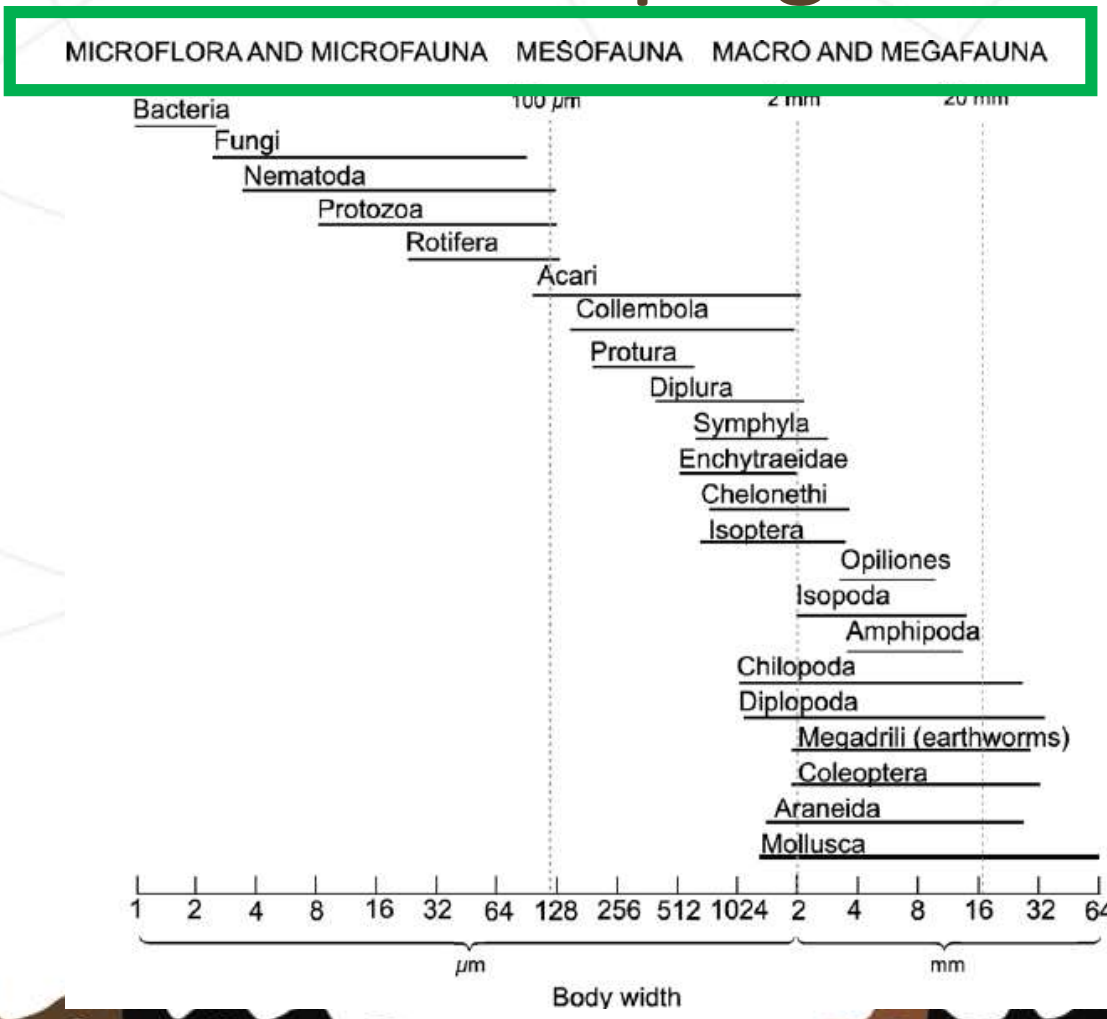
Uncovering linkages between soil fauna and ecosystem function using factor analysis and structural equation modelling

Ashley B. Jernigan[1], Matthew Ryan[2], Kyle Wickings[1]

[1]Department of Entomology, Cornell Agritech, Cornell University, Geneva, New York 14456, USA

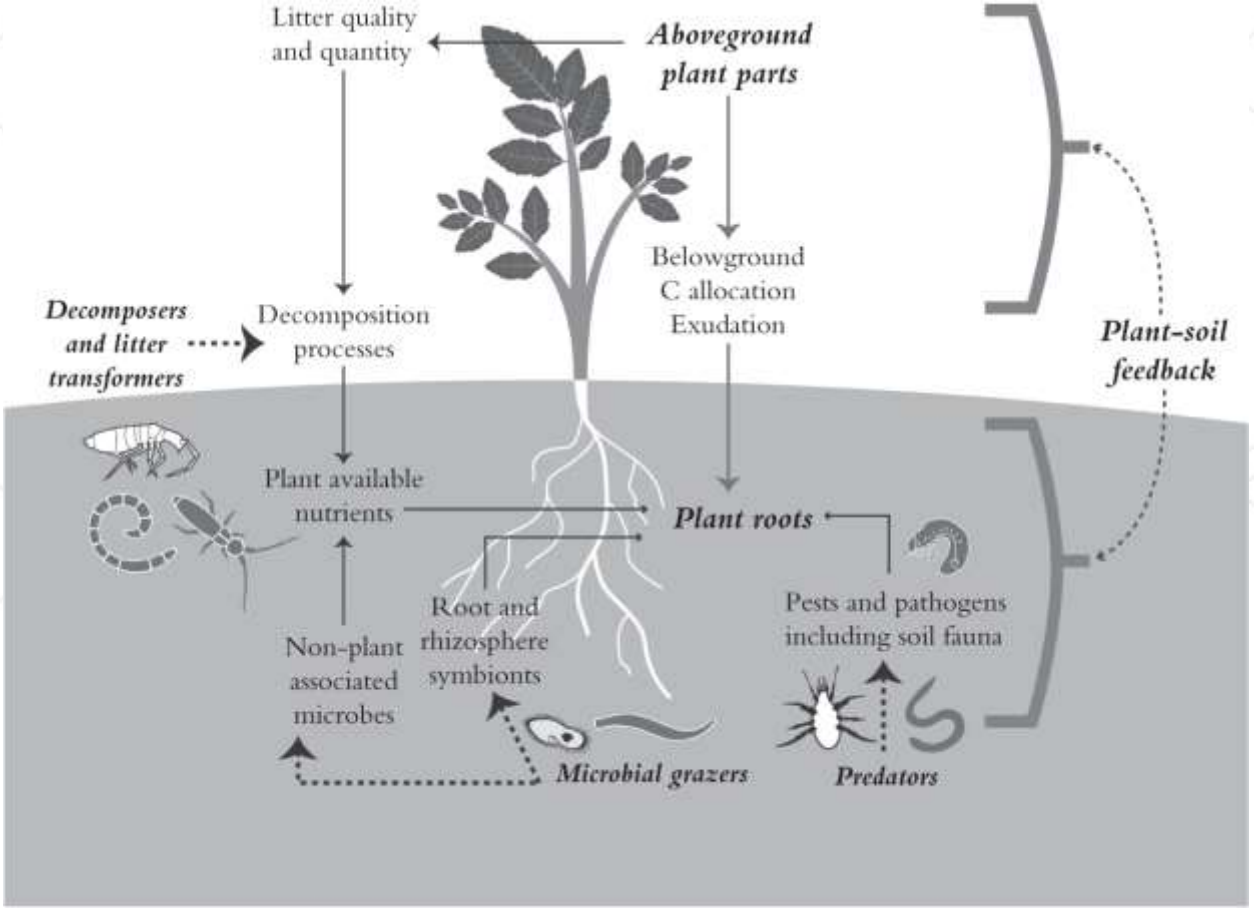
[2]Soil and Crop Sciences Section, School of Integrative Plant Sciences, Cornell University, Ithaca, New York 14853, USA

Soil Fauna Grouping Methods



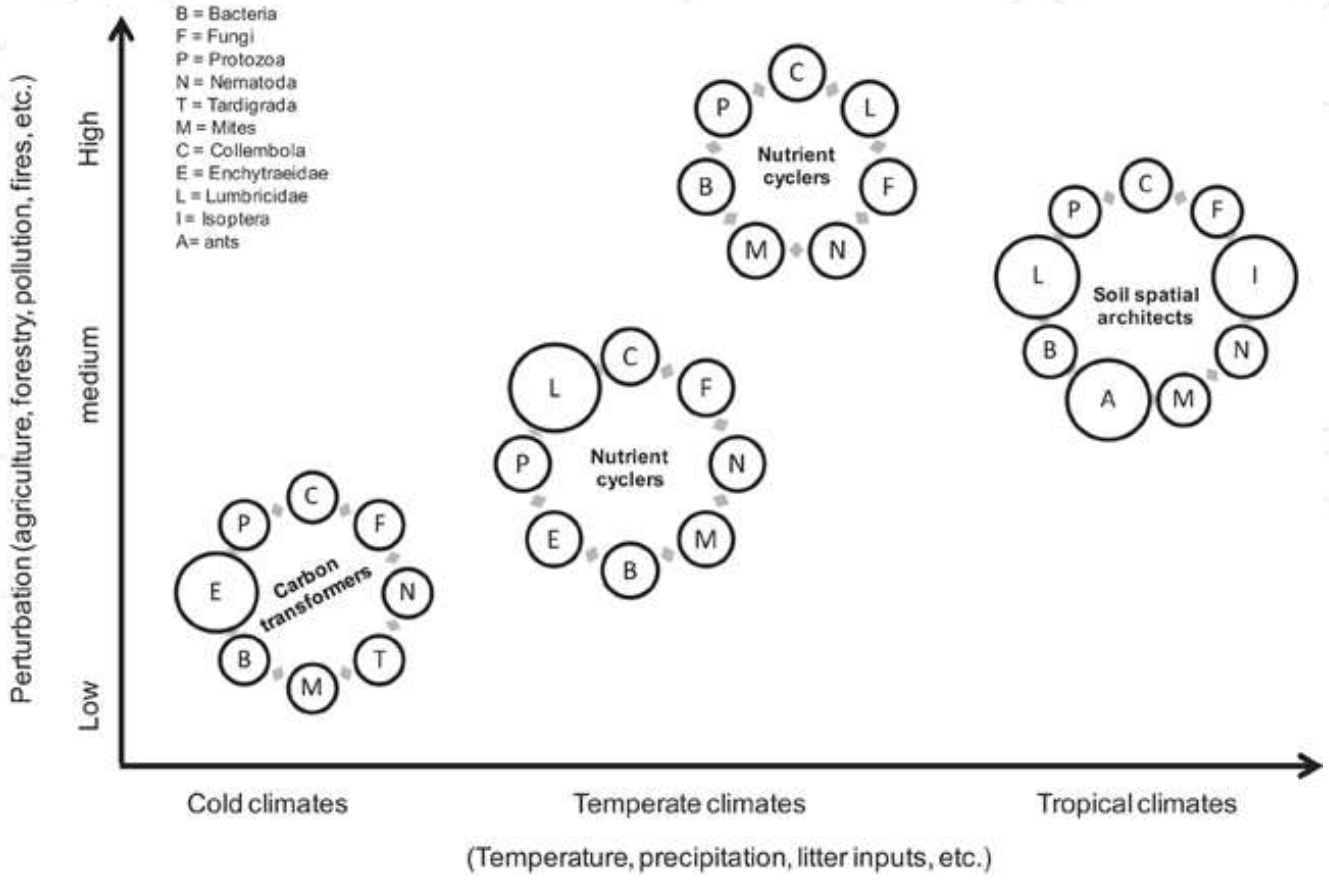
Swift et al., 1979

Soil Fauna Groups & Ecosystem Function



Nielsen, 2019

Soil Fauna Groups & Environment



María Jesús I. Briones, 2014

Process of Grouping Soil Fauna

Soil Fauna Group 1

Soil Fauna Group 2

Soil Fauna Group 3

Process of Grouping Soil Fauna

Soil Fauna Group 1

Soil Fauna Group 2

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Fauna impacts on **ecosystem function**

Process of Grouping Soil Fauna

Soil Fauna Group 1

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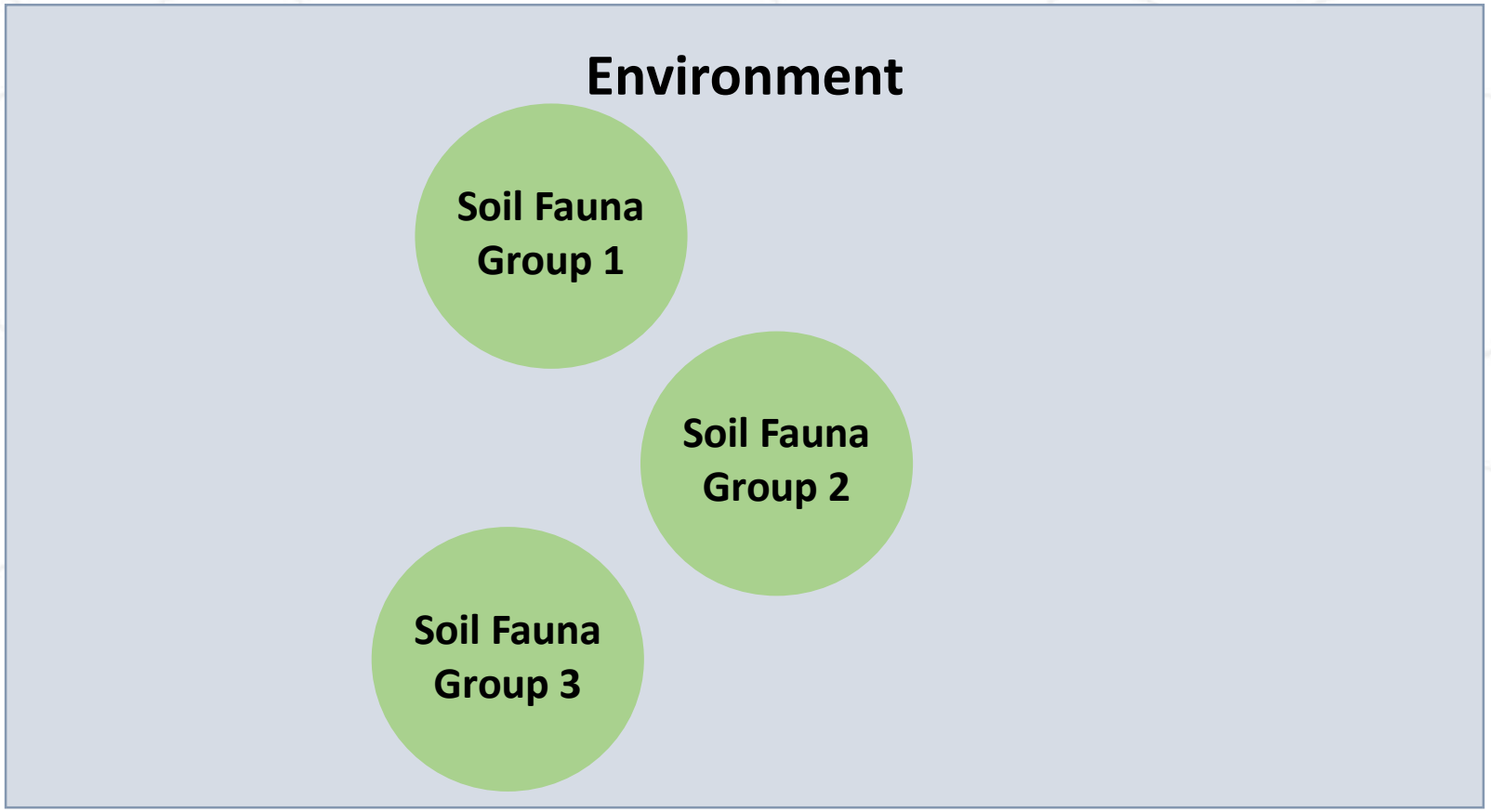
Fauna impacts on **ecosystem function**

Process of Grouping Soil Fauna

Environment

Process of Grouping Soil Fauna



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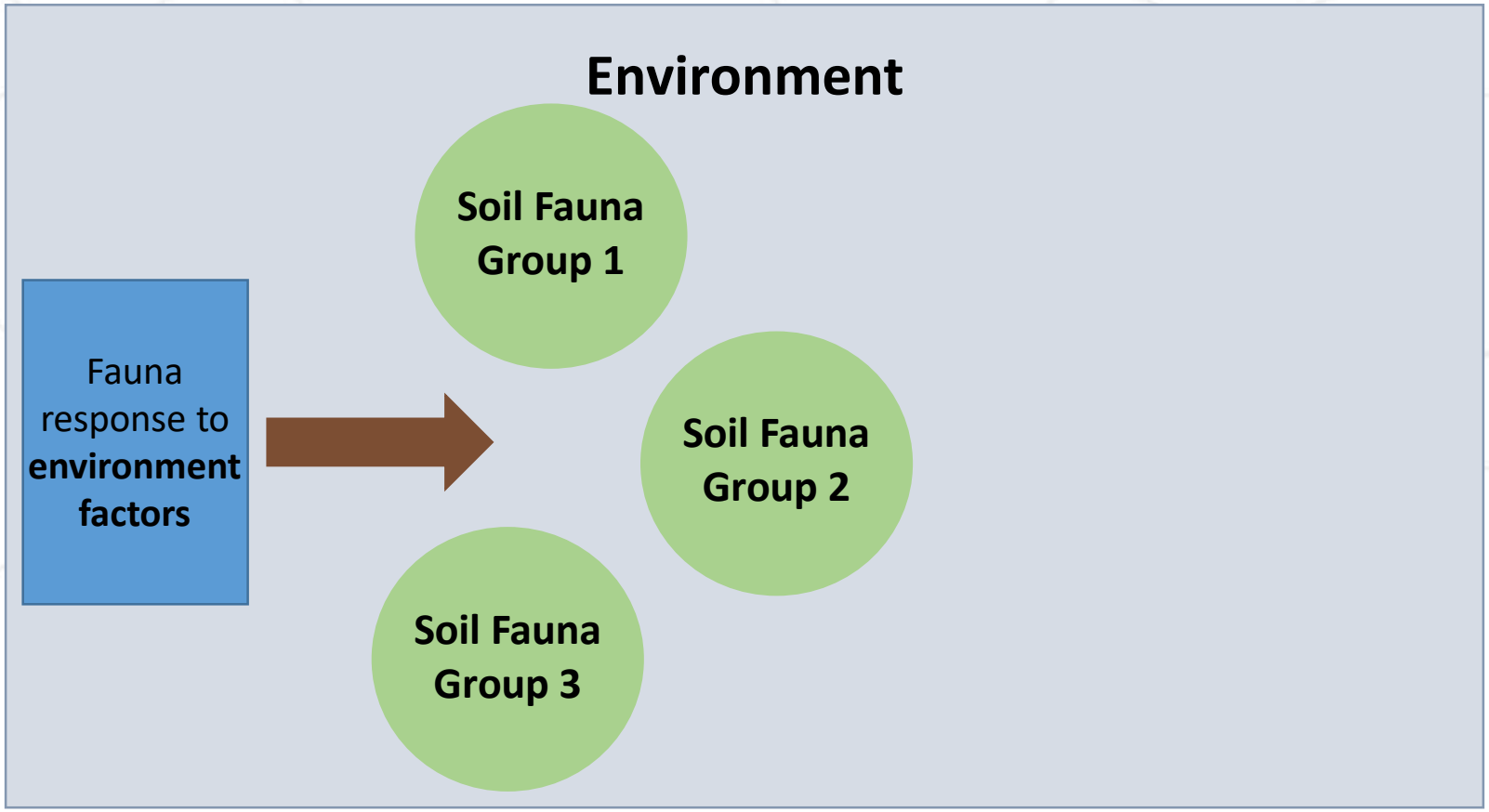
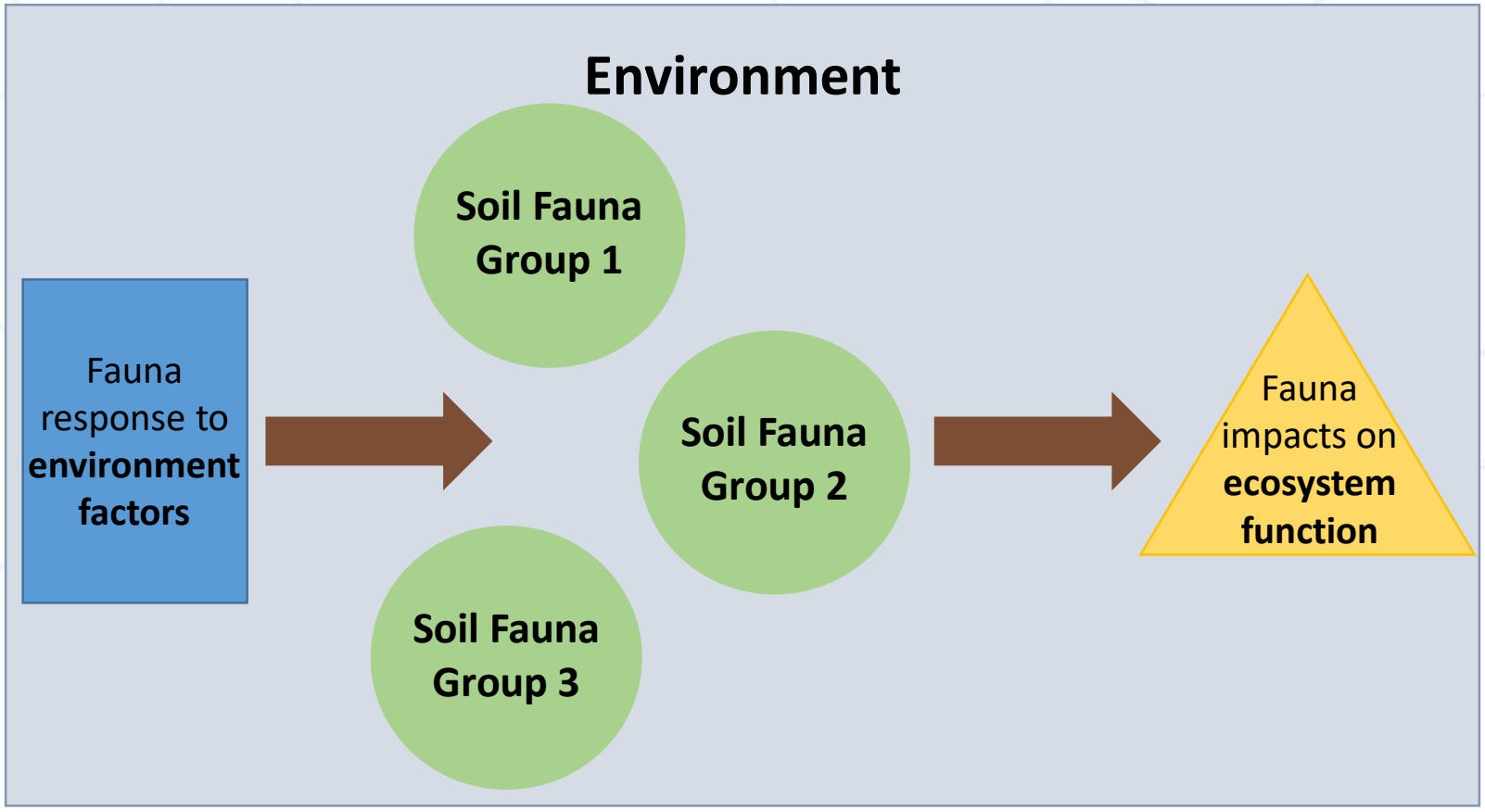


Grouping Soil Fauna by Environmental Responses to Predict Impacts on Ecosystem Functions



Statistical Techniques to Group Community Data

Statistical Techniques to Group Community Data

- Cluster Analysis
  - Hierarchical clustering (HCA)
  - Disjoint clustering
- Factor Analysis
  - Principle component analysis
  - Common factor analysis
  - Image factoring
  - Maximum likelihood method

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  - Image factoring
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Using Factor Analysis to Group Fauna Based on Responses to Environmental Conditions

Fauna response to **environment factors**

Soil Fauna Group 1

Soil Fauna Group 2

Soil Fauna Group 3

Factor Analysis

Sample #	Taxa 1	Taxa 2	Taxa 3	Taxa 4	Taxa 5	Taxa 6 . . .
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
. . .						

Factor Analysis

	Sample #	Taxa 1	Taxa 2	Taxa 3	Taxa 4	Taxa 5	Taxa 6 . . .
Treatment 1	1						
	2						
	3						
	4						
Treatment 2	5						
	6						
	7						
	8						
Treatment 3	9						
	10						
	. . .						

Factor Analysis






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10							
. . .							

https://insectdrawings.umn.edu/plant-feeding-mites-acari.html
https://insectsdiditfirst.files.wordpress.com/2013/05/collembolaboth.png

Factor Analysis

Sample #	Taxa 1	Taxa 2	Taxa 3	Taxa 4	Taxa 5	Taxa 6 . . .
1	12	0	2	19	0	115
2	53	0	40	66	0	142
3	34	0	31	43	2	97
4	62	0	71	79	0	135
5	78	3	86	85	0	85
6	90	0	102	119	0	117
7	88	2	97	92	0	106
8	47	0	44	55	0	72
9	15	0	24	26	0	93
10	23	0	18	32	11	88
. . .						

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Statistical Techniques to Explore Relationships in Environment

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- Canonical Correlation Analysis (CCorA)
- Canonical Correspondence Analysis (CCA)
- Redundancy Analysis (RDA)
- Path Analysis
- Structural Equation Modelling (SEM)
  - Traditional
  - Piecewise

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- Path Analysis
- **Structural Equation Modelling (SEM)**
  - Traditional
  - Piecewise

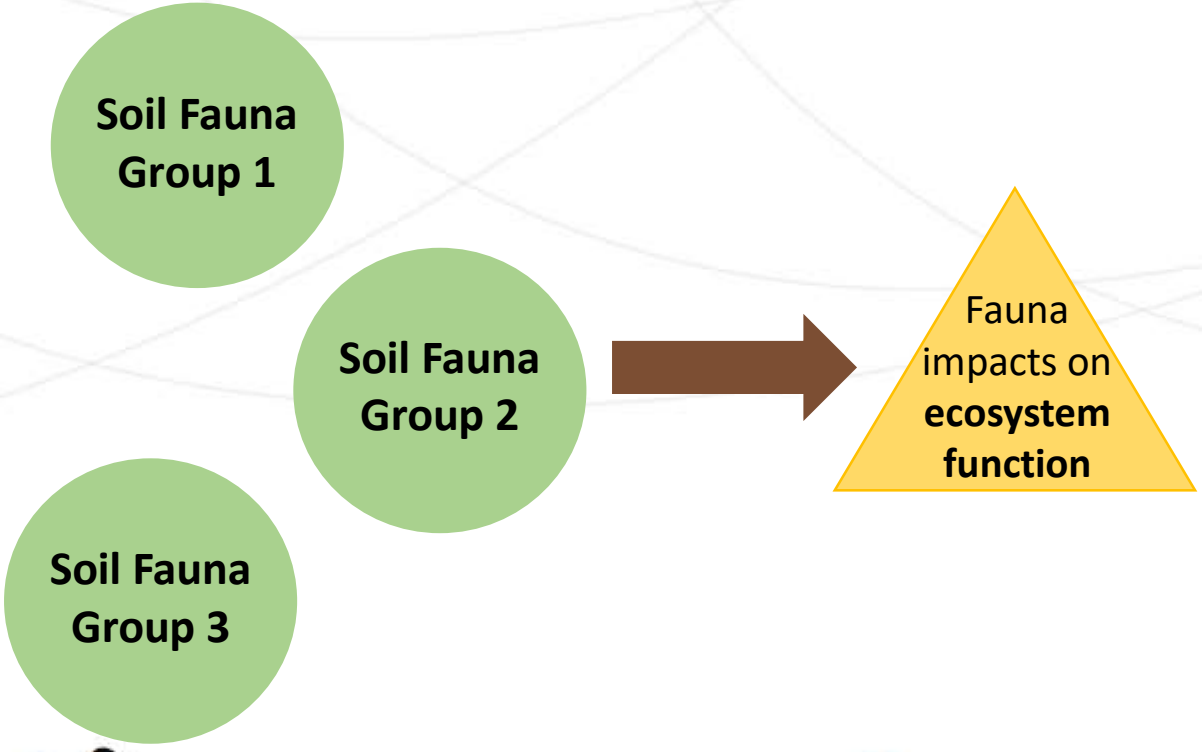
Structural Equation Modelling

- Traditional SEM
  - Variance-covariance matrices
- Piecewise SEM
  - Linear regressions

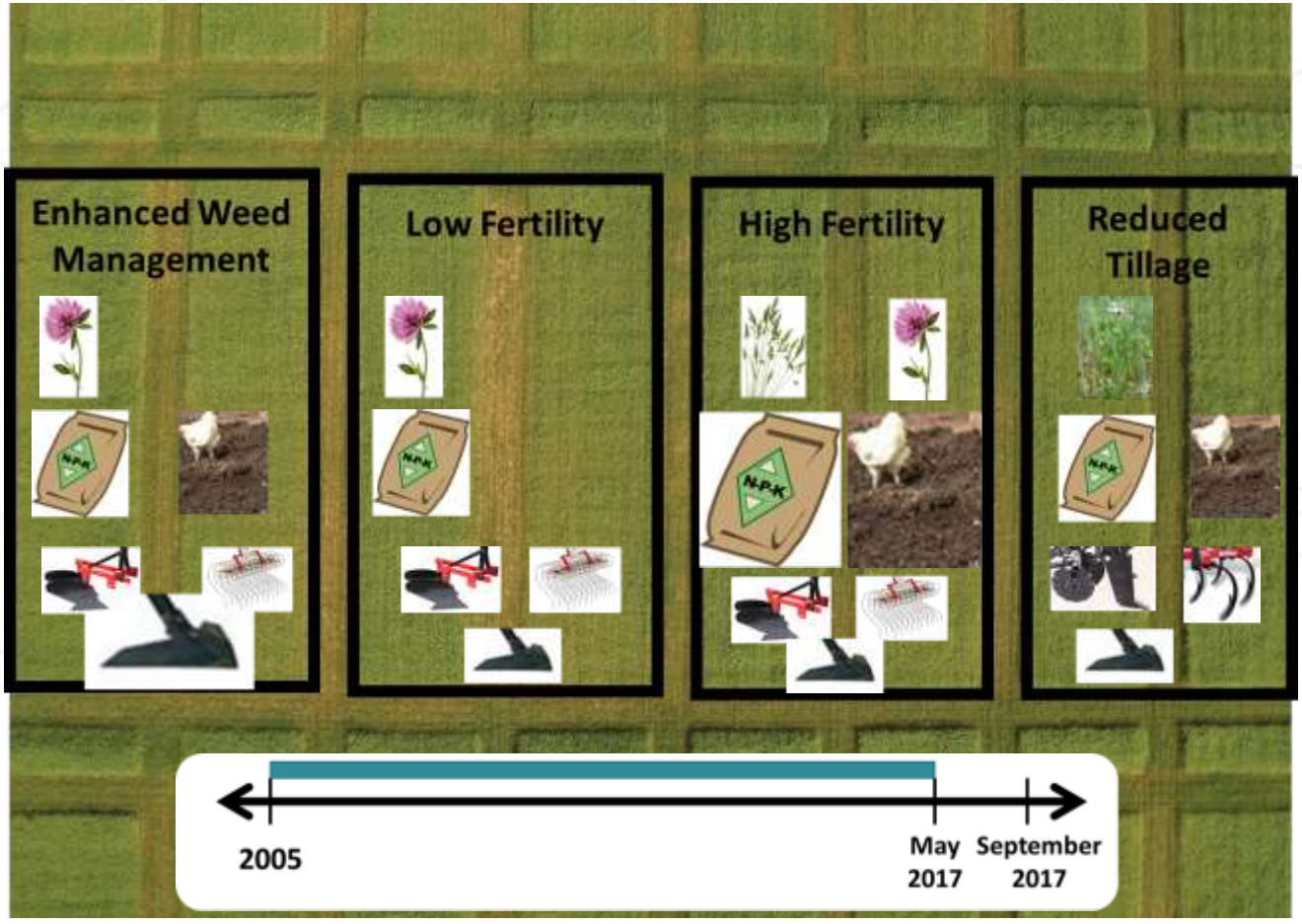
GOAL: Determine relationships between variables with directionality

Structural Equation Modelling

GOAL: Determine relationships between variables with directionality



Organic Grain Cropping Systems Experiment



Aerial Photo: E. Shields

OGCS Legacy Effects Trial

- **Evaluate legacy effects**
- Experiment area was moldboard plowed, then disked and harrowed
- Sorghum sudangrass crop
- After planting, no further management before termination

Response Variables

Soil Surface Moisture

Respiration

Active Carbon

Organic Matter

pH

Soil Characteristics

36 days before planting

Magnesium

Nitrate

Aggregate Stability

Phosphorus

Potassium

Calcium

Crop Biomass

Total Weed Biomass

Annual Weed Biomass

Perennial Weed Biomass

Above Ground Plant Biomass

63 days after planting

Indicator Species

Weed Species Richness

Weed Community Composition

Total Abundance

Family Abundances

Soil Invertebrates

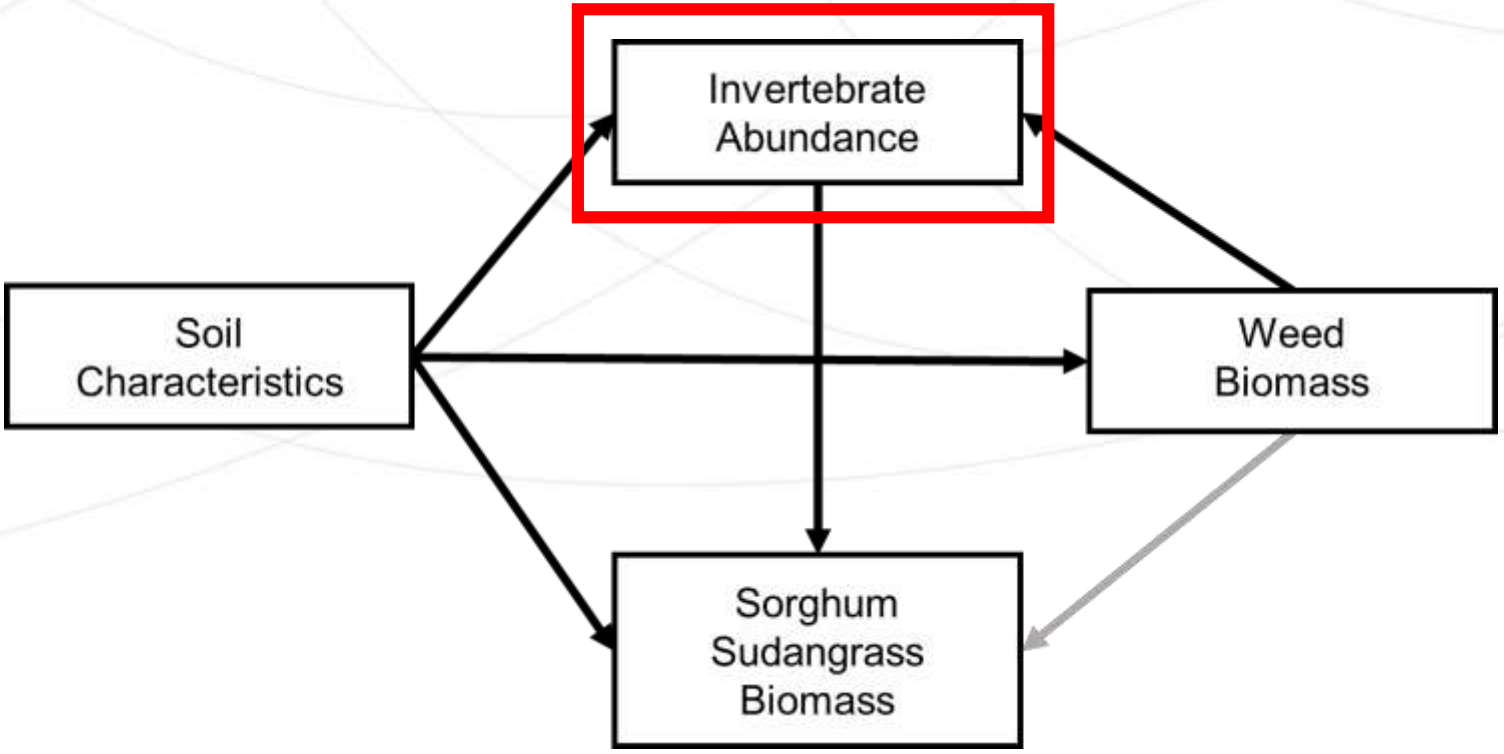
34 and 70 days after planting

Community Composition

Indicator Species

Agroecosystem Interactions

Piecewise Structural Equation Modelling



SEM: Soil Invertebrates

SEM: Soil Invertebrates

FaunaF1

FaunaF2

Photos: (1) http://www.soilbiodiversityuk.myspecies.info (2) https://www.[illegible].org (3) [illegible]padil[illegible].au (4) https://www.ent.iastate.edu (5) https://www.photo.net/ (6) http://www.[illegible]species.[illegible]

SEM: Soil Invertebrates

FaunaF1

FaunaF2

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SEM: Above Ground Biomass

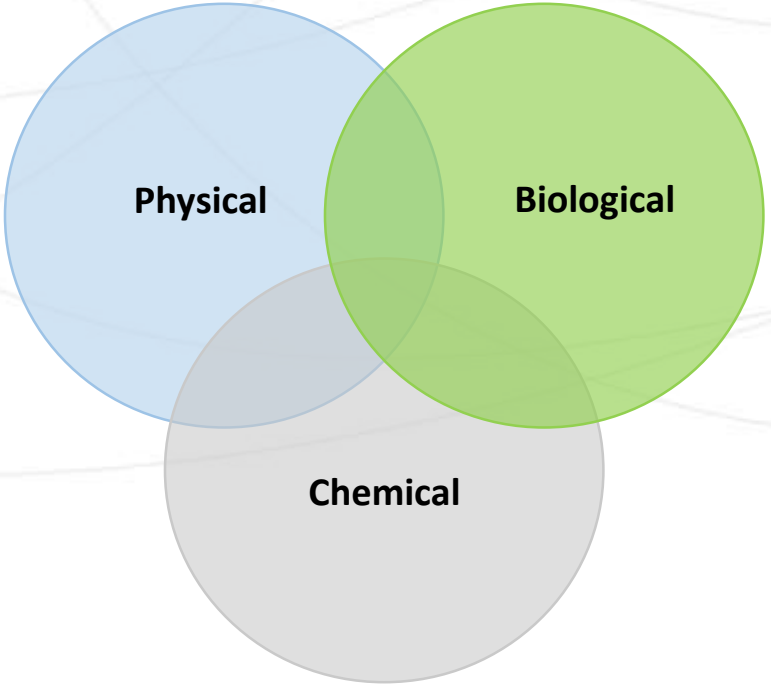
WeedsF1

Crop Biomass

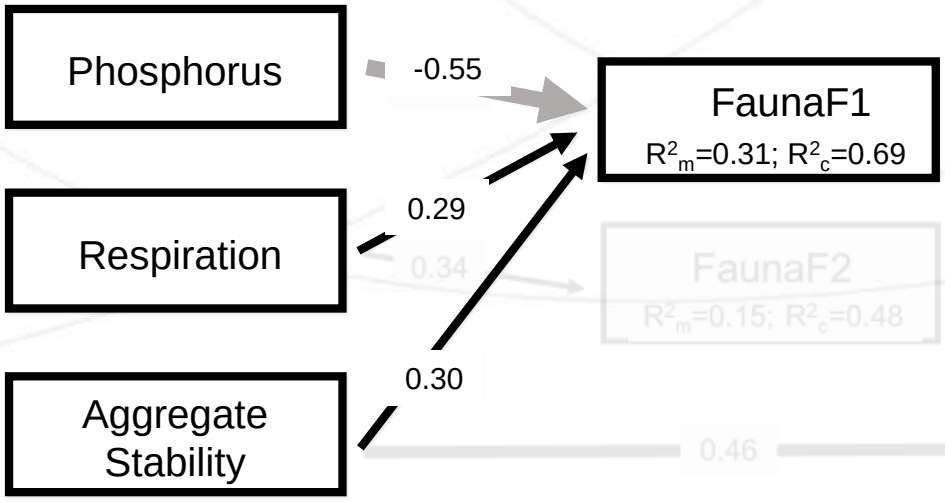
(1) http://purdueturftips.blogspot.com (2) https://courses.missouristate.edu (3) https://www.canr.msu.edu

SEM: Soil Characteristics

- Soil Moisture
- Phosphorus
- Respiration
- Aggregate Stability



Multiple soil characteristics were predictive of FaunaF1



FaunaF2 only impacted by respiration

Soil Moisture

Phosphorus

Respiration

Aggregate Stability

0.65

-0.55

0.29

0.34

0.30

0.46

FaunaF1

R^2_m=0.31; R^2_c=0.69

FaunaF2

R^2_m=0.15; R^2_c=0.48

0.31

WeedsF1 only impacted by soil moisture

Crop biomass impacted by diverse factors

WeedsF1

-0.38

FaunaF2

0.31

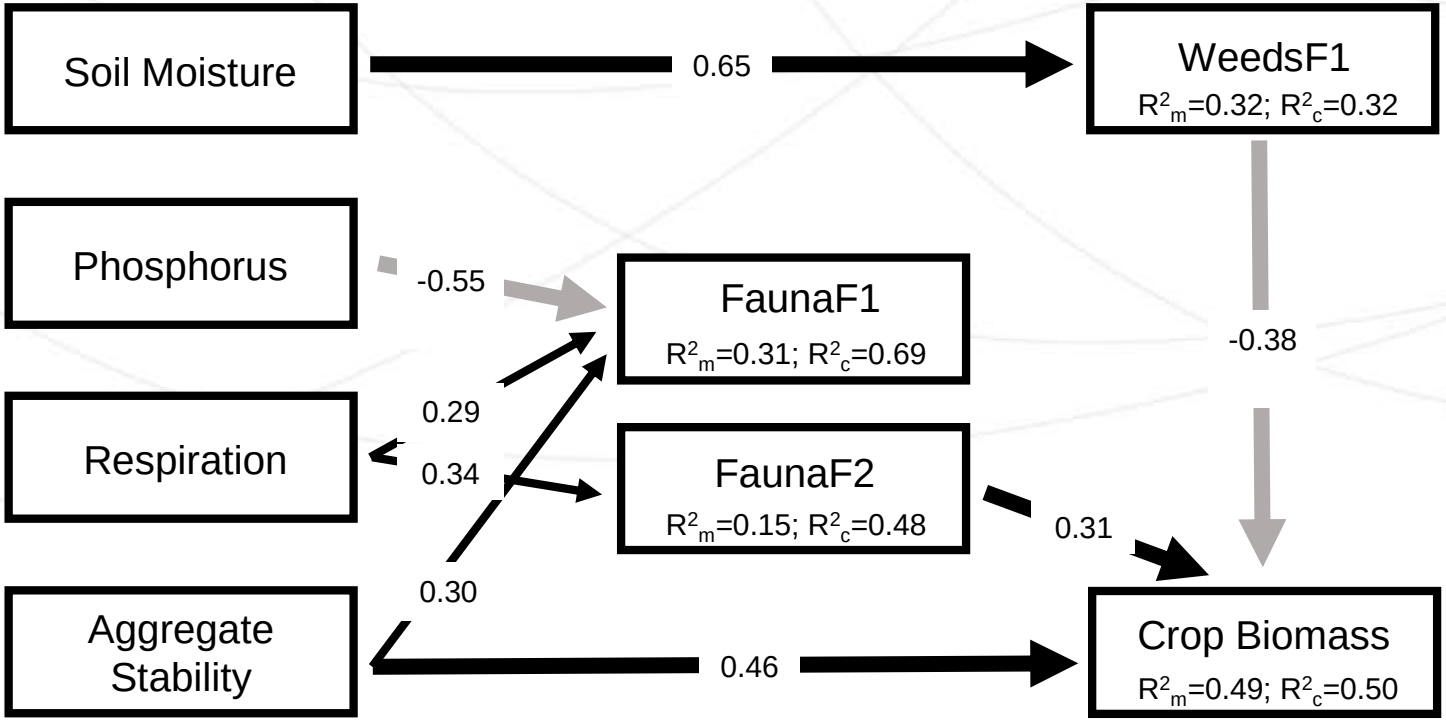
Aggregate Stability

0.46

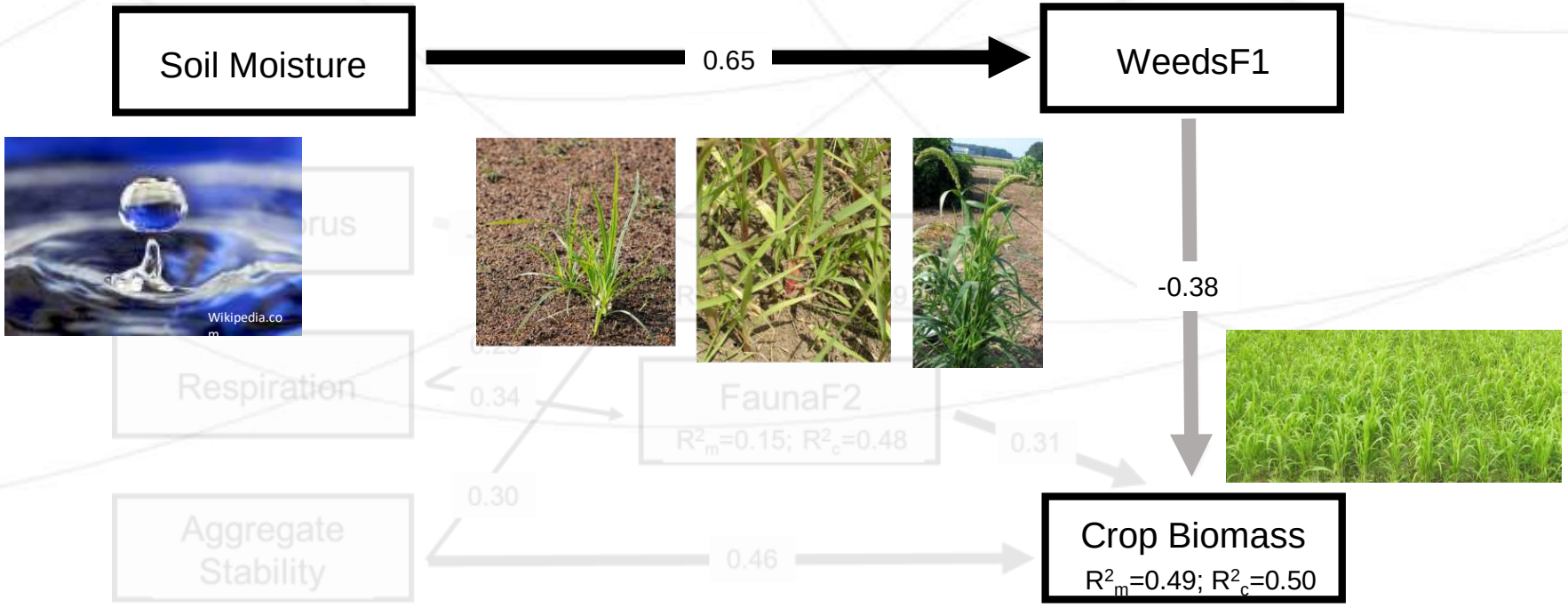
Crop Biomass

R^2_m=0.49; R^2_c=0.50

Complete SEM model for Organic Grain Cropping Systems



Weeds mediate soil moisture effects on crop productivity



Soil invertebrates mediate microbial community effects on crop productivity

Respiration

0.34

FaunaF2

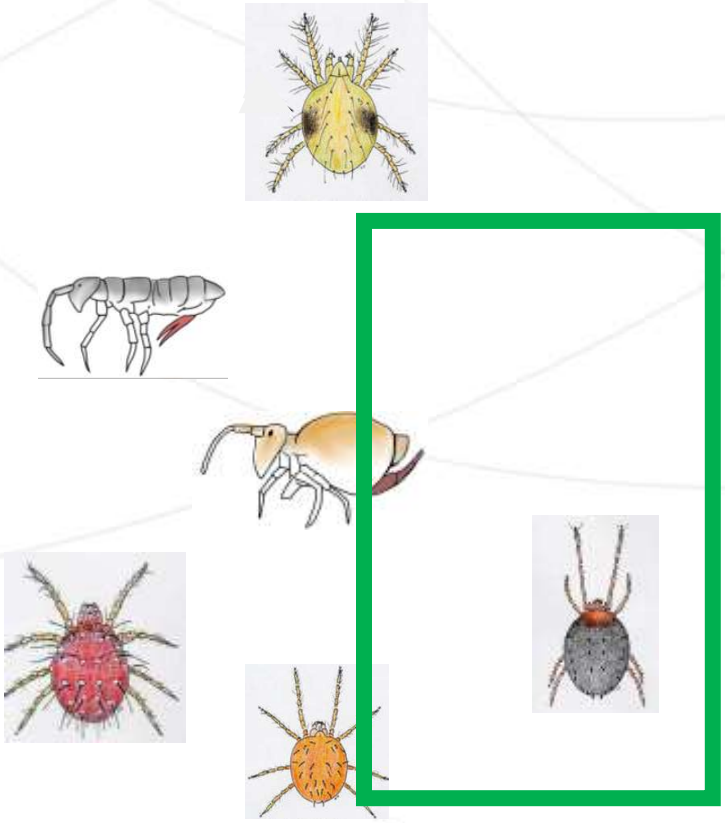
R^2_m=0.15; R^2_c=0.48

0.31

Crop Biomass

R^2_m=0.49; R^2_c=0.50

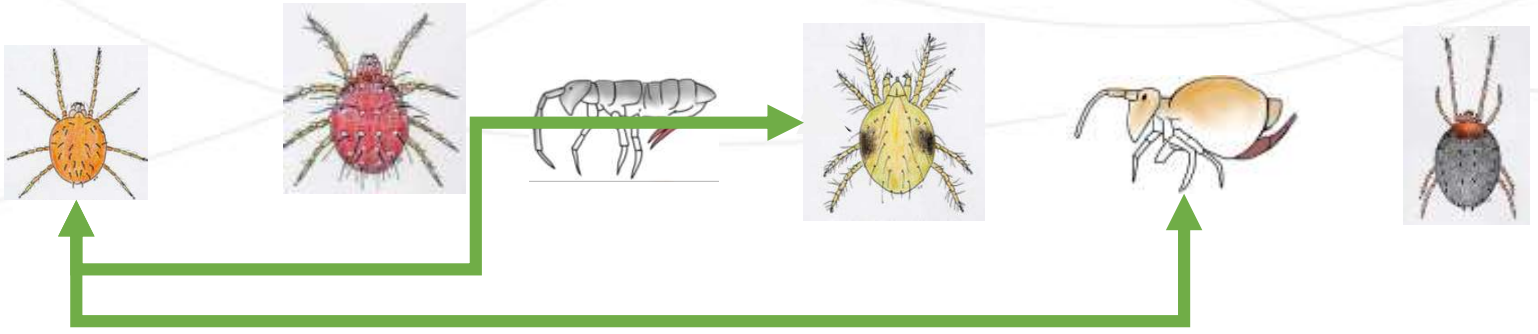
Main Take-Aways from Example



Crop Production

What does this mean for soil ecology?

Another option for identifying correlation structures between taxa in a diverse dataset



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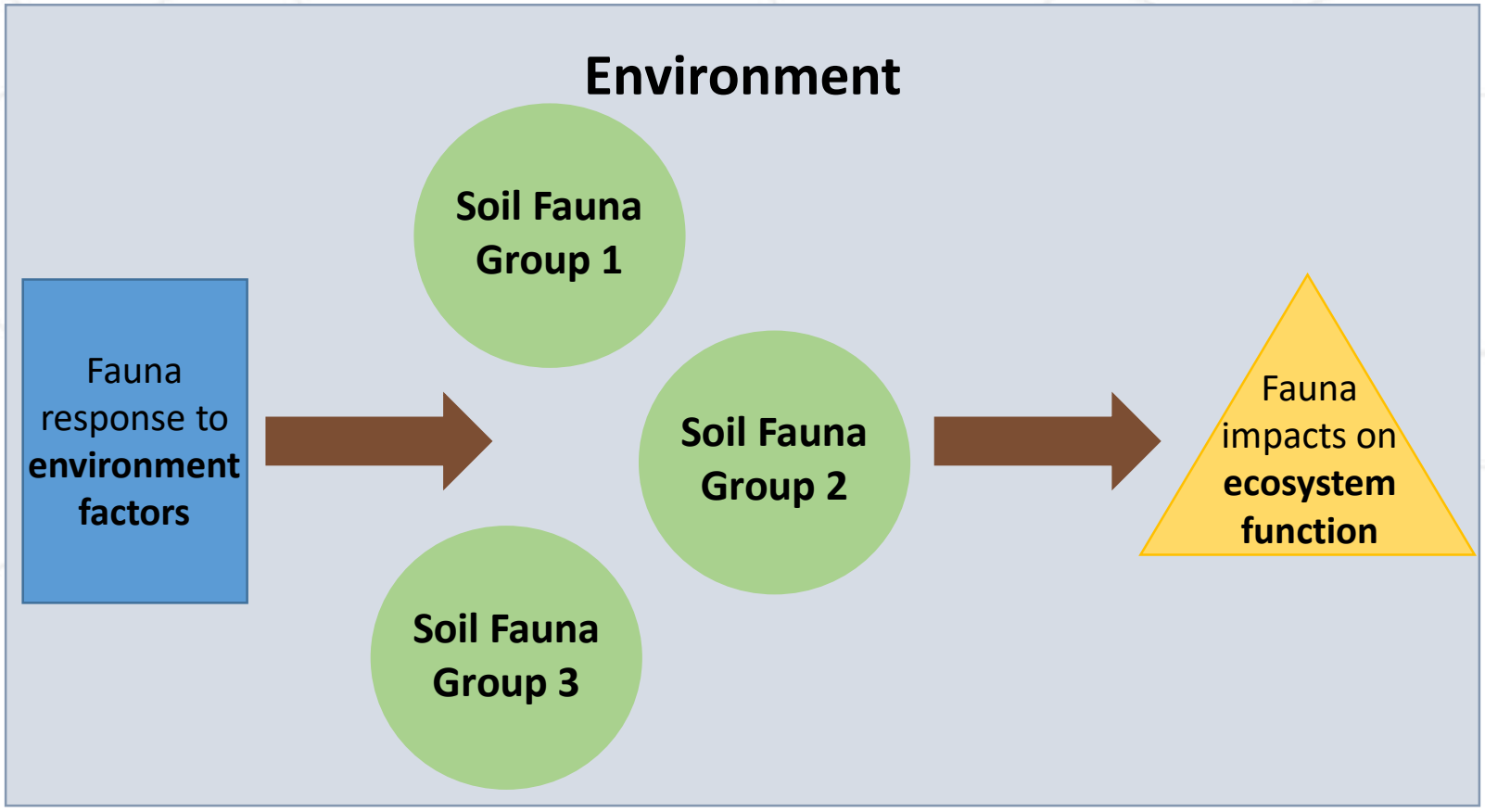
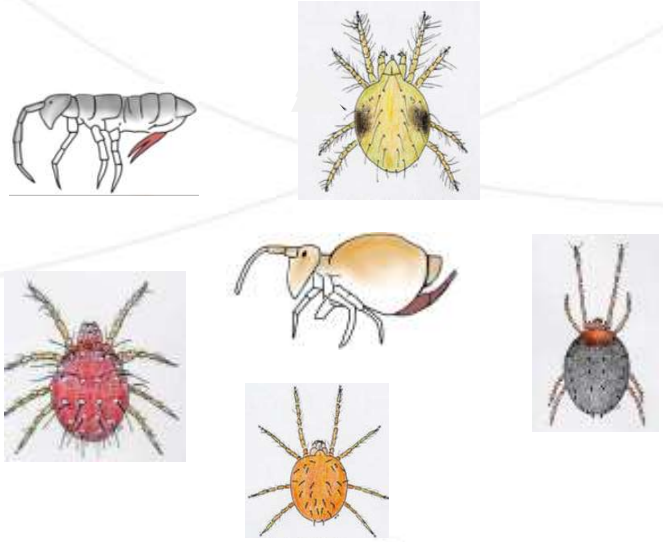


What does this mean for soil ecology?

A technique to consider to when analyzing how soil fauna communities and their interactions contribute to ecosystem services



Ecosystem Services

What are the next steps?

- Determine which taxonomic level of identification is best when applying these statistical techniques
- Explore fauna relationships using these techniques in different environmental contexts
  - Forests
  - Other Cropping Systems
  - Tropical Environments

Acknowledgements

- Sustainable Cropping Systems Lab (PI: Matthew Ryan)
- Soil Arthropod Ecology Lab (PI: Kyle Wickings)
- Everyone who assisted with the Organic Grains Cropping Systems Experiment
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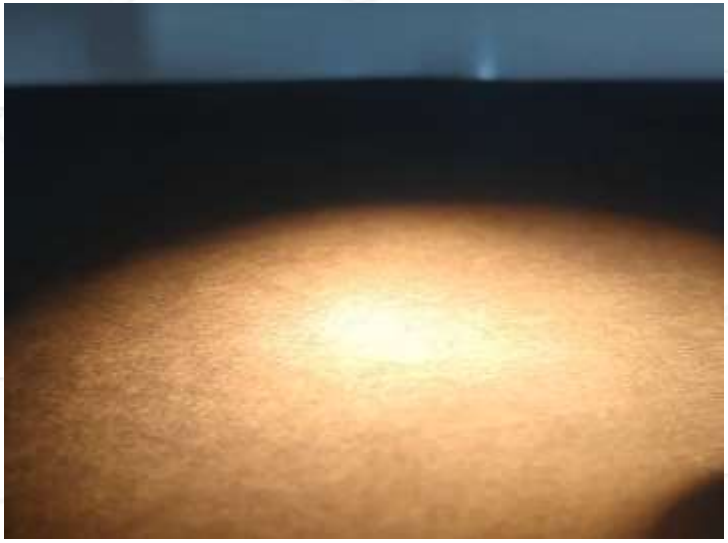
Contact Information

Ashley Jernigan

- Email: abj35@cornell.edu
- Twitter: https://twitter.com/Jernigan_AB
- LinkedIn: https://www.linkedin.com/in/ashley-jernigan-0a765188/
- ResearchGate: https://www.researchgate.net/profile/Ashley_Jernigan



Further Information:

Jernigan, A. B., Wickings, K., Mohler, C. L., Caldwell, B. A., Pelzer, C. J., Wayman, S., and Ryan, M. R.: Legacy effects of contrasting organic grain cropping systems on soil health indicators, soil invertebrates, weeds, and crop yield, Agr. Syst., 177, 102719, https://doi.org/10.1016/j.agsy.2019.102719, 2020.

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