passive
Soil residence time (years)	1-2 Quickly depleted resource	500-5000
Source	Recent plant litter- sugars, starches, proteins	Humic acids, lignins, phenolic compounds -> chemically protected, often old, soil humus
% of soil organic matter	Not much	60-95% -> LOTS
Complexity	"Ready-made" Simple, monomeric. Predictible configuration for enzymatic attack	"Work to get it" Very complex, random in configuration, bonded with soil minerals

Microbial Fuel Users

	Labile/Active	**Recalcitrant/Passive**
Life strategies	"R-selection, zymogenous": high level of activity and rapid growth on easily utilizable substances -> intermittent activity and dormancy	"K-selection and L-selection;autochthonous , oligotrophic": low growth rate and activity continuous activity, storage capacity
Life cycles	fast generation times, rapid growth	Slow growth rates and generation times
Organisms	Sugar fungi, many bacterial species	"white rot" fungi, gm- rods, actinomycetes
Enzymes	Common, widely produced: Hydrolytic (β-glucosidase), both intra- and extra-cellular	Specialized, produced by restricted groups: Oxidative fungi and actinomycetes-> phenol oxidase and peroxidase, extracellular

What was the question?

Can useful narratives of microbial substrate resources shifts with global climate change be created based on ecological economics and high/low gain theories?

Ecological economics and h/l gain

List of 12 hypotheses related to high and low gain

"It may be that some of these hypotheses pertain to all living systems, whereas others are more restricted in their application." **[6]**

Map to High-Low Gain Hypotheses

	High-gain systems	**Low-gain systems**	**Labile**	**Humic**
1	Use steep energy gradient	Use shallow energy gradient	Easy to capture and access -> High EROI	Difficult to capture and access -> Low EROI
2	High-quality resource will likely initiate high-gain phase; steep gradient will drive high-gain expansion	Entering a low-gain phase subject to chance due to shallow gradient	Explosions in populations when becomes available	Environmental conditions drive activation of spores; chance arrival of users to location (-> large probing hyphae)
3	A new type of resource use	Expands an existing resource use	Pulsed availability	Continuous availability
4	Resources abundant where found (LOCALLY)	Resources scarce (LOCALLY)	See #5	SOM is only 6% (average globally) of soil

Combined Tainter et al., 2003 and Allen et al., 2001

Map to High-Low Gain Hypotheses

	High-gain systems	**Low-gain systems**	**Labile**	**Humic**
5	Local and concentrated	Extensive; exploitation expands across space	Surface soils, seasonal: Concentrated at right place and time	60-90% of SOM LOTS of it but dispersed
6	Dissipative and inefficient	More energy degradation, requiring higher efficiency	TBD. (?Vs #1?)	TBD
7	Minimal demands on system	High demands on systems	Easy enzyme synthesis	Costly enzyme synthesis, chance aquisition
8	Impressive in energy capture	Impressive in organization and structure	Little organization required	•Specialized extracellular enzymes •Morphology •Storage capacity •Often secondary metabolite producers

Map to High-Low Gain Hypotheses

	High-gain systems	**Low-gain systems**	**Labile**	**Humic**
9	Brief duration	Lasts significantly longer	Quickly depleted; fast-growing users	Long turnover times; slow growth users
10	New levels at top of hierarchy	New levels in middle of hierarchy	??internal	??
11	Self-organized by its history	Organized in reference to environment; by an external design element	Life cycle adapted to maximize use when available	Always present; Requires appropriate system state to use it
12	Manage through context or will self-repair	Manage by manipulating parts	→ Perturbation of labile users won't have large impact. **Humic use will be more sensitive to perturbations (temperature increase, other global climate changes) -> greater temperature sensitivity.**	

1. Produce energy economics models

Q: How does the substrate use under given conditions relate to: resources, capital, waste and production under high- and low-gain scenarios?

Strategy:

1. Put processes in ecological framework

- Substrate ->resources
- Existing biomass: maintenance -> capital
- Increasing machinery and biomass (enzymes, ribosomes): growth ->production
- Respiration -> waste
- Reproduction -> production

2. Frame issues in terms of trade-offs and high/low gain hypotheses

2. Produce complementary narratives and associated mechanisms

e.g. ↑ T -> Microbial stress->

↓ energy efficiencies (e.g. greater CO_2 waste)

↑organization (e.g. lipid resynthesis) -> ???

1. Labile substrate depletion…vs…
2. Acclimation

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