Understanding the Consequences of Biodiversity Loss for Ecosystem Functioning:

Integration of Quantitative System Modeling of Trophic Networks and Experimental Long-Term Data

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Outline:

Introduction
Methods
Preliminary Results and discussion
Conclusions
Herbivory

Biodiversity

Decomposition

Plant productivity

Polination

soil microbial biomass and respiration

(Ebeling et al., 2008; Vogel et al., 2013)

(Loranger et al., 2014)

(Balvanera et al., 2006)

(Ebeling et al., 2008)

(Eisenhauer et al., 2012; Vogel et al., 2013)
(Ebeling et al., 2014)

Also Petermann et al. 2010; Scherber et al. 2010; Ebeling et al., 2014, Lefcheck et al., 2015

Eisenhauer et al., 2012
Ecosystem emergence properties: whole is incommensurable and greater than the sum or difference of its parts.
It is shown that plant diversity increases biomass and abundance of organisms within different trophic levels:

- Plant biomass (Balvanera et al., 2006)
- Microbial biomass (Vogel et al., 2013) (Eisenhauer et al., 2012)
- Abundance of herbivore arthropods (Ebeling et al., 2014)
- Abundance of decomposer arthropods (Ebeling et al., 2014)
- Abundance of soil decomposers (Ebeling et al., 2014)

1. Plant diversity might increase system conservation properties (maximize storage).
Hypotheses:

2. Plant species richness affect different function rates and processes in ecosystem:

   flower visits by pollinators (Ebeling et al., 2008)
   herbivory rates (Loranger et al., 2014)
   predation rates
   decomposition (Ebeling et al., 2008)
   and decomposition rates (Vogel et al., 2013).
   microbial respiration (Vogel et al., 2013).

2. Plant diversity increases total system activity (maximize throughflow) and internal organization (maximize circulation of matter).
3. Studies shows that in ecosystems with higher plant diversity the potential trophic links are more fully realized in contrast to the low plant diversity systems. (Rzanny, 2012)

It is found also that plant species richness affects diversity of the organisms of the consequent trophic levels. For instance:

- affect pollinator richness (Ebeling et al., 2008),
- increases species diversity of herbivores (Ebeling et al., 2014),
- increases species diversity of decomposers (Ebeling et al., 2014),
- increase in species diversity of soil decomposers (Eisenhauer et al., 2012).

Also the diversity is increasing the multiple ecosystem functioning simultaneously (Ebeling et al., 2008)

3. Plant diversity increases level of system development and stability (information growth).
Field site of the Jena Experiment showing the main experimental plots (20/20 m) varying in plant species richness (1, 2, 4, 8, 16, and 60) and plant functional group richness (1, 2, 3, and 4: grasses, small herbs, tall herbs, legumes).

Photo credit: http://www.the-jena-experiment.de/
Study area
**Aim:** to test if whole network functions of grasslands change along the plant biodiversity variations.

Flow based trophic networks (Biomass based)

Multinetwork Comparison

Effect of Biodiversity losses

Functional System-wide Properties

\[
\begin{align*}
\frac{dx}{dt} &= 0 \\
\frac{dx}{dt} &= F_1 + Z \\
\frac{-dx}{dt} &= -F_1 - Y
\end{align*}
\]
Step 1

Collaboration: to bring the expertise of multiple research groups to create the conceptualize the model of ecosystem.
Below-ground fauna sampling

Photo credit: http://www.the-jena-experiment.de/
Above-ground fauna sampling

Photo credit: http://www.the-jena-experiment.de/
Above-ground fauna sampling

Photo credit: http://www.the-jena-experiment.de/
Engineering activity of fauna

Photo credit: (Ebeling et al., 2006)
http://www.the-jena-experiment.de/
Methods

80 main plots
Methods

above-ground

below-ground

→ internal flow (f)

→ inflow (z)

→ outflow (y)

Currency: biomass (g dry mass m\(^{-2}\) d\(^{-1}\))
Biomass models (trophic networks) for plots with low (A) (1 species) and high (B) (60 species) plant species richness. (red arrows are inflows and outflows, black arrows are internal flows).
Number of compartments: 12
Link Density: 2.5
Connectance: 0.208333

Number of flows:
Inflow: 1
Outflow: 10
Internal flows: 30
Network analysis is performed based on the final state of the solution when systems have reached a static steady state (\( \frac{dx_i}{dt} = 0 \), when inputs and outputs become equal).
<table>
<thead>
<tr>
<th>Network measure, abbreviation (units)</th>
<th>Equation</th>
</tr>
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<tbody>
<tr>
<td><strong>Total System Storage, ( TSS ) (gm(^{-2}))</strong></td>
<td>( TSS = \sum X_i ), where ( X_i ) is the amount of storage of compartment ( i=1,\ldots, n ), where ( n ) is a number of compartments.</td>
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<tr>
<td><strong>Total System Throughflow, ( TST ) (gm(^{-2})d(^{-1}))</strong></td>
<td>( TST = \sum T_i ), where ( T_i ) is the total amount of flow through compartment ( 1,\ldots, n ), where ( n ) is a number of compartments. Hannon, 1973; Finn, 1976; Han, 1997.</td>
</tr>
<tr>
<td><strong>Cycling Index, ( CI ) (unitless)</strong></td>
<td>( CI = \frac{TST_c}{TST} ), where ( TST_c ) is the cycled portion of ( TST ), is the weighted sum of cycling efficiencies ( C_i ) of all compartments ( i=1,\ldots, n ), where ( n ) is a number of compartments. ( C_i = \frac{(n_{ii} - 1)}{n_{ii}} ), where ( n_{ii} ) is the number of times a flow quantity will return to ( i ) before being lost from the system, ( (n_{ii} - 1) ) is the relative amount cycled. Finn, 1976; 1980.</td>
</tr>
<tr>
<td><strong>Relative ascendancy, ( RA ) (unitless)</strong></td>
<td>( RA = \frac{AMI}{H_f} ), where AMI (bits) - the average mutual (Rutledge et al., 1976), ( H_f ) is a Shannon (Shannon, 1948) flow diversity, Ulanowicz, 1986; 1997; Ulanowicz and Mann, 1981.</td>
</tr>
</tbody>
</table>
To compare networks within the study area in respect to plant biodiversity variations.
Field site of the Jena Experiment showing the main experimental plots (20/20 m) varying in plant species richness (1, 2, 4, 8, 16, and 60) and plant functional group richness (1, 2, 3, and 4: grasses, small herbs, tall herbs, legumes).

Photo credit: http://www.the-jena-experiment.de/
Preliminary Results

F = 4.7, DF = 1.75, p = 0.03
F=6.94, DF=1.75, p=0.01
F=4.69, DF=1,74, p=0.03
Preliminary Results

F=3.99, DF=1,73, p=0.04

F=5.25, DF=1,73, p=0.02
Conclusions

Our results demonstrate that plant diversity has whole-system-level effects on the ecosystem and its functions. Plant species richness positively affects conservation functions of ecosystems through increase in storage. The storage pool would buffer the system against variation in inputs and outputs to the system.

Furthermore, our results reveal legumes to be essential in circulation of biomass within the study systems.

Positive effects of plant species richness on system throughflow indicates that increasing plant diversity maximizes system power to perform work, while plant diversity loss reduces ecosystem activity.

Moreover, the positive effects of plant species richness on increase of relative ascendancy demonstrate the stabilizing effects of plant diversity on the ecosystem by making it more resistant to rapid changes by external perturbations.
Ecosystems are complex, but with a balanced mix of empirical description and theory they will yield to scientific understanding.

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THE JENA EXPERIMENT

Freie Universität Berlin

Technische Universität München

Faculty of Engineering

An interdisciplinary approach to engineering at the University of Georgia