Legume supported cropping systems for Europe

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Some background

• Europe imports 12% world soybean production (13 M t or 15 M ha of borrowed land)
• Growing meat consumption drives increased plant protein imports
• Fertiliser and soya bean prices are increasing
• Policy intervention has failed to increase areas of European legumes
Internationally traded reactive nitrogen

Fertilizer (31 Tg)

Grain (12 Tg)

Meat (0.8 Tg)

What contribution can legumes make to climate smart agriculture?

- How much do legumes contribute to N inputs in European agriculture?
- What affect do legumes have on N budgets?
- Can legumes contribute to greenhouse gas mitigation?
- What are the economics/barriers to legume production in Europe?
Estimating continental scale N fixation

- Many estimates exist of BNF per hectare in different crops in different countries
- BNF depends greatly on biomass
- >10-fold range in biomass from best to worst growing conditions, even within a country
- Area and yield data available for grain legumes, but hard to obtain for forage legumes
Estimated BNF in EU27 in 2009
The Totals

- BNF (kt)
- Grasslands
  - Temporary 173
  - Extensive 114
  - Intensive 305
  - Total Grassland 592
- Grain legumes 247
- Total EU27 839

- Fertiliser value at 0.9€ kgN\(^{-1}\) €755M

- Synthetic fertiliser application (2000) 11,200 kt N
Historical data analysis

- The biomass harvested from each crop sequence increased as the proportion of legume crops with the cropping sequence grew.

- Maximum N fixation rates associated with legume/non legume mixtures.

Iannetta et al, unpublished
Comparison of N\textsubscript{2}O emissions from legume and non-legume crops

<table>
<thead>
<tr>
<th>Category and Species</th>
<th>Site Years</th>
<th>Total N\textsubscript{2}O emissions per growing season or year (kg N\textsubscript{2}O-N ha\textsuperscript{-1})</th>
<th>Range</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Range</td>
<td>Mean</td>
</tr>
<tr>
<td>Pure legume stands</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfalfa</td>
<td>14</td>
<td>0.67-4.57</td>
<td>1.99</td>
<td></td>
</tr>
<tr>
<td>White clover</td>
<td>3</td>
<td>0.50 – 0.90</td>
<td>0.79</td>
<td></td>
</tr>
<tr>
<td>Mixed pasture sward</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grass-clover</td>
<td>8</td>
<td>0.10 – 1.30</td>
<td>0.54</td>
<td></td>
</tr>
<tr>
<td>Legume Crops</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Faba bean</td>
<td>1</td>
<td>-</td>
<td>0.41</td>
<td></td>
</tr>
<tr>
<td>Lupin</td>
<td>1</td>
<td>-</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>Chickpea</td>
<td>5</td>
<td>0.03 – 0.16</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>Field pea</td>
<td>6</td>
<td>0.38 – 1.73</td>
<td>0.65</td>
<td></td>
</tr>
<tr>
<td>Soybean</td>
<td>33</td>
<td>0.29 – 7.09</td>
<td>1.58</td>
<td></td>
</tr>
<tr>
<td>Mean of all legumes</td>
<td></td>
<td></td>
<td></td>
<td>1.29</td>
</tr>
</tbody>
</table>

Jensen et al., 2013, Agronomy for Sustainable Development
Nitrous oxide emissions
Pea cultivar matters

Pappa, unpublished data
Affects of *Rhizobium* species on $\text{N}_2\text{O}$ emissions

Itakura et al 2012, Nature Climate Change
Emission factors are sensitive to cultivar and climate

Williams et al, In preparation
Nitrous oxide emissions - Species and rotations matter – Romania 2011

![Graph showing cumulative N\textsubscript{2}O and yield for various crops and rotations.](image)
Environmental controls

$N_2O$ emissions more sensitive to rainfall than BNF

Williams et al, In preparation
Pre-crop effects

López-Bellido et al, 2011
Farming systems
Case study areas

- Sud-Muntenia, Romania (NARDI)
- Calabria, Italy (UDM)
- North-Eastern Scotland (SRUC)
- Western Sweden (SLU)
- Brandenburg, Germany (ZALF)

Source: Eurostat, M. Reckling
Generation and evaluation of crop rotations

Generation takes all agronomic suitable options into account

- Crop rotation model used to generate a series of crop rotations
- Evaluated by local agronomists

- Evaluation of whole crop rotations
  - Nitrogen assessment: N balance, nitrate-N leaching and N$_2$O emissions
  - Infestation risk assessment: Pests, diseases and weeds
  - Gross margin assessment: Revenues and costs

Bachinger & Zander 2007; Reckling et al. 2014a
## Crop rotation comparisons (selection)

<table>
<thead>
<tr>
<th>Country, Region</th>
<th>Non-legume rotation</th>
<th>Gross margin (Euro)</th>
<th>N leaching (kg/ha)</th>
<th>N$_2$O (kg/ha)</th>
<th>Legume rotation</th>
<th>Gross margin change</th>
<th>Leaching change</th>
<th>N$_2$O change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Romania</td>
<td>Rapeseed Maize Wheat</td>
<td>432</td>
<td>13</td>
<td>3.5</td>
<td>Soybean Maize Wheat Rapeseed</td>
<td>+86</td>
<td>+1</td>
<td>-0.7</td>
</tr>
<tr>
<td>Sweden</td>
<td>Rapeseed Wheat Linseed Wheat S barley</td>
<td>644</td>
<td>34</td>
<td>3.7</td>
<td>Rapeseed Wheat Fababean Wheat S barley</td>
<td>-51</td>
<td>0</td>
<td>-1.3</td>
</tr>
<tr>
<td>Germany</td>
<td>Rapeseed Wheat S barley</td>
<td>130</td>
<td>28</td>
<td>4.7</td>
<td>Rapeseed Wheat Rye Rye Pea</td>
<td>-19</td>
<td>-8</td>
<td>-1.2</td>
</tr>
</tbody>
</table>

Zander et al, 2014
Scotland

<table>
<thead>
<tr>
<th>Generated rotations</th>
<th>GM without all pre-crop effects</th>
<th>add. revenue pre crop effect</th>
<th>GM with all pre-crop effects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[€/ha]</td>
<td>[€/ha]</td>
<td>[€/ha]</td>
</tr>
<tr>
<td>winter rape - winter wheat - spring barley - spring barley - spring barley</td>
<td>390</td>
<td>38</td>
<td>428</td>
</tr>
<tr>
<td>winter rape - winter wheat - spring oat - winter wheat - spring barley</td>
<td>380</td>
<td>38</td>
<td>417</td>
</tr>
<tr>
<td>winter wheat - spring barley - spring oat</td>
<td>285</td>
<td>285</td>
<td></td>
</tr>
<tr>
<td>winter rape - winter wheat - faba bean - winter wheat - spring barley</td>
<td>355</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td>winter rape - winter wheat - spring barley - pea - winter wheat - spring barley</td>
<td>350</td>
<td>31</td>
<td>31</td>
</tr>
</tbody>
</table>

Zander et al, 2014
Conclusions

• Legumes contribute 839 kt N to European agriculture (<10% Fertiliser N)
• Legumes benefit following crops in rotations
• They can reduce N losses particularly in the form of N₂O
• Economics barriers to legume production remain, however some of the benefits are undervalued

• A climate smart contribution!
Acknowledgements

Financial support from The European Commission is gratefully acknowledged

Legume Futures Grant No 245216