How to present Structural Equation Models?

Swiss SEM team

04.11.2021

Department of Evolutionary Biology and Environmental Sciences

University of Zurich

Exercise: Draw your idea

How would you draw your model output for others to reproduce and evaluate this model?

What can you expect to see out in nature?

Journal of Experimental Child Psychology 167 (2018) 93–116

Contents lists available at ScienceDirect

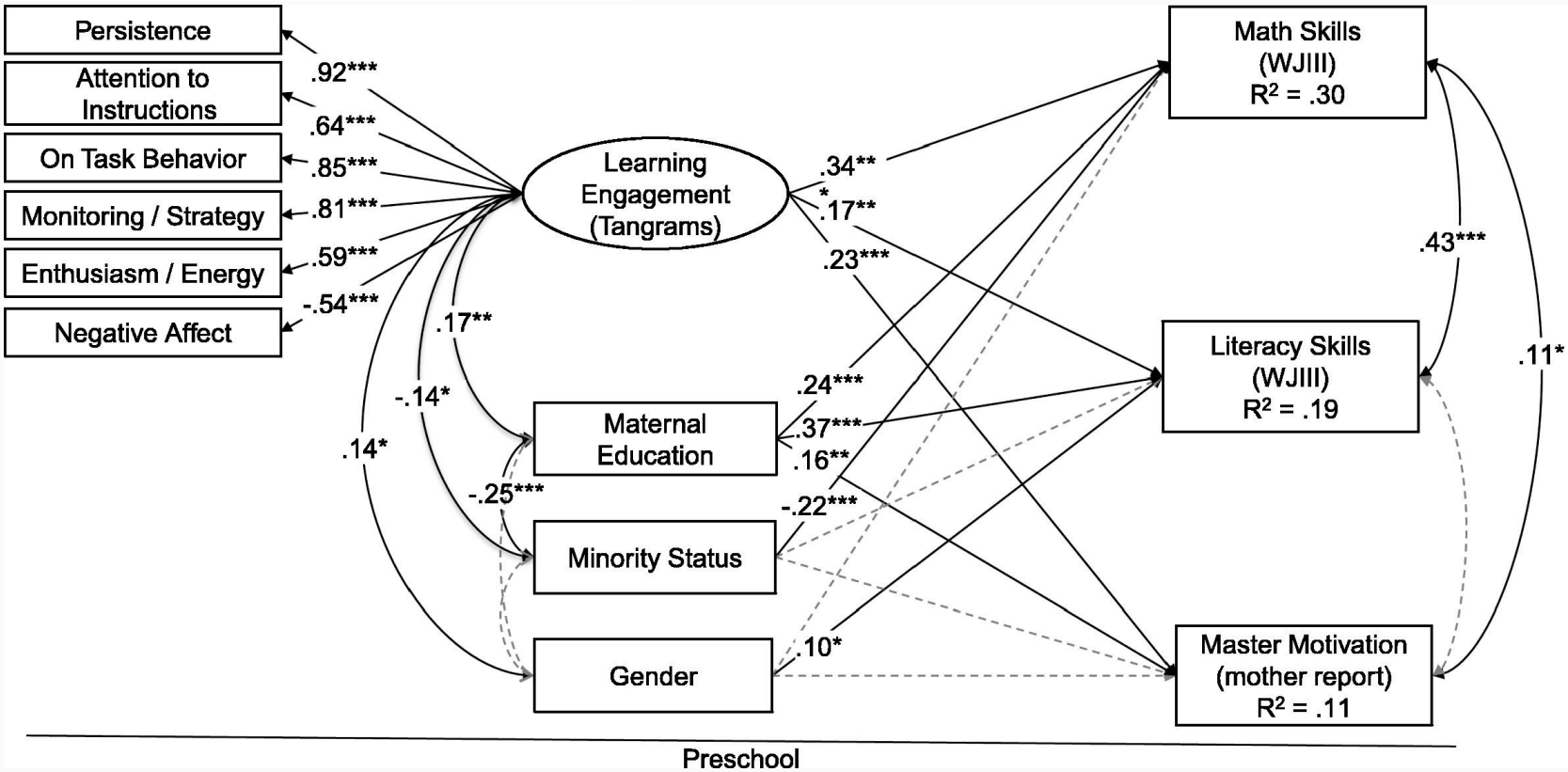
Journal of Experimental Child Psychology

journal homepage: www.elsevier.com/locate/jecp

Measuring preschool learning engagement in the laboratory

Simone E. Halliday [a,*], Susan D. Calkins [b], Esther M. Leerkes [b]

[a] Department of Psychology, The University of North Carolina at Greensboro, Greensboro, NC 27412, USA
[b] Department of Human Development and Family Studies, The University of North Carolina at Greensboro, Greensboro, NC 27412, USA



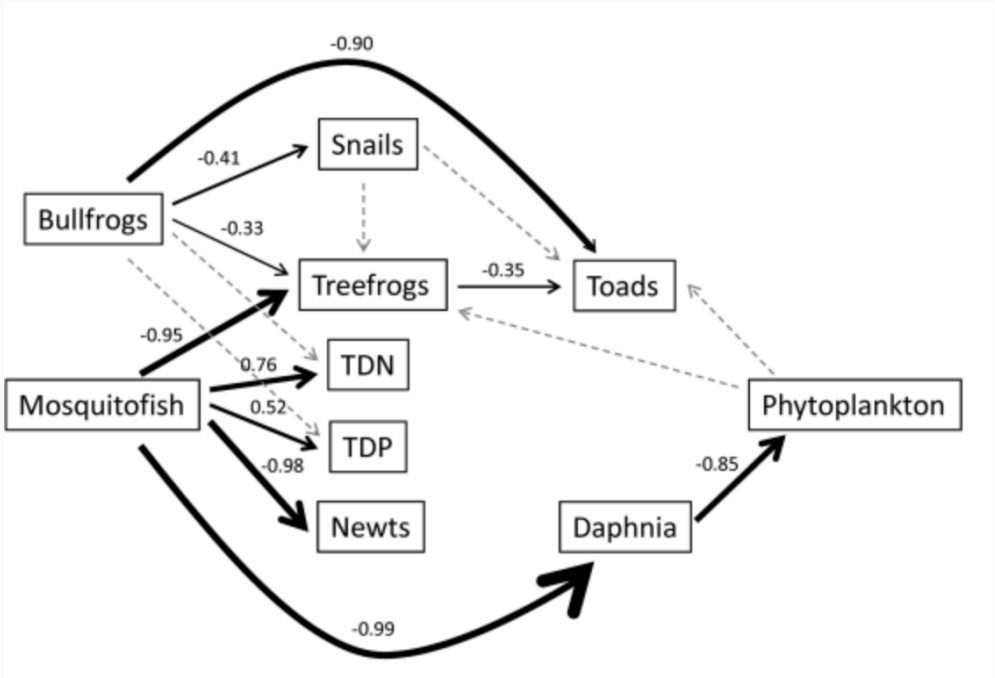
What can you expect to see out in nature?

Ecology, 93(6), 2012, pp. 1254–1261
© 2012 by the Ecological Society of America

Community ecology of invasions: direct and indirect effects of multiple invasive species on aquatic communities

Daniel L. Preston,[1,3] Jeremy S. Henderson,[2] and Pieter T. J. Johnson[1]

[1]*Department of Ecology and Evolutionary Biology, University of Colorado, Ramaley N122, Campus Box 334, Boulder, Colorado 80309 USA*
[2]*Department of Zoology, Oregon State University, 3029 Cordley Hall, Corvallis, Oregon 97331 USA*



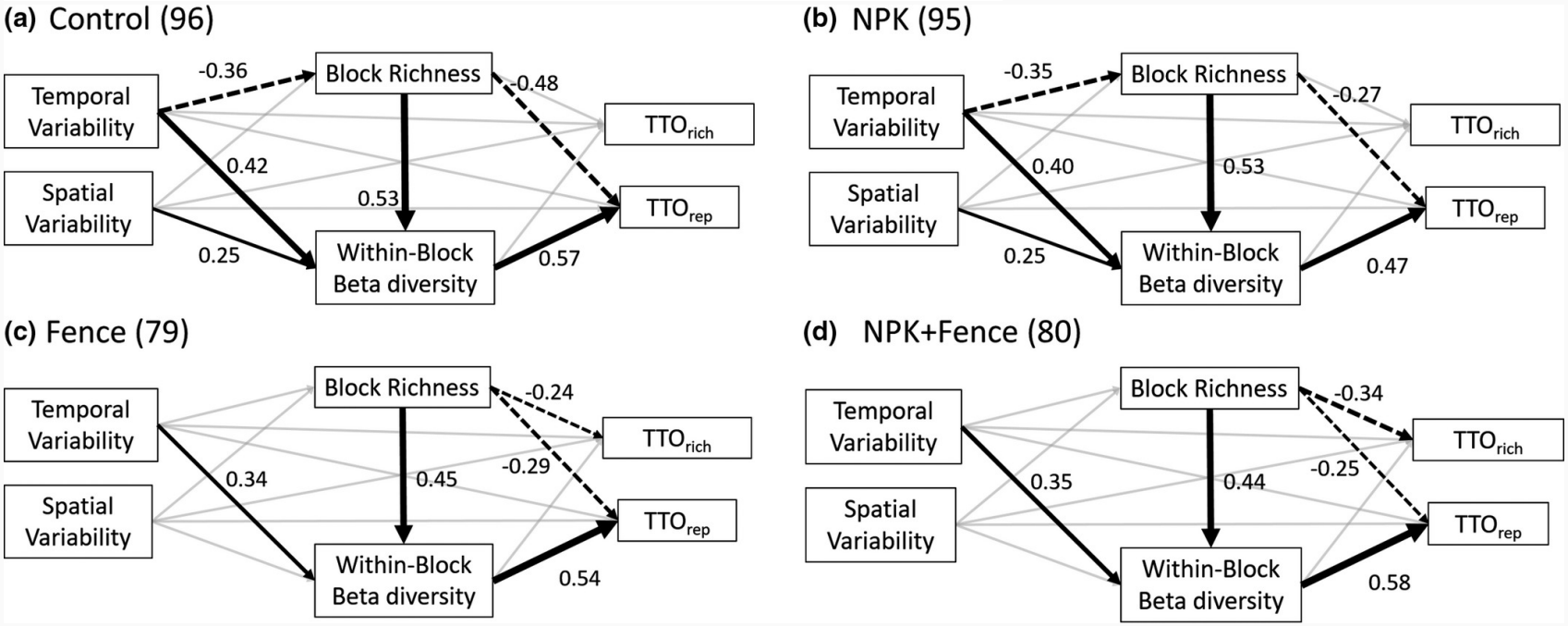
What can you expect to see out in nature?

ECOLOGY LETTERS

Letter | Full Access

Spatial heterogeneity in species composition constrains plant community responses to herbivory and fertilisation

Dorothee Hodapp, Elizabeth T. Borer, W. Stanley Harpole, Eric M. Lind, Eric W. Seabloom, Peter B. Adler, Juan Alberti, Carlos A. Arnillas, Jonathan D. Bakker, Lori Biederman ... See all authors



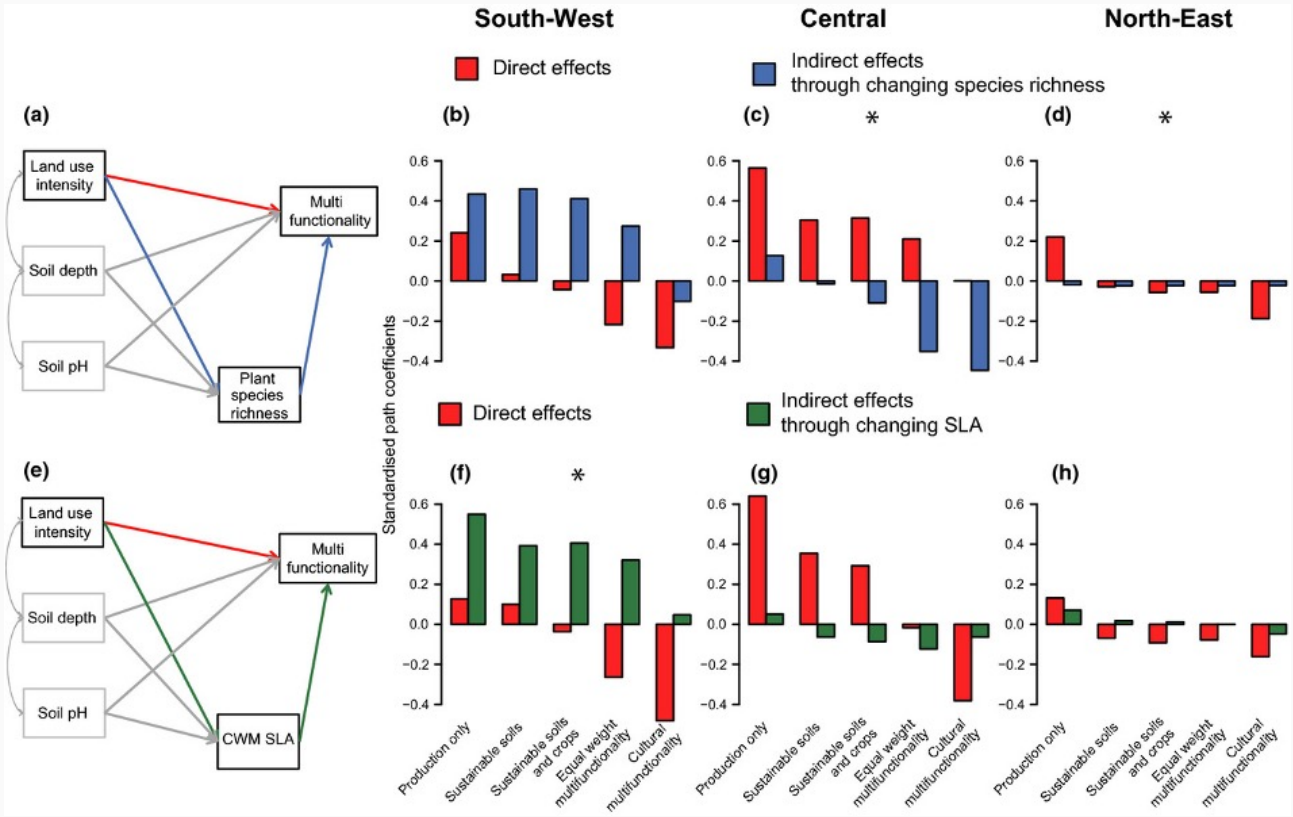
What can you expect to see out in nature?

ECOLOGY LETTERS

Letter | Open Access

Land use intensification alters ecosystem multifunctionality via loss of biodiversity and changes to functional composition

Eric Allan, Pete Manning, Fabian Alt, Julia Binkenstein, Stefan Blaser, Nico Blüthgen, Stefan Böhm, Fabrice Grassein, Norbert Hölzel, Valentin H. Klaus, Till Kleinebecker ... See all authors



What can you expect to see out in nature?

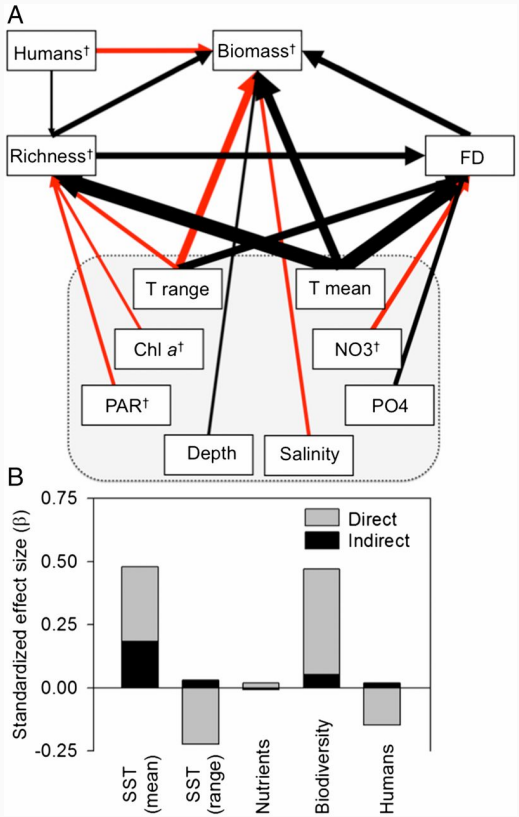
PNAS

Biodiversity enhances reef fish biomass and resistance to climate change

J. Emmett Duffy[a,1], Jonathan S. Lefcheck[b], Rick D. Stuart-Smith[c], Sergio A. Navarrete[d], and Graham J. Edgar[c]

[a]Tennenbaum Marine Observatories Network, Smithsonian Institution, Washington, DC 20013-7012; [b]Department of Biological Sciences, Virginia Institute of Marine Science, The College of William & Mary, Gloucester Point, VA 23062; [c]Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, TAS 7001 Australia; and [d]Estación Costera de Investigaciones Marinas and Center for Marine Conservation, LINC-Global, Pontificia Universidad Católica de Chile, Casilla 114-D, Santiago, Chile

Edited by James A. Estes, University of California, Santa Cruz, CA, and approved April 13, 2016 (received for review December 11, 2015)



What can you expect to see out in nature?

nature COMMUNICATIONS

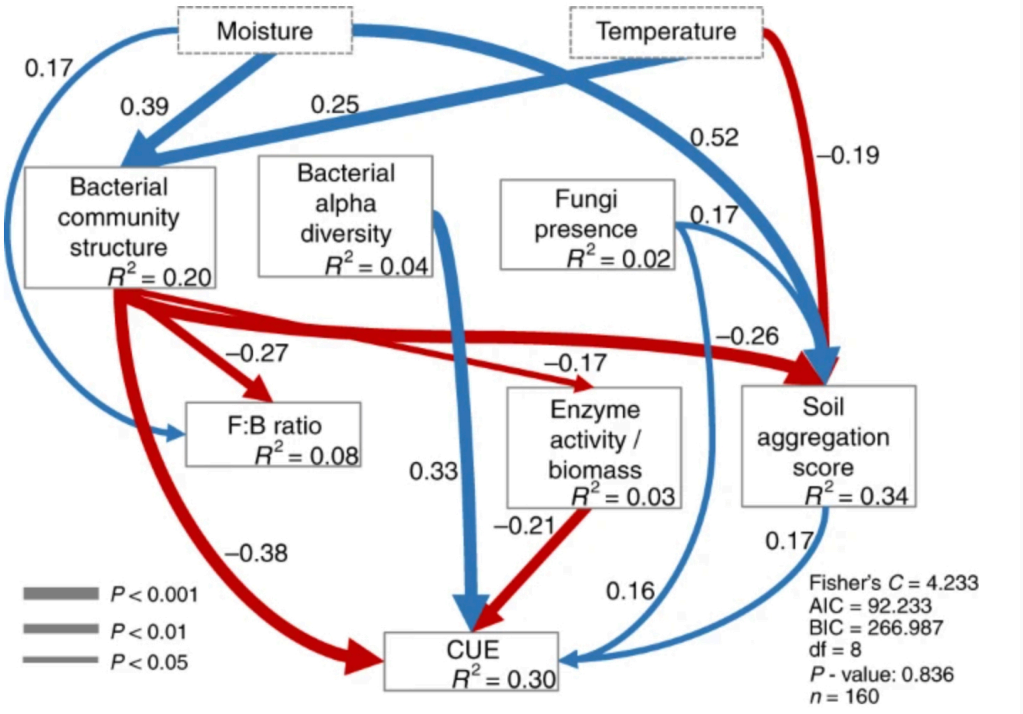
ARTICLE

https://doi.org/10.1038/s41467-020-17502-z OPEN

Microbial diversity drives carbon use efficiency in a model soil

Luiz A. Domeignoz-Horta[1✉], Grace Pold[2], Xiao-Jun Allen Liu[1], Serita D. Frey[3], Jerry M. Melillo[4] & Kristen M. DeAngelis[1✉]

Fig. 4: Structural equation model showing the relative influence of soil abiotic and biotic factors on CUE.



What can you expect to see out in nature?

The ISME Journal (2018) 12:1817–1825
https://doi.org/10.1038/s41396-018-0096-y

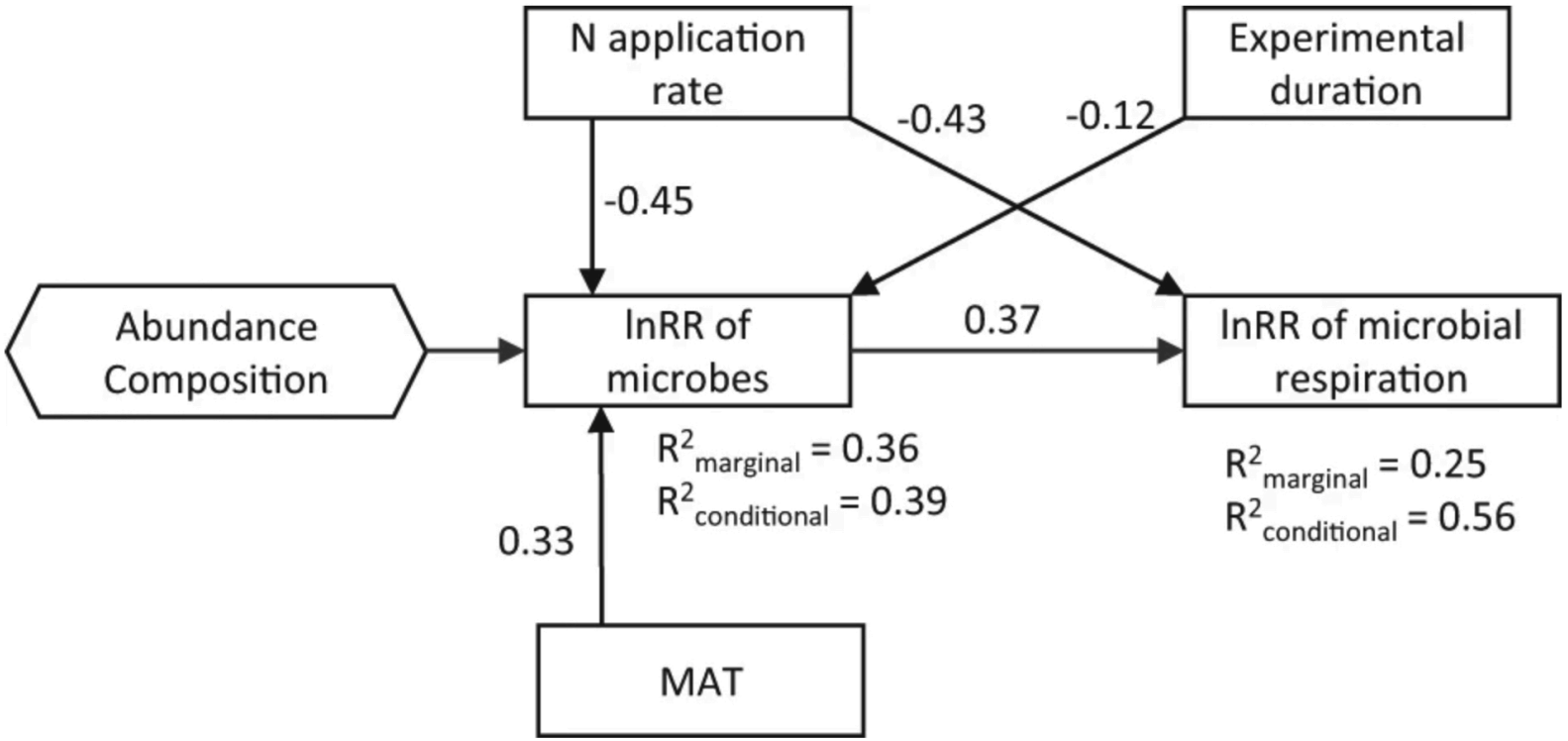
ISME

ARTICLE

Global negative effects of nitrogen deposition on soil microbes

Tian'an Zhang[1] · Han Y. H. Chen[2] · Honghua Ruan[1]

Received: 24 October 2017 / Revised: 13 February 2018 / Accepted: 20 February 2018 / Published online: 27 March 2018
© International Society for Microbial Ecology 2018



What can you expect to see out in nature?

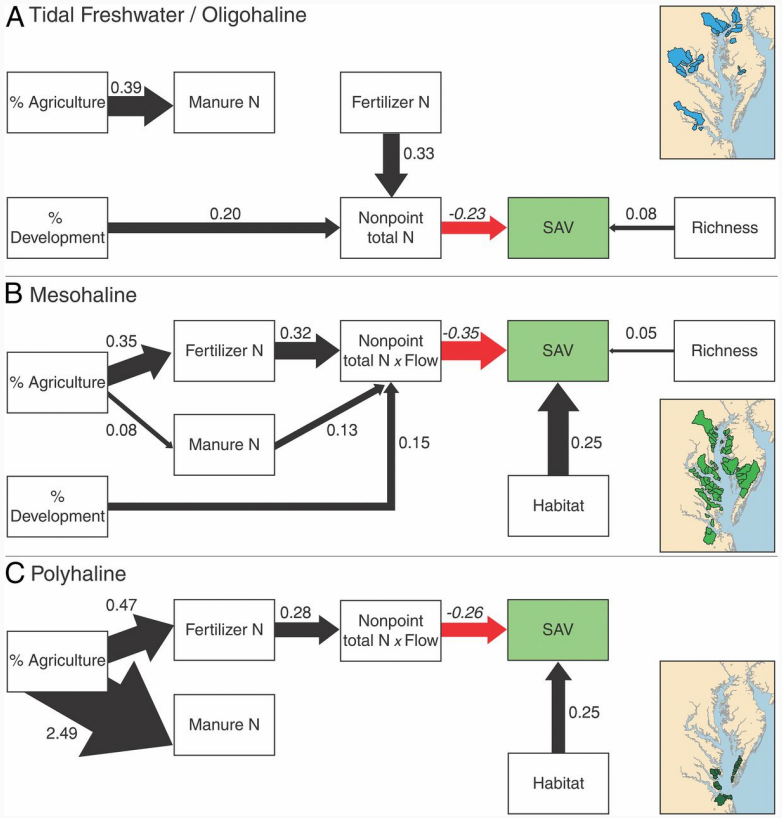
PNAS

Check for updates

Long-term nutrient reductions lead to the unprecedented recovery of a temperate coastal region

Jonathan S. Lefcheck[a,b,1], Robert J. Orth[b], William C. Dennison[c], David J. Wilcox[b], Rebecca R. Murphy[d], Jennifer Keisman[e], Cassie Gurbisz[f,g], Michael Hannam[h], J. Brooke Landry[i], Kenneth A. Moore[b], Christopher J. Patrick[j], Jeremy Testa[k], Donald E. Weller[h], and Richard A. Batiuk[l]

[a]Center for Ocean Health, Bigelow Laboratory for Ocean Science, East Boothbay, ME 04544; [b]Department of Biological Sciences, Virginia Institute of Marine Science, The College of William & Mary, Gloucester Point, VA 23062; [c]University of Maryland Center for Environmental Science, Cambridge, MD 21613; [d]University of Maryland Center for Environmental Science, Chesapeake Bay Program Office, Annapolis, MD 21403; [e]US Geological Survey, Baltimore, MD 21228; [f]National Socio-Environmental Synthesis Center, Annapolis, MD 21401; [g]Environmental Studies Program, St. Mary's College of Maryland, St. Mary's City, MD 20686; [h]Smithsonian Environmental Research Center, Edgewater, MD 21037; [i]Maryland Department of Natural Resources, Annapolis, MD 21401; [j]Texas A&M University Corpus Christi, Corpus Christi, TX 78412; [k]University of Maryland Center for Environmental Science, Chesapeake Biological Laboratory, Solomons, MD 20688; and [l]US Environmental Protection Agency, Annapolis, MD 21403



What can you expect to see out in nature?

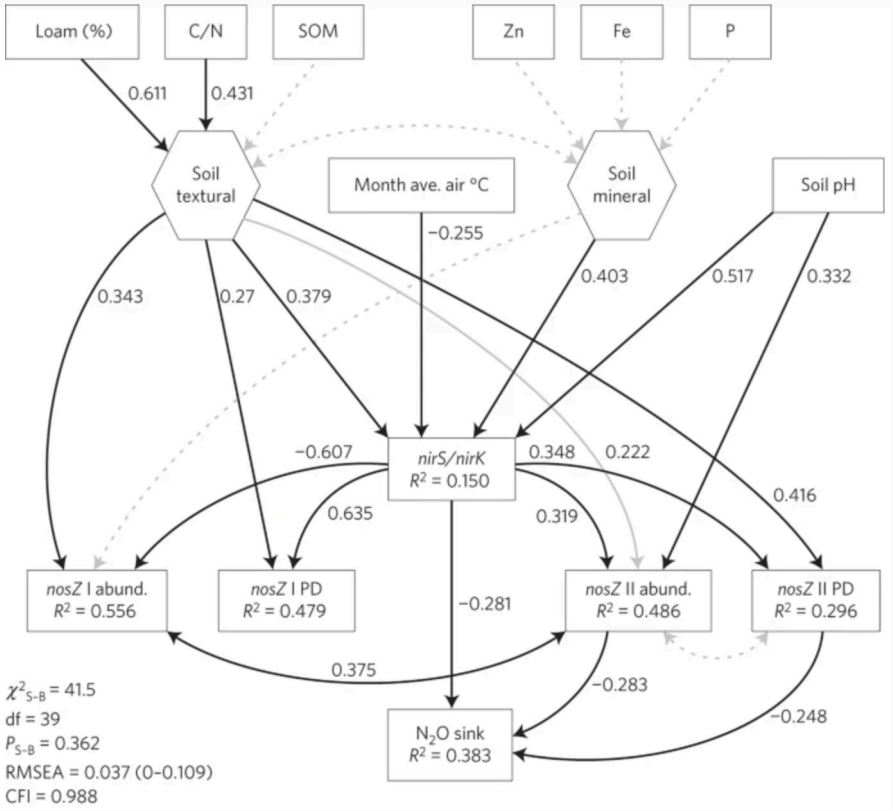
nature climate change

LETTERS

PUBLISHED ONLINE: 13 JULY 2014 | DOI: 10.1038/NCLIMATE2301

Recently identified microbial guild mediates soil N_2O sink capacity

Christopher M. Jones[1,2†], Ayme Spor[1†], Fiona P. Brennan[1,3,4], Marie-Christine Breuil[1], David Bru[1], Philippe Lemanceau[1], Bryan Griffiths[3,5], Sara Hallin[2*] and Laurent Philippot[1]



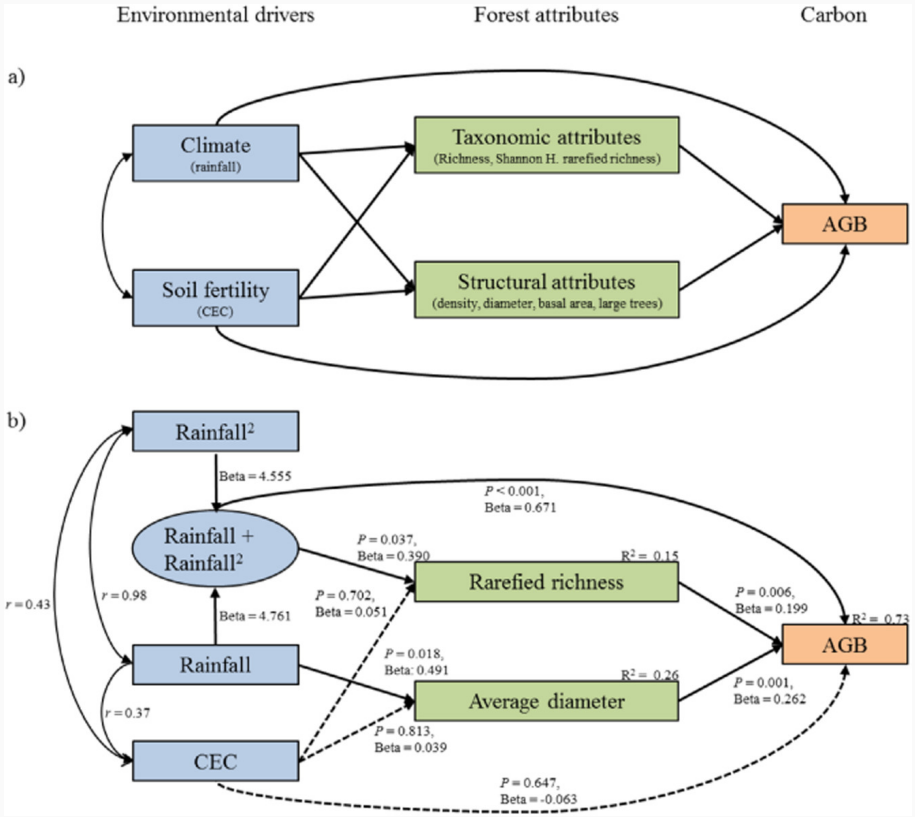
What can you expect to see out in nature?

Global Ecology and Biogeography
A Journal of Macroecology

Research Papers | Full Access

Diversity enhances carbon storage in tropical forests

L. Poorter ✉, M. T. van der Sande, J. Thompson, E. J. M. M. Arets, A. Alarcón, J. Álvarez-Sánchez, N. Ascarrunz, P. Balvanera, G. Barajas-Guzmán, A. Boit, F. Bongers, F. A. Carvalho ... See all authors



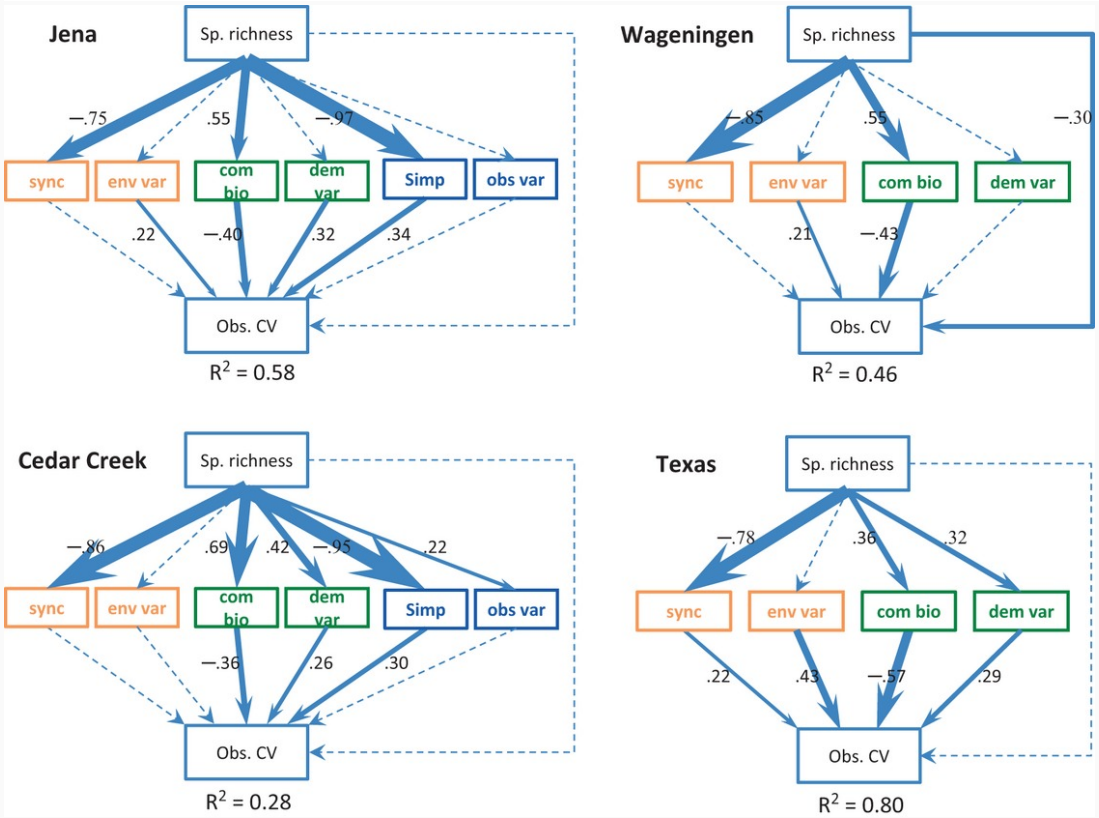
What can you expect to see out in nature?

ECOLOGY LETTERS

Letter | Full Access

Predicting ecosystem stability from community composition and biodiversity

Claire de Mazancourt, Forest Isbell, Allen Larocque, Frank Berendse, Enrica De Luca, James B. Grace, Bart Haegeman, H. Wayne Polley, Christiane Roscher, Bernhard Schmid ... See all authors



What can you expect to see out in nature?

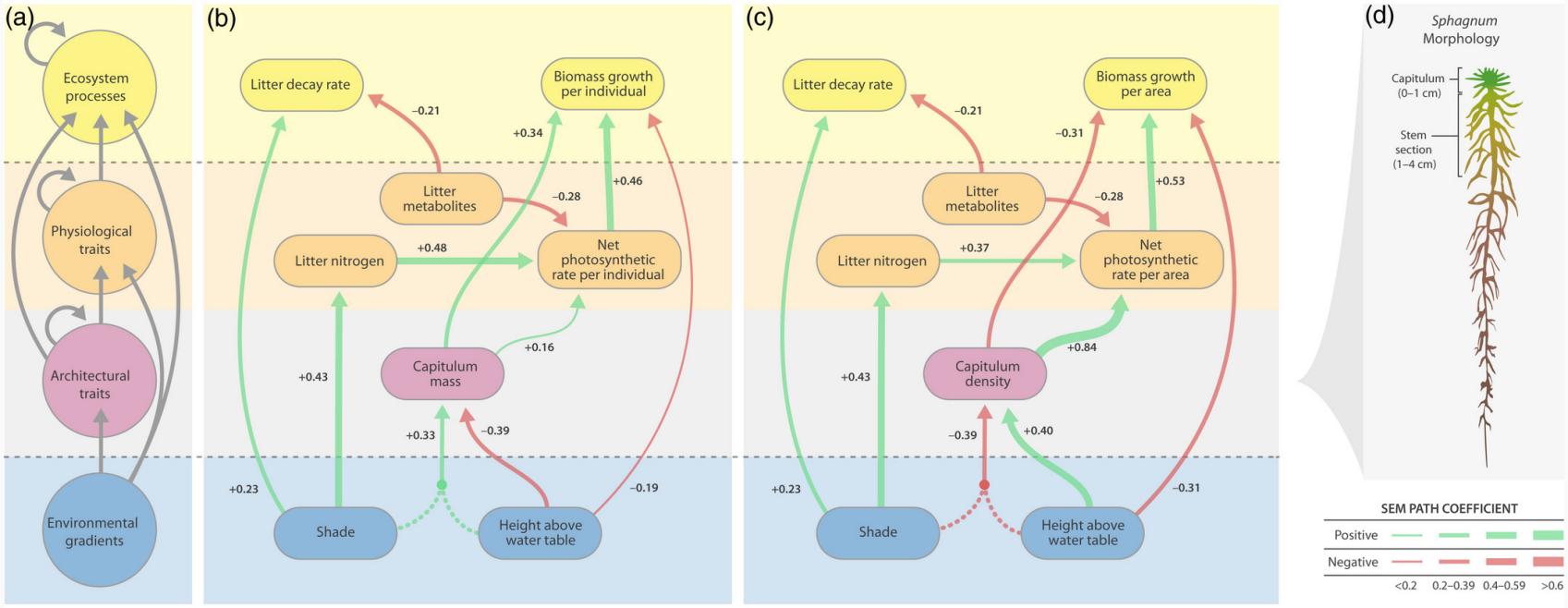
Journal of Ecology

BRITISH ECOLOGICAL SOCIETY

RESEARCH ARTICLE | Open Access

Scaling functional traits to ecosystem processes: Towards a mechanistic understanding in peat mosses

Adriano Mazziotta, Gustaf Granath, Håkan Rydin, Fia Bengtsson, Jon Norberg



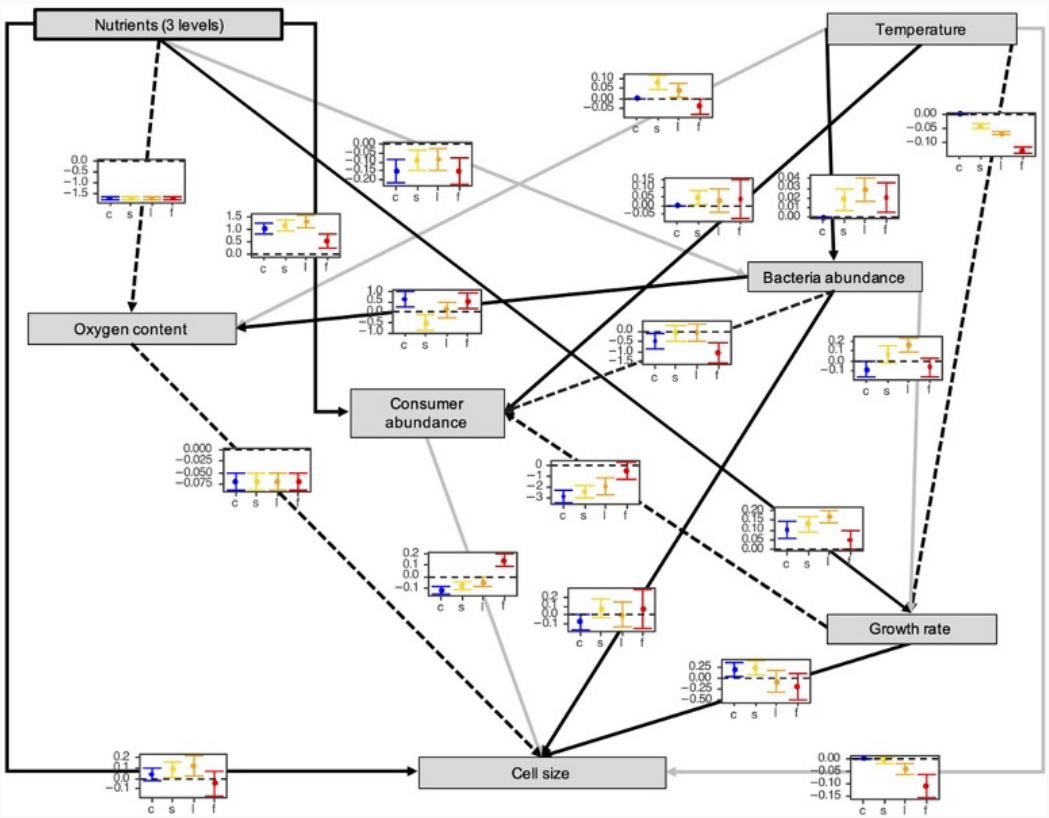
What can you expect to see out in nature?

RESEARCH ARTICLE

Functional Ecology | BRITISH ECOLOGICAL SOCIETY

Testing multiple drivers of the temperature-size rule with nonlinear temperature increase

Andrea Tabi[1,2] | Aurélie Garnier[1,3] | Frank Pennekamp[1]



Discussion

What makes a good data visualization?

Theory

- What is the important information to convey?

Theory

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- Breaking up models into several panels or figures

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    - Top to bottom, or left to right

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    - Moving information to a supplement

Theory

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- Try to have high information-to-ink ratio
- Display variables that is informative for reader rather than distracting:
    - Top to bottom, or left to right
    - Moving information to a supplement
- Use colours that work for colour-blind people

What is a good SEM drawing?

- Starting from what you draw and what you just saw, what is the minimum necessary information to include in an SEM?

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- What is missing in your drawing?

What is a good SEM drawing?

There are no rules. Here are our guidelines to help drawing an informatiove, interpretable and reproducible SEM diagram.

1) Show the relevant variables

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2) Represent causal relationships by the path coefficients

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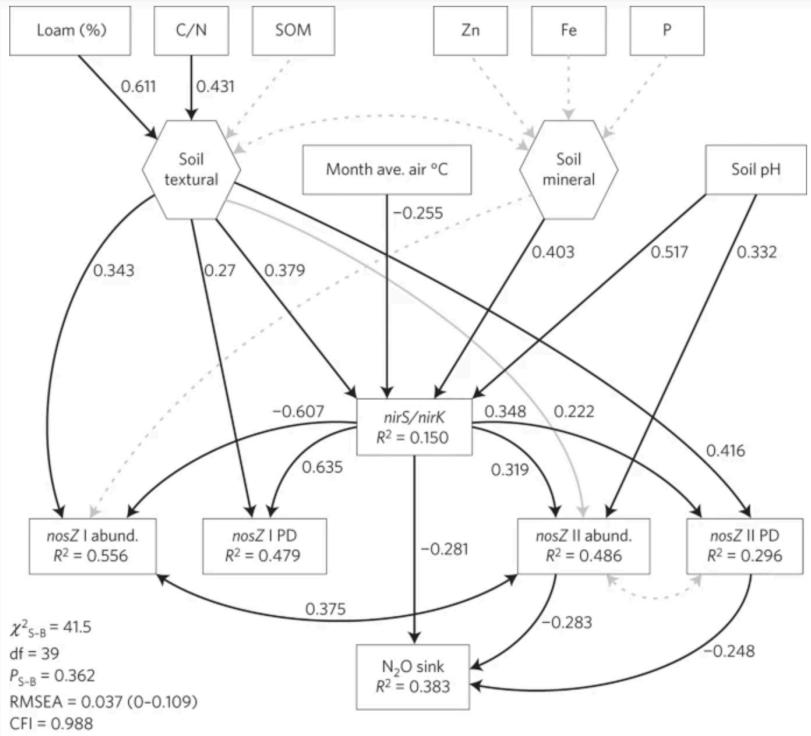
2) Represent causal relationships by the path coefficients
3) Represent all relevant paths (regardless of significance)
4) Report goodness of fit of the model
5) Report explanatory power for endogenous variables
6) Include tables with additional coefficients and derived quantities

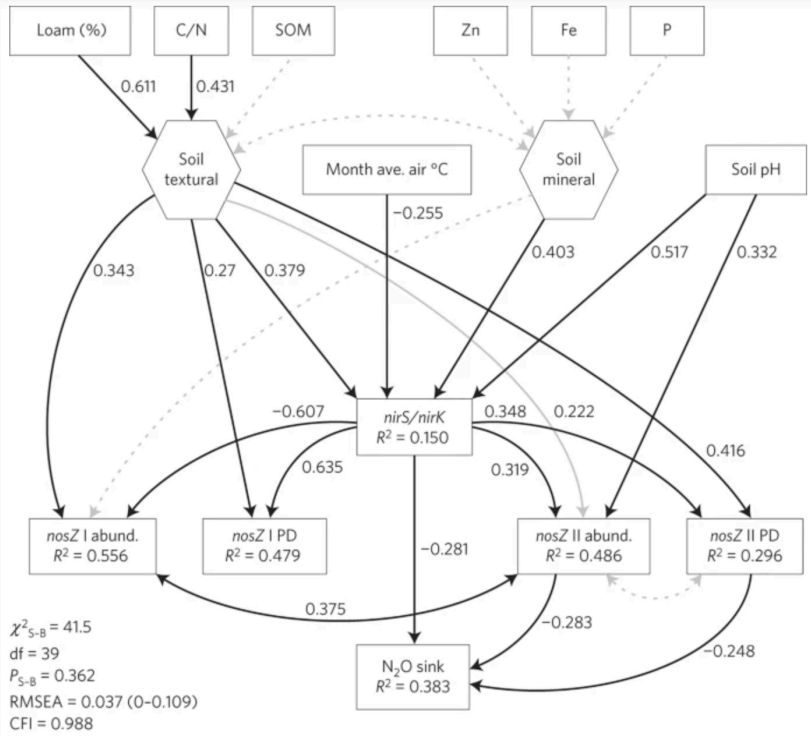
Show the relevant variables

- Squares are manifest (measured) variables



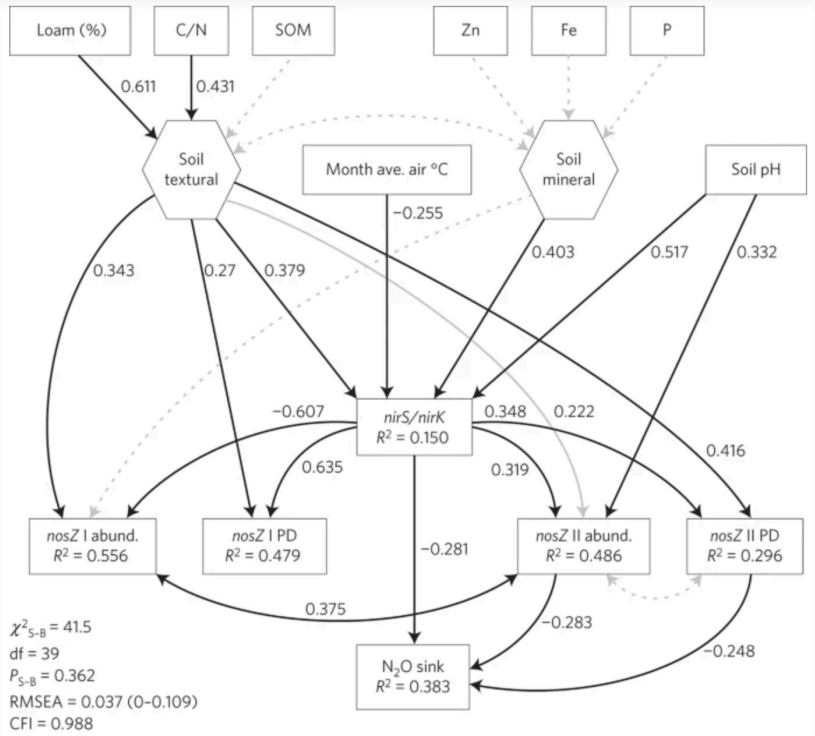
Show the relevant variables

- Squares are manifest (measured) variables
- Ellipses are latent variables



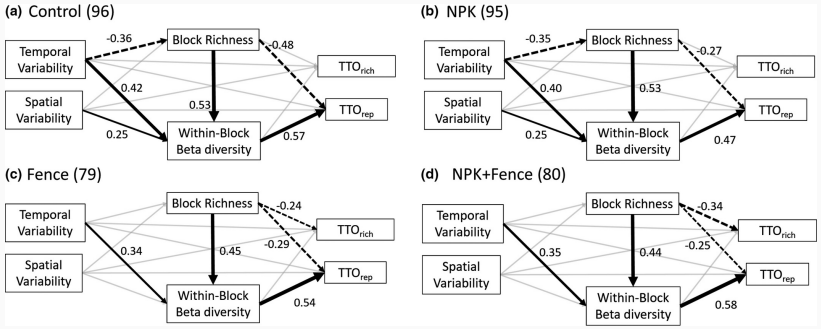
Show the relevant variables

- Squares are manifest (measured) variables
- Ellipses are latent variables
- Hexagons for composite variables



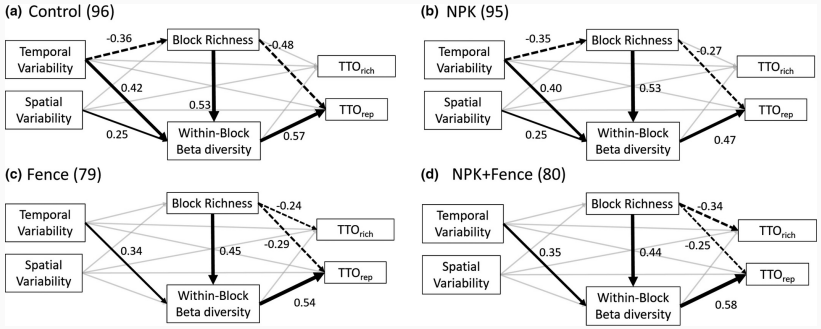
Represent causal relationships by the path coefficients

- Indicate the magnitude, direction, and significance by:



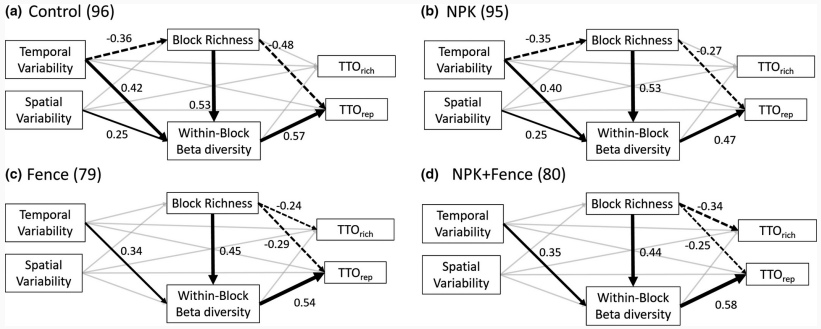
Represent causal relationships by the path coefficients

- Indicate the magnitude, direction, and significance by:
  - Linetype or color for direction



Represent causal relationships by the path coefficients

- Indicate the magnitude, direction, and significance by:
  - Linetype or color for direction
  - Dashed vs solid for significance



Represent causal relationships by the path coefficients

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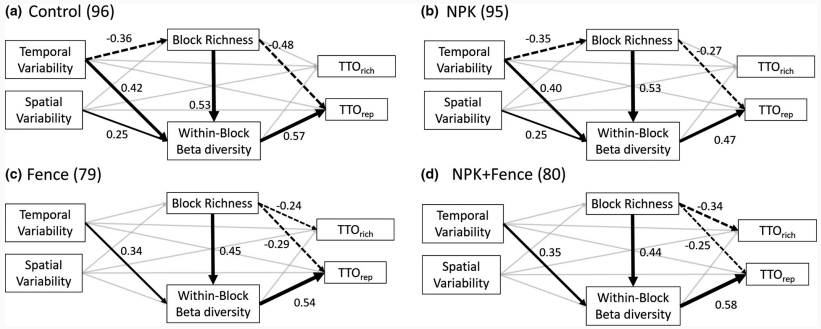
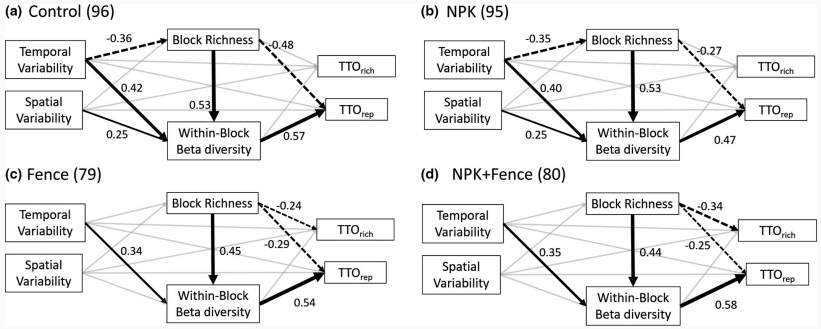
  - Linetype or color for direction
  - Dashed vs solid for significance
  - Arrow width for magnitude



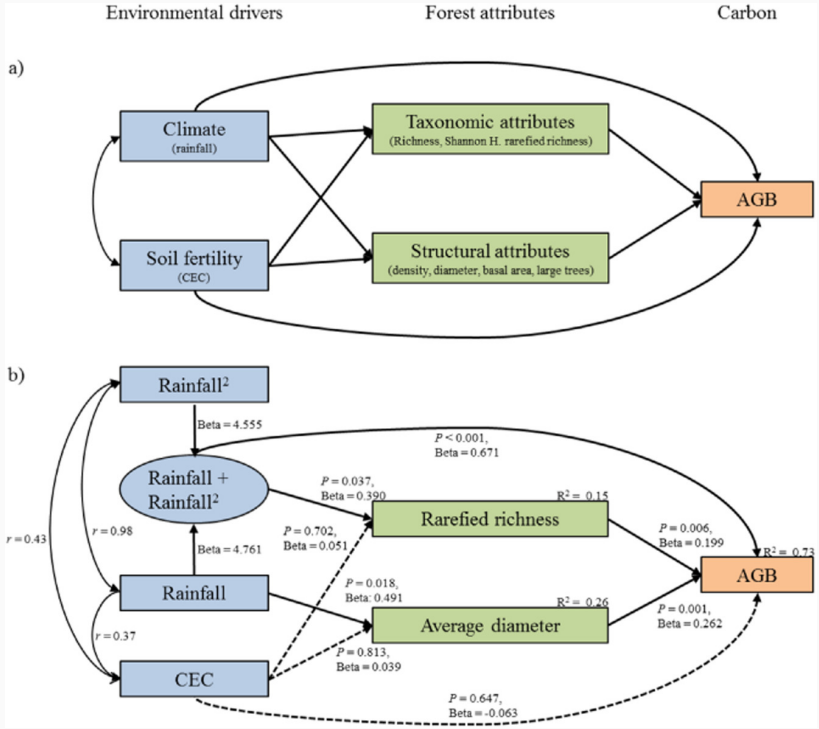
Represent causal relationships by the path coefficients

- Indicate the magnitude, direction, and significance by:
  - Linetype or color for direction
  - Dashed vs solid for significance
  - Arrow width for magnitude
  - Labelling with coefficient



Represent all relevant paths (regardless of significance)

- Represent all causal paths included in your model regardless of significance.



Represent all relevant paths (regardless of significance)

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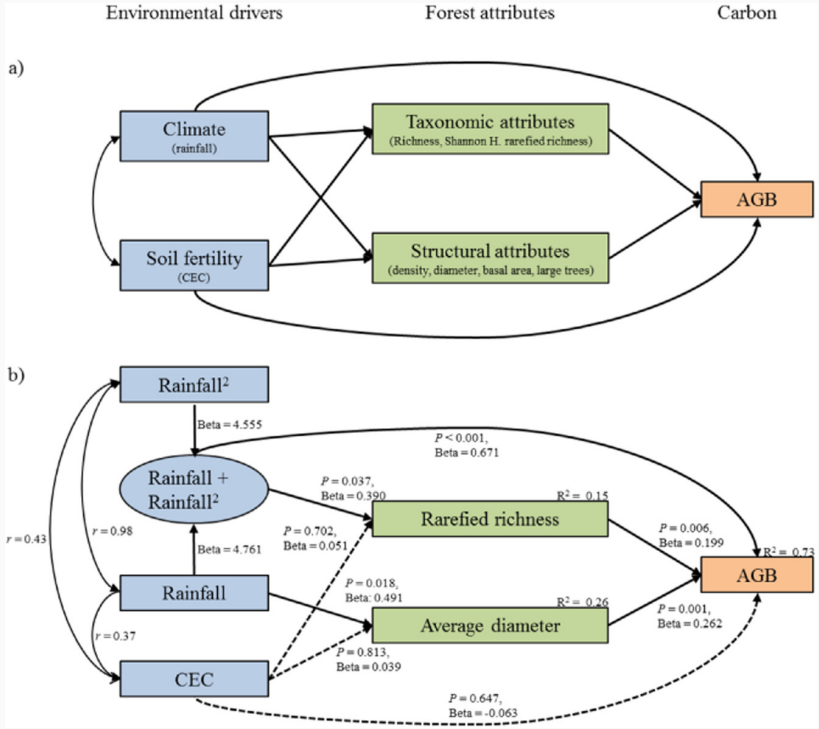
- Not necessarily in the same figure.



Represent all relevant paths (regardless of significance)

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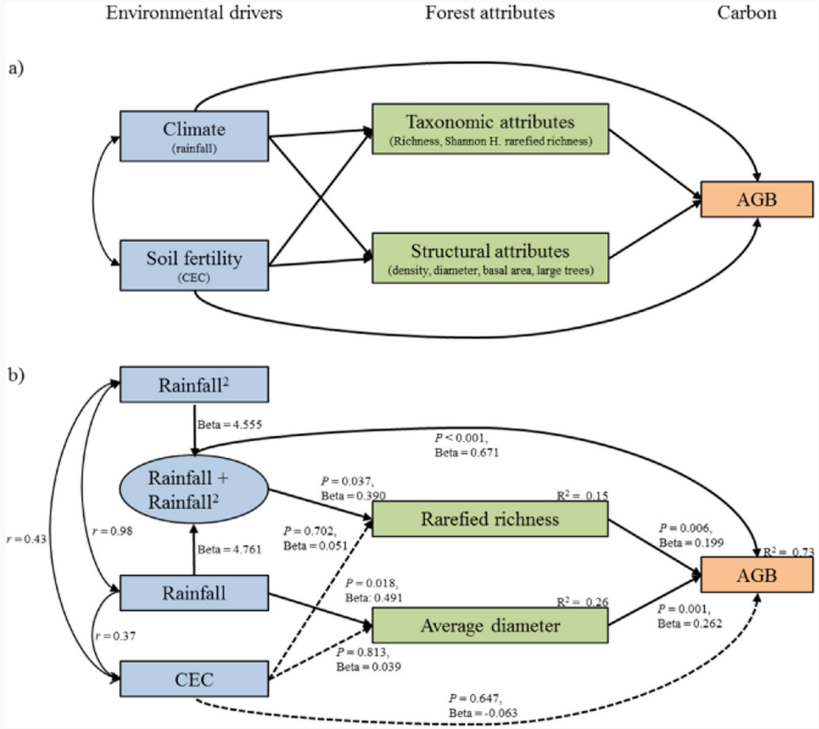
- Not necessarily in the same figure.
- Represent important correlations.



Represent all relevant paths (regardless of significance)

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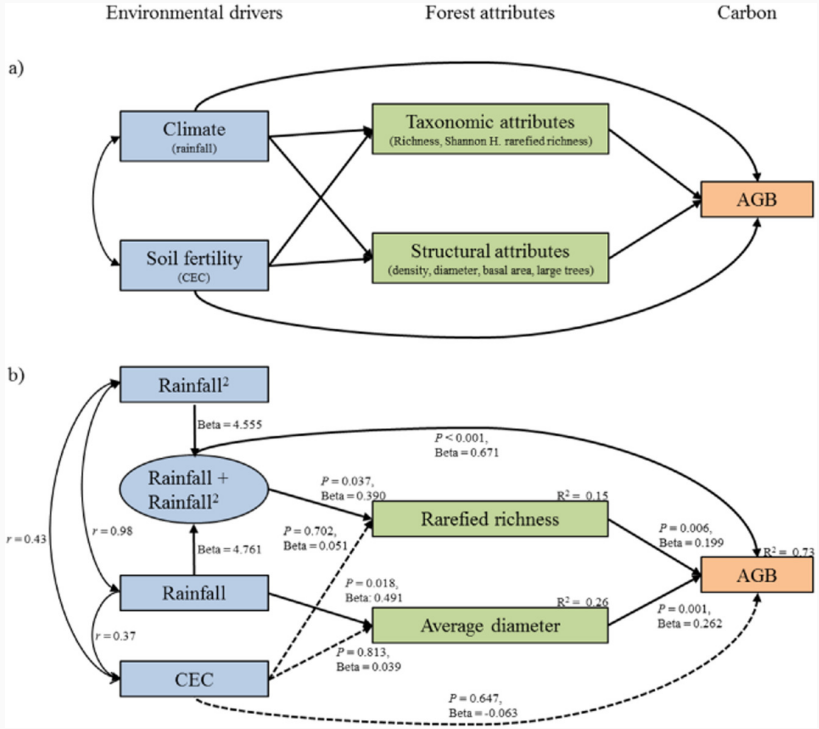
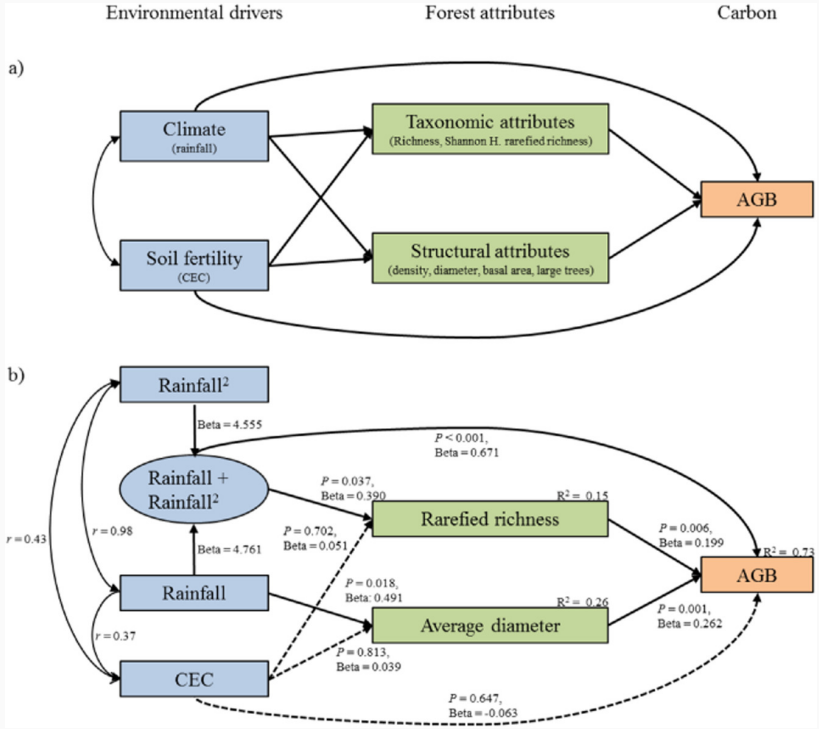
- Represent important correlations.
- Exogenous variables can be included.



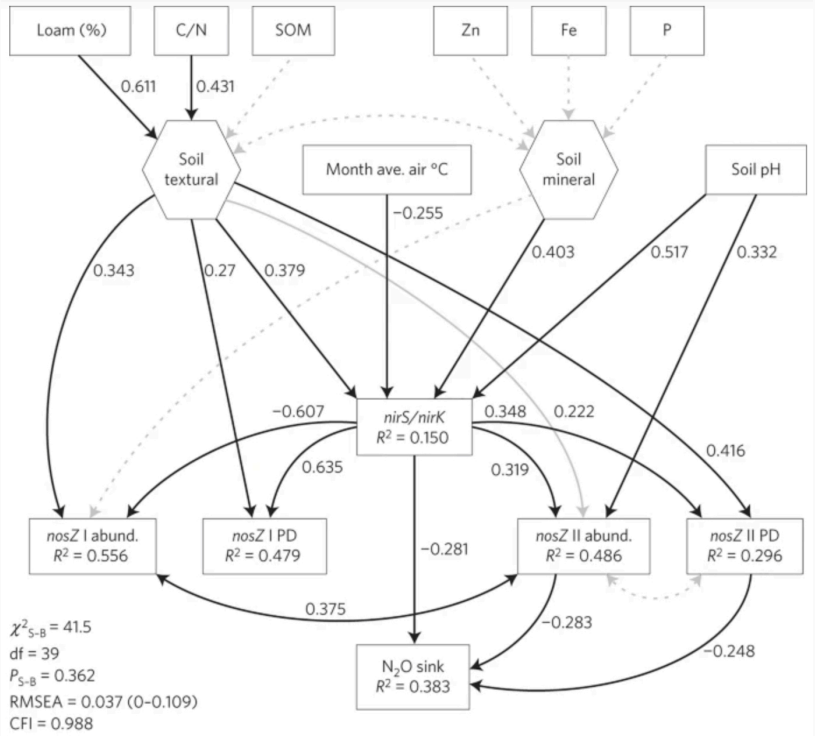
Represent all relevant paths (regardless of significance)

- Represent all causal paths included in your model regardless of significance.
- Not necessarily in the same figure.
- Represent important correlations.
- Exogenous variables can be included.
- Always include correlations among the errors of endogenous variables.



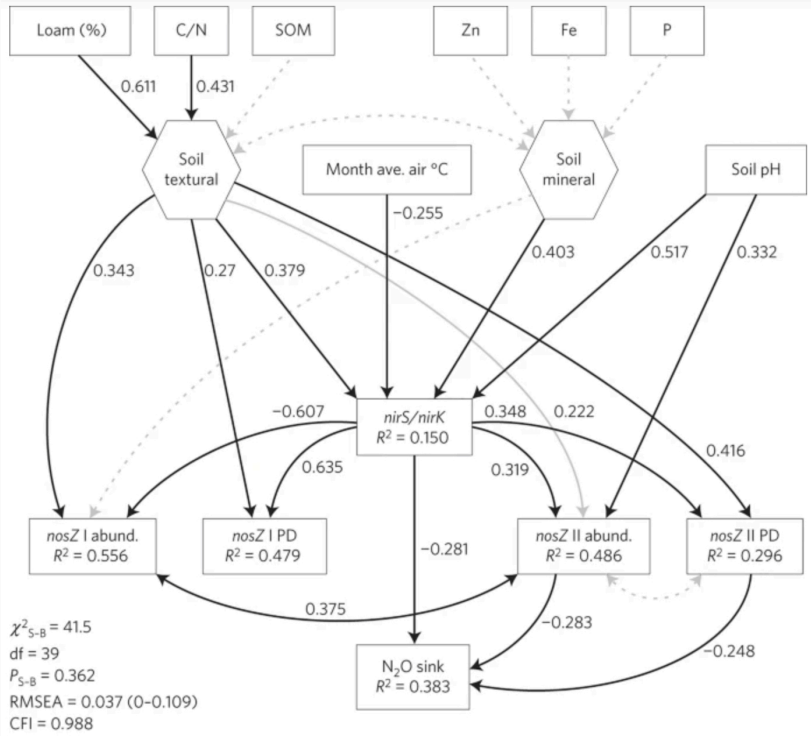
Report model goodness of fit

- Covariance-based approaches:



Report model goodness of fit

- Covariance-based approaches:
  - χ^2



Report model goodness of fit

- Covariance-based approaches:
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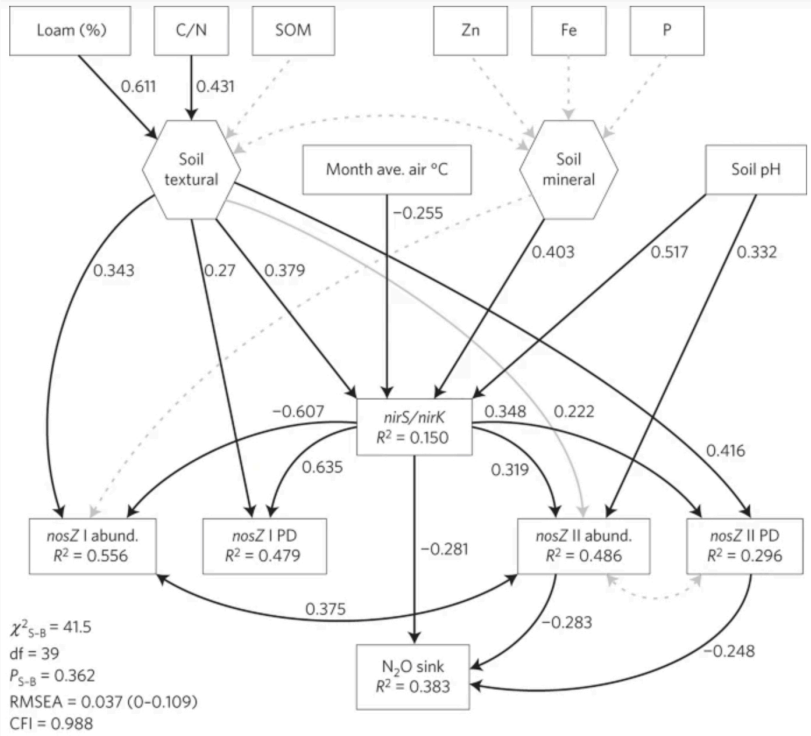
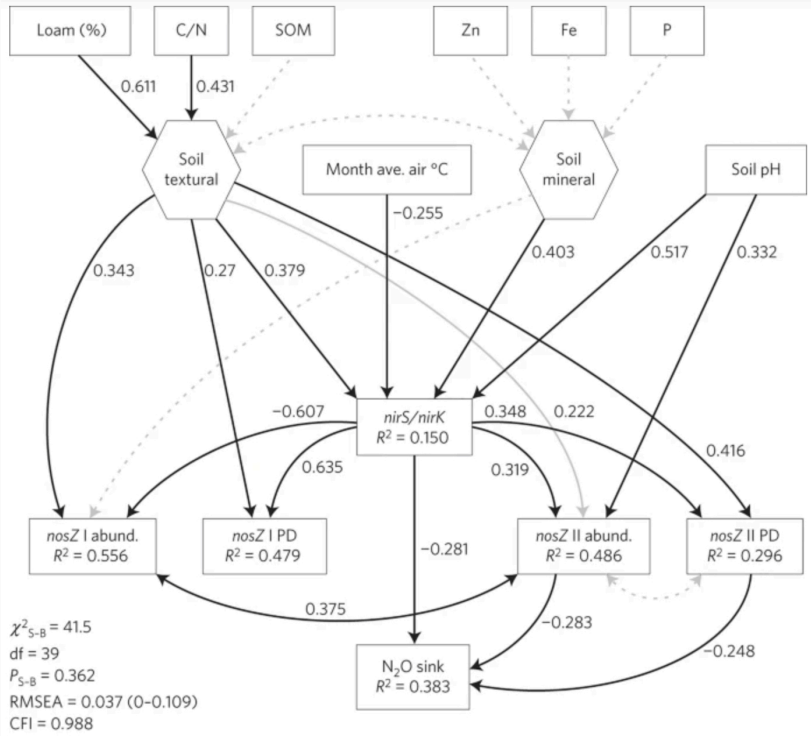
  - CFI



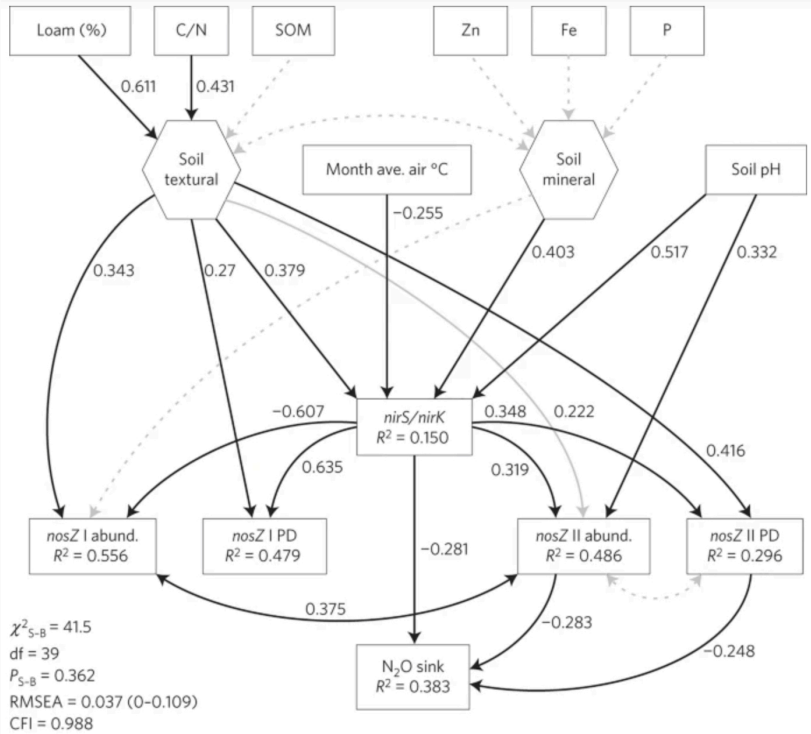
Report model goodness of fit

- Covariance-based approaches:
  - χ^2
  - CFI
  - SRMR



Report model goodness of fit

- Covariance-based approaches:
  - χ^2
  - CFI
  - SRMR
  - RMSEA



Report explanatory power for endogenous variables

- Residual error or R^2

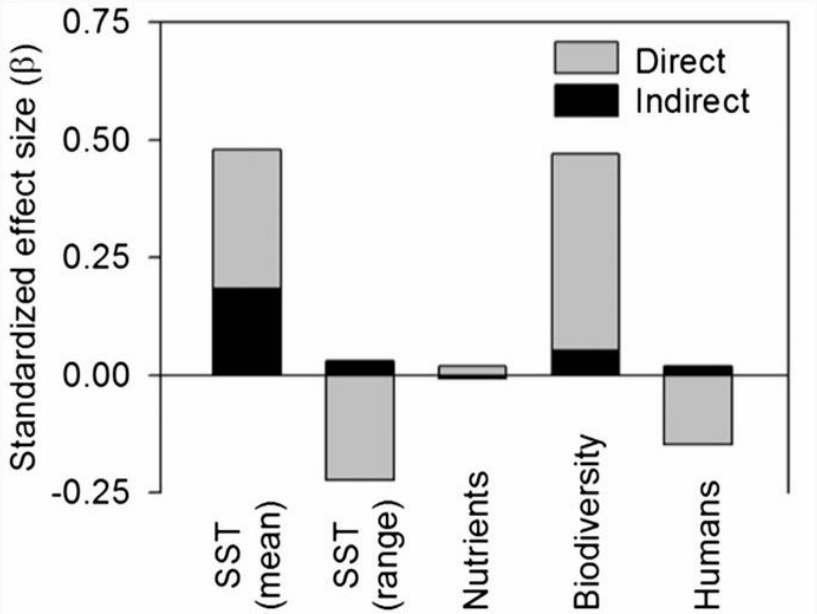
TABLE 1 Coefficients of determination (R^2) for the five endogenous variables in the structural equation model

Variable	Fast	Linear	Slow	Constant
Cell size	0.30	0.31	0.43	0.44
Dissolved oxygen content of medium	0.63	0.61	0.60	0.56
Consumer abundance	0.22	0.44	0.50	0.43
Bacteria abundance	0.11	0.11	0.08	0.08
Growth rate	0.77	0.66	0.37	0.11

Include tables with additional coefficients and derived quantities

- Table of path coefficients

	Constant	
term	estimate	SE
Cell size ~Bacteria abundance	-0.075	0.044
Consumer abundance ~Bacteria abundance	-0.486	0.177
Oxygen content ~Bacteria abundance	0.615	0.193
Growth rate ~Bacteria abundance	-0.087	0.043
Consumer abundance ~Growth rate	-2.811	0.27
Cell size ~Growth rate	0.211	0.078
Oxygen content~temperature	0	0
Growth rate ~temperature	0	0
Consumer abundance ~temperaturep	0	0
Cell size ~temperature	0	0
Bacteria abundance~temperature	0	0
Cell size ~Consumer abundance	-0.122	0.016
Bacteria abundance~nutrients	-0.152	0.035
Cell size ~nutrients	0.041	0.033
Oxygen content ~nutrients	-1.683	0.049
Consumer abundance ~nutrients	1.014	0.101
Growth rate ~nutrients	0.101	0.024
Cell size ~Oxygen content	-0.068	0.01

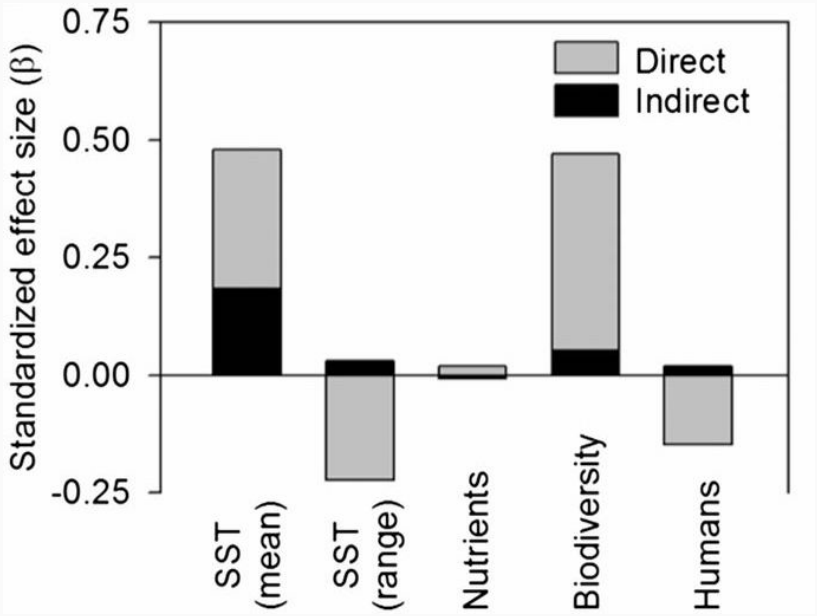


Include tables with additional coefficients and derived quantities

- Table of path coefficients

	Constant	
term	estimate	SE
Cell size ~Bacteria abundance	-0.075	0.044
Consumer abundance ~Bacteria abundance	-0.486	0.177
Oxygen content ~Bacteria abundance	0.615	0.193
Growth rate ~Bacteria abundance	-0.087	0.043
Consumer abundance ~Growth rate	-2.811	0.27
Cell size ~Growth rate	0.211	0.078
Oxygen content~temperature	0	0
Growth rate ~temperature	0	0
Consumer abundance ~temperaturep	0	0
Cell size ~temperature	0	0
Bacteria abundance~temperature	0	0
Cell size ~Consumer abundance	-0.122	0.016
Bacteria abundance~nutrients	-0.152	0.035
Cell size ~nutrients	0.041	0.033
Oxygen content ~nutrients	-1.683	0.049
Consumer abundance ~nutrients	1.014	0.101
Growth rate ~nutrients	0.101	0.024
Cell size ~Oxygen content	-0.068	0.01

- Direct, indirect and total effects



Data presentation

- Showing the underlying data

Data presentation

- Showing the underlying data
    - Plots of raw correlations

Data presentation

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  - Plots of raw correlations
  - Correlation tables

Data presentation

- Showing the underlying data
  - Plots of raw correlations
  - Correlation tables
  - Shows distribution of data

Data presentation

- Showing the underlying data
  - Plots of raw correlations
  - Correlation tables
  - Shows distribution of data
  - Partial plots

Room for artistry

- This will depend on the audience and support:

Room for artistry

- This will depend on the audience and support:
    - Is this a paper?

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- This will depend on the audience and support:
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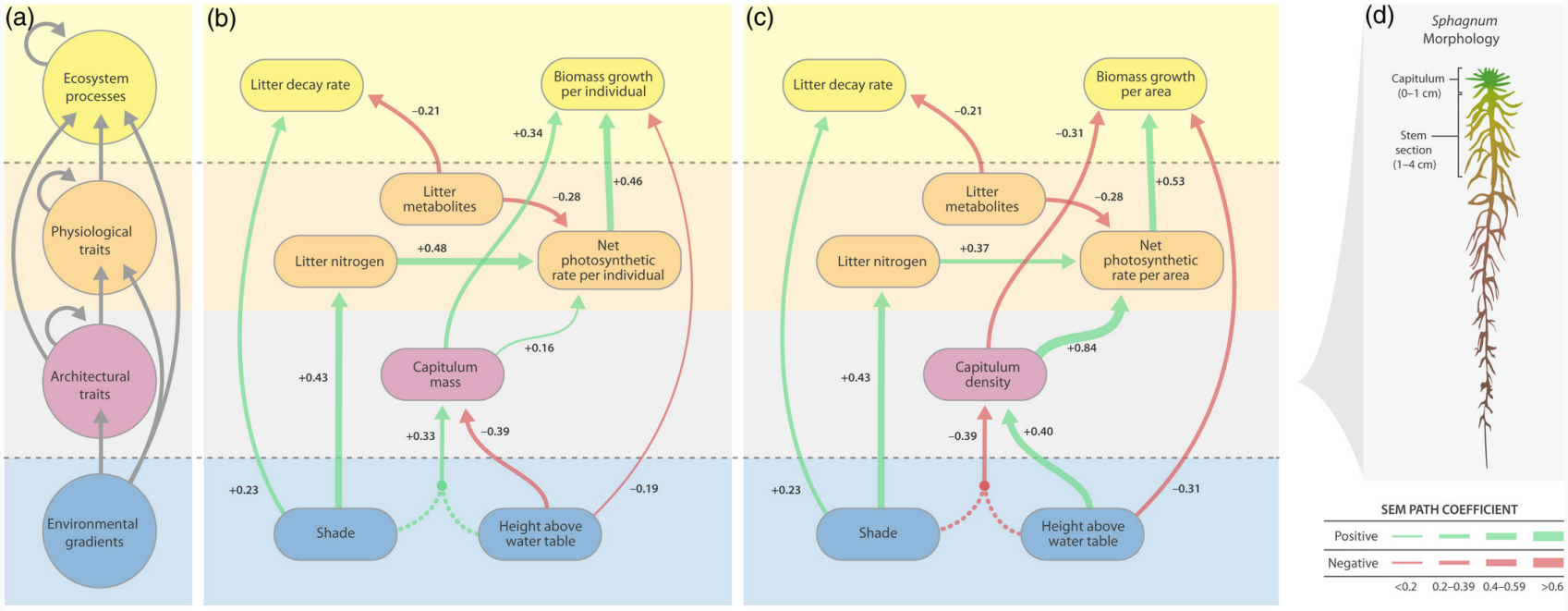
  - Is this a presentation?
  - What is the narrative structure?
- Key thing here is that one structure might not work in every case.
- Not advocating for anything in particular, but note that the same model for a paper might not be the right presentation for an SEM.

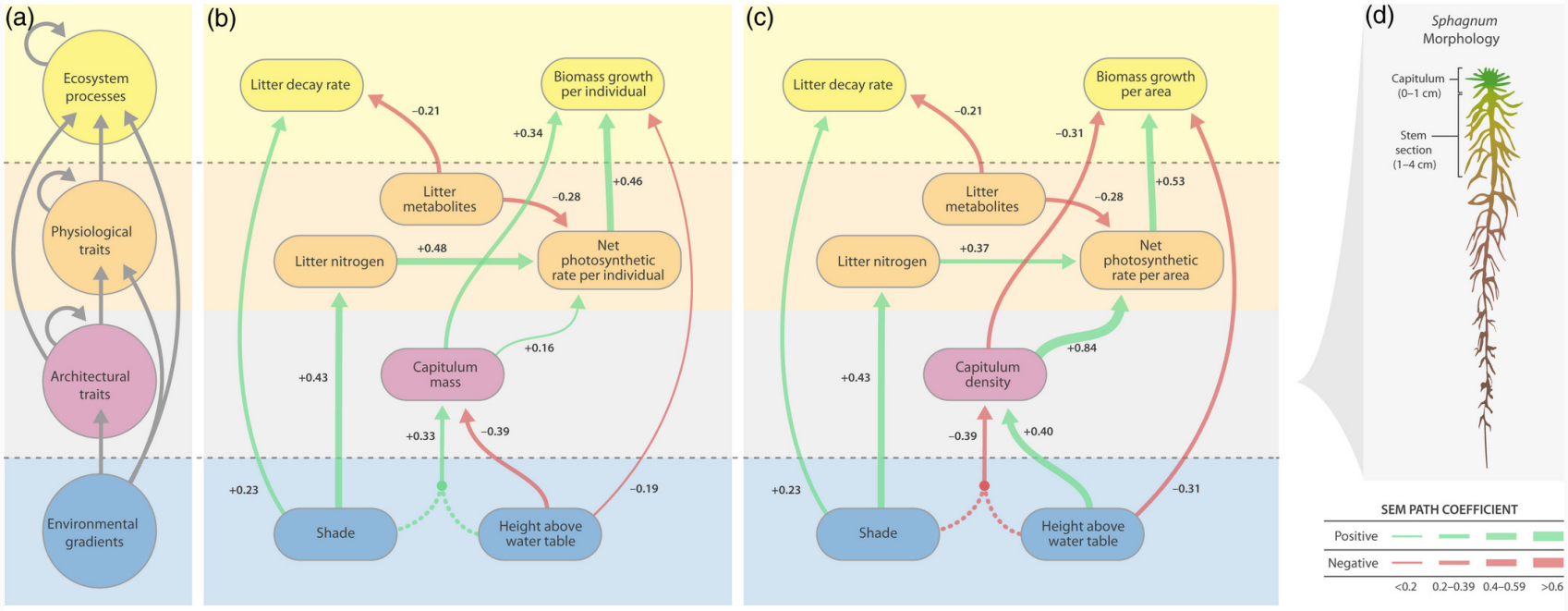
Room for artistry

- Meta models:



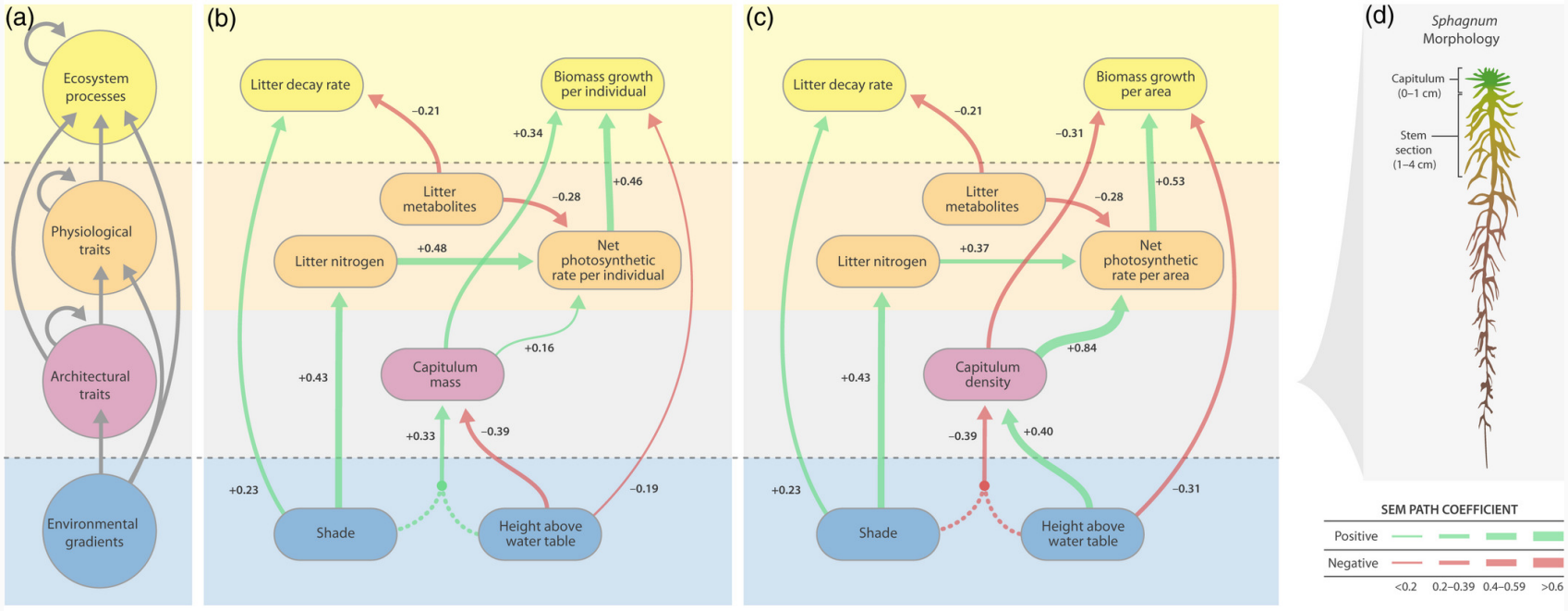
Room for artistry

- Meta models:
  - Shows the core concepts and their relationships, ignoring the data.



Room for artistry

- Meta models:
  - Shows the core concepts and their relationships, ignoring the data.
  - The most abstracted vision of the causal process you are trying to capture



Building the plot

- Dedicated packages available in R (e.g., semPlot, lavaanPlot)

Building the plot

- Dedicated packages available in R (e.g., semPlot, lavaanPlot)
- Fine-tuning in external software like powerpoint, illustrator, or Inkscape.

Questions?