The importance of manure and cropping systems for P management – how do we reach long term sustainability?

Paul Withers, Barbro Ulen, Helena Arronsson and Paulo Pavinato
Issues with Manures

• Large volumes due to high demand for meat – and range of materials expanding

• Policy drivers now in place to encourage land application – a resource with multiple benefits

• Often applied in excess of requirements leading to soil P accumulation

• Potential substitute for fertilisers – more highly valued than ever before

• Must be managed for effective utilization and environmental protection
Rapid expansion after 1950 and further increases to 2050.

Inputs of manure nutrients exceed those of fertiliser inputs.

100% substitution of manures for fertilisers would remove the P surplus (but not the N surplus).

Scenario analysis predicted that better integration of livestock and cropping systems is the best way to reduce fertiliser P use.

Bouwman et al. 2011
Export of particulate P (filled bars) and dissolved reactive P (unfilled bars) from small agricultural streams in the different countries.

(Ulén et al., 2012)
Agriculture’s impact on regional P flows occurs largely through livestock densities!

Senthilkumar et al. 2012
Land Use Distribution in the UK

- Only 20% of arable crops receive livestock manure each year

- 2.8 M tonnes of manure must be recycled from west to east to balance P demand (Bateman et al., 2012)

- Spatial disconnects:
  - arable to livestock
  - rural to urban
Technological Innovation

1. Reduction in P input
2. Bio-refinery
3. Manure separation
4. P recovery
5. P export

Livestock → Manure → Arable land

Non-food

Concentrated feed fertilizer

P import

Mineral concentrates

Schoumans et al. 2012
Manure Utilization on the Farm

Constraints

• Variable composition and quality
• Low confidence in nutrient release rates
• Difficulties of uniform/precise application
• Costs of storage and transport
• Unbalanced supply of NPK for crops
• Rate restrictions in some areas (e.g. NVZs)
• Public perceptions of contamination
• Stringent regulations for land application of wastes

Dilemma: Manure is a valuable sustainable renewable Resource but many barriers to overcome to improve utilization
Improving Utilization on the Farm

- Accounting for total nutrient content
- Matching supply with demand (N v P)
- Exporting what cannot be utilised
- Maximising efficiency of use (timing)
- Reducing losses to water
Manures are equally effective sources of P over a rotation provided background soil P is adequate.

Livestock manures have generally greater P availability than other manure types (Oenema et al. 2012)

Use manures to build-up the soil fertility bank and use inorganic fertilisers where P availability more critical.
ALOWANCE - Manures Landbank

Estimates the allowable landbank for spreading of *new* wastes based on physical and regulatory constraints:

Used to estimate landbank shortfalls in different areas and the length of time it will be available.

Available landbank in E&W is 5.1M ha or 55% of total productive land

Nicholson et al. 2012
Incorporation of pig slurry reduces the risk of P leaching (64%) from structured soils but not completely!

Liu, J. et al., 2012
• Incorporation of manures very effective

• Multiple manure applications spread the risk but still greater than the control
Manure Management

Brimstone 2003-2006

Drained clay soils

Cattle slurry 20 kg P/ha

Soil Olsen P – 6 mg/L

Mean of 3 years

Export greater from grass than arable land

Largest losses when applied to wet soils in winter and spring

Sagoo et al. - accepted
# Managing the Risk

## Brimstone Farm

<table>
<thead>
<tr>
<th>Timing</th>
<th>NO$_3$-N</th>
<th>NH$_4$-N</th>
<th>P</th>
<th>Compaction (X compliance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autumn</td>
<td>★★★</td>
<td>★</td>
<td>★</td>
<td>★</td>
</tr>
<tr>
<td>Winter</td>
<td>★</td>
<td>★★★★</td>
<td>★★★★</td>
<td>★★★★</td>
</tr>
<tr>
<td>Spring</td>
<td>★</td>
<td>★★★</td>
<td>★★★</td>
<td>★★★</td>
</tr>
<tr>
<td>Summer</td>
<td>★</td>
<td>★</td>
<td>★</td>
<td>★</td>
</tr>
</tbody>
</table>

★ Low risk; ★★ Medium risk; ★★★★ High risk
Issues with Cropping Systems

- Intensification of cropping systems has led to loss of OM, soil degradation and erosion
- Widespread implementation of measures to control erosion but variability in effectiveness and side effects
- Precision farming capability expanding rapidly
- Different crop species have potential to conserve and recover soil P – designer cropping
Agriculture is a major driver of soil degradation

Key farming methods that have increased erosion include:

- Over-exploitation of soils
- Cultivation of marginal land
- High sheep stocking densities on upland soils
- Over-cultivation of lowland soils
- Removal of hedgerows
- Soil compaction
- Introduction of tramlines
Reducing Erosion Risk

- Identify vulnerable areas
- Provide crop cover
- Improve OM/soil structure
- Alleviate soil compaction
- Contour cultivation
- Manage tramlines
- In-field buffer strips
- Restrict livestock access
- Reversion to grass
## Tillage and Liming Effects

### Nutrient leaching (kg ha\(^{-1}\) year\(^{-1}\))

<table>
<thead>
<tr>
<th>Tillage</th>
<th>no plots</th>
<th>PP</th>
<th>DRP</th>
<th>NO(_3)-N</th>
<th>OrgN*</th>
<th>N/P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional ploughing</td>
<td>12</td>
<td>0.81</td>
<td>0.11</td>
<td>23.4</td>
<td>3.4</td>
<td>29</td>
</tr>
<tr>
<td>Structure limed</td>
<td>4</td>
<td>0.46**</td>
<td>0.13</td>
<td>26.9</td>
<td>2.6</td>
<td>50</td>
</tr>
<tr>
<td>Shallow tillage</td>
<td>8</td>
<td>0.93</td>
<td>0.12</td>
<td>22.4</td>
<td>3.0</td>
<td>24</td>
</tr>
<tr>
<td>Not ploughed, fallow</td>
<td>4</td>
<td>0.63</td>
<td>0.14</td>
<td>3.3**</td>
<td>2.9</td>
<td>8</td>
</tr>
</tbody>
</table>

** Significant lower than conventional ploughed

(Svanbäck et al., submitted)
The Problem with Reduced Till

<table>
<thead>
<tr>
<th>Soil depth (cm)</th>
<th>Soil test P (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 2.5</td>
<td>60</td>
</tr>
<tr>
<td>2.5 - 5</td>
<td>49</td>
</tr>
<tr>
<td>5 - 12.5</td>
<td>34</td>
</tr>
<tr>
<td>12.5 - 20</td>
<td>26</td>
</tr>
</tbody>
</table>

Lake Erie - 1500 fields in reduced-till analysed to 20cm (Johnson, 2013)

Brazil savanna – 14 years no till compared to conventional (Nunes et al. 2011)

- Build-up of STP at the soil surface
- Link between STP and dissolved P (DRP) in runoff
Potential Benefits of Catch Crops

- Nutrient capture over winter (less N leaching)
- Soil protection
- Soil fertility
- Improve soil structure
- Weed suppression

Take up variable amounts of P but no benefit to succeeding crop

Pavinato et al. – in prep
Phosphorus for Two?

Hinsinger et al. 2011
Precision Farming

P in soil

Need of fertilizer

Precision Farming
From Knowledge to Action

Self-evaluation of farms for improved nutrient management

1. Basic information about the farm
   Soil mapping nutrient content of own manure

Main house Kłębek’s farm Photo: E. Ryjak.
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4. Possible actions

Self-evaluation of farms for improved nutrient management

Main house  Kłębek's farm  Photo: E. Ryjak.
Conclusions

• Fundamental need to close the P cycle using 4R strategy
• Meat demand will drive larger manure volumes
• Manure has multiple benefits (not just P) but some conflicts in P-rich areas
• Designer cropping has potential to conserve and recover soil P
• Integration of manure/cropping needed but how and at what scale?
Conclusions

• Nutrient accounting on farm essential - export
• Improve precision and efficiency on the farm
• Reduce losses by managing the risk
• Must consider pollution trade-offs - models
• Knowledge transfer/advisory tools still key