Using plant functional traits to understand the landscape distribution of multiple ecosystem services

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The problem: Ecosystem services mapping methods

Challenge: using the best possible ecological understanding to produce ecosystem service assessments

- Ecosystem services mapping studies often use land use / land cover – ES identity
- Source of uncertainty in estimates of ecosystem services

Need to introduce ecological realism!
Presentation overview

• The role of (plant) functional diversity in ecosystem service provision
• A model for direct and indirect effects of land use and environment on ecosystem services
• Using plant functional traits to understand the landscape distribution of multiple ecosystem services
  ➢ Case study in the French Alps
Functional traits as indicators of ecosystem services

• Defining relationships between organisms’ characters and ecosystem service delivery through relationships between traits and key ecosystem functions

• Traits through which organisms:
  – Consume or transform resources
  – Modify the physical structure of the habitat
  – Modify the chemistry of the environment
  – Interact with other organisms (incl. dispersal)
  – In some cases (e.g. microbes) the traits sensu stricto are actually not known, just the participation to specific processes

➢ Traits as tools to quantify ecosystem service delivery

* Trait value at species or community level; functional divergence
Structure-function relationships in plants: plant functional traits

**Function**
- Fecundity
- Dispersal
- Establishment
- Light interception
- Competitive ability
- Resorption of nutrients; decomposability of litter
- Absorption (nutrients, water)
- Carbon fluxes (exsudation...)

**Functional trait**
- Seed mass
- Plant canopy height
- Traits of living leaves
- NIRS spectrum
- Density, diameter
- Specific root length
Evidence for the effects of functional traits on ecosystem functioning

- Many services are underpinned by multiple traits, often from several groups of organisms
Species functional traits: Fodder digestibility in montane grasslands

Relation between digestibility and (A) growing degree days to flowering, (B) leaf dry matter content for 13 grass species from permanent grasslands grown in monocultures

- **Species traits** determine digestibility
- Relationship confirmed at community level: Garnier et al. unpublished

**Notes:**

- Species traits determine digestibility
- Relationship confirmed at community level: Garnier et al. unpublished

**Graphs:**

- **(A)** Digestibility (g/kg DM) vs. Degree days until flowering
- **(B)** Digestibility (g/kg DM) vs. Leaf Dry Matter Content (mg/g)

*Pontes et al. Funct Ecol 2007*
Community-level functional trait effects: Litter decomposability along climate and land use gradients in Europe

~ MAT - DistInt - DistFreq
+ Rainfall*DistFreq + MAT*DisInt

Conceptual model:
Using plant functional traits to understand biodiversity responses and ecosystem effects.

Mapping ecosystem services based on land use

Land use

Topography

Soil properties

Ecosystem properties

Ecosystem services

Plant functional diversity

TRAIT EFFECTS = INDIRECT EFFECTS

TRAITS EFFECTS = INDIRECT EFFECTS

DIRECT EFFECTS

Lavorel et al. J. Ecol. In press
Mapping ecosystem services using plant traits

Lavorel et al. J. Ecol. In press
The French alpine LTSER platform

Transdisciplinary network
40 scientists, 25 PhD & postdocs
1 national & 1 regional park

Guisane catchment

Vercors high plateaux

Villar d’Arène

Summer range
Permanent grasslands (mowing)
Summer grazing

Terraces (crops)
Mowing & fertilised
Mowing & unfertilised
Spring+autumn grazing
Ecosystem services identified by local stakeholders at Lautaret

<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Ecosystem Service</th>
<th>Stakeholder Description of Ecosystem Attributes</th>
<th>Modelled Relevant Ecosystem Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local farmers</td>
<td>Grass quantity for hay &amp; grazing</td>
<td></td>
<td>Above-ground biomass in mown grasslands</td>
</tr>
<tr>
<td></td>
<td>Forage quality</td>
<td></td>
<td>Sward height</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Palatability for grazing</td>
</tr>
<tr>
<td>National Park Authority</td>
<td>Flowering diversity for aesthetic value</td>
<td></td>
<td>Crude protein content</td>
</tr>
<tr>
<td>Visitors and locals</td>
<td>Conservation of biodiverse grasslands</td>
<td></td>
<td>Relative abundance of legumes</td>
</tr>
<tr>
<td>Locals</td>
<td>Appropriate stewardship of cultural landscape features</td>
<td></td>
<td>Plant diversity</td>
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<tr>
<td></td>
<td>Snow-gliding risk</td>
<td></td>
<td>Simpson's biodiversity index</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Large accumulations of dead grass</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Spring litter in un-mown grasslands</td>
</tr>
</tbody>
</table>

Measurable indicators

45 semi-structured interviews with locals and visitors

Quétier et al. 2007 Ecol. Appl.; 2009 REC
Statistical models of ecosystem services

Field data:
→ 55 vegetation surveys stratified by LU trajectory, altitude and landscape sectors

• Environmental drivers
  – Altitude, Slope, Land-use trajectories (LUT), Nitrogen and Phosphorus Nutrition Indices (NNI, PNI), soil Water Holding Capacity (WHC)

• Community functional traits (CWM, FDvg)
  – Vegetation Height, Leaf Dry Matter Content (LDMC), Leaf Nitrogen Content (LNC), Leaf Phosphorus Content (LPC), Flowering phenology

• Ecosystem properties
  – Green biomass (fodder quantity), Fodder quality (digestible N), Litter mass, soil C and N pools, Plant species diversity (H)

➢ GLM for alternative models with selection by adjusted-R and AIC
Step 1: Driving variables

- Land use
- Topography
- Soil properties
- Ecosystem properties
- Ecosystem services
- Plant community traits
Step 2: Modelling community functional trait responses

- Topography
- Land use
- Soil properties
- Ecosystem properties
- Ecosystem services
- Plant community traits

Leaf nitrogen content ~
31.0 - 0.015*Altitude + 0.23* mean Fert. / LU
Step 3: Projecting effects on ecosystem properties

**Community traits**
- Vegetation Height
- Leaf Nitrogen Content
- Leaf Dry Matter Content
- Flowering phenology

**Ecosystem properties**
- Digestibility
- Available soil nitrate
- Litter Mass
- Plant species diversity
- Biomass production

**Ecosystem services**
- Fodder quality
- Soil fertility
- Cultural heritage
- Aesthetic value
- Fodder quantity

Green biomass \( \sim -2 + 7.53 \times \text{LNC} + 6.56 \times \text{VegHt} + 7.83 \times \text{WHC} \)

**Topography**

**Land use**

**Soil properties**
Step 4: Projecting ecosystem services

Fodder quantity + Fodder quality + Flowering phenology

½ Date of flowering + ½ Phenological diversity

Overlay = sum of mapped values

Grassland agronomic value
Mapping multiple ecosystem services

Agronomic value

Cultural value

Pollination value

Soil C stocks

Total ES value

Lavorel et al. J. Ecol. In press
Step 5: Evaluating multi-functionality

Principal component analysis

1st axis of differentiation: Cultural heritage value

2nd axis of differentiation: Biomass production

Fodder production and plant species diversity independent: reconciling conservation and production objectives!
Conclusions

• Plant-trait based model provides a mechanistic view into dynamics of ecosystem services and into multifunctionality
• Strong determinism of services by land use: current management and land use legacies
• Criteria for ecosystem service integrated modelling:
  ☺ Biophysical realism
  ☺ Analysis of biophysical trade-offs and synergies
  ☺ Stakeholder involvement: beneficiaries identify ES and trait-based ES indicators
Thank you for your attention!
Direct and indirect abiotic effects on C and N stocks across the landscape
Application of the land use + abiotic model to a broader landscape

Gos et al. in prep.
Step 3: Projecting effects on ecosystem properties

Model results

- ‘LU+abiotic’ and ‘Traits’: better explanation than ‘LU’
- ‘LU+abiotic’ (if avail.) and ‘Traits’ equivalent

<table>
<thead>
<tr>
<th>Ecosystem property</th>
<th>CWM_VH</th>
<th>CWM_LDMC</th>
<th>CWM_LNC</th>
<th>CWM_LPC</th>
<th>FD_VH</th>
<th>FD_LDMC</th>
<th>FD_LNC</th>
<th>FD_LPC</th>
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<tbody>
<tr>
<td>Green biomass</td>
<td>&lt;0.001</td>
<td>0.016</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
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<tr>
<td>Litter mass</td>
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<td>0.507</td>
<td>0.074</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
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<td>&lt; 0.001</td>
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<td>Crude Protein</td>
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<td>Content</td>
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<td>&lt; 0.001</td>
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<tr>
<td>Soil carbon</td>
<td>0.679</td>
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<td>&lt; 0.001</td>
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</tbody>
</table>

- Prevalent role of CWM traits vs. limited role of FD traits in final model