Over efficiëntie in de plantaardige productie

Prof. Martin van Ittersum - Plant Production Systems group, Wageningen University
Resource use efficiency

- kg product per kg input (kg N, kg pesticide, etc.)
- kg product per unit resource (hour labour, hectare, etc.)
- products, inputs and resources can also be expressed in monetary values
Accordingly, no production resource is used less efficiently and most production resources are used more efficiently with increasing yield level due to further optimizing of growing conditions.

Therefore strategic research that is to serve both agriculture and its environment should not be so much directed towards the search for marginal returns of variable resources, as towards the search for the minimum of each production resource that is needed to allow maximum utilization of all other resources.
Production-ecological principles & practice

**Defining factors**
- CO\(_2\)
- radiation
- temperature
- crop genetics

**Limiting factors**
- water
- nutrients (N, P, K)

**Reducing factors**
- weeds
- pests
- diseases
- pollutants

**Potential production**

**Limited production**

**Actual production**

**Yield gap**

**Breeding and biotechnology**

Van Ittersum and Rabbinge, 1997. Field Crops Research
Slide: Harrie Lovenstein
Yield and supporting data for rainfed maize

Rainfed maize

Select crop:
Rainfed maize

Select aggregation level:
Climate zones

Select yield indicator:
- Relative yield: Ya / Yw x 100%

Select variable:
Mean value

Apply crop mask: No

Legend:
- all classes
- current classes

To view data details: Click on the map.
Decomposing the yield gap

Winter wheat yield (ton ha\(^{-1}\))

Crop inputs (x)

Yp
Y_{HF}
Y_{TEx}
Ya

Technology yield gap
Resource yield gap
Efficiency yield gap
Actual yield

Yield and supporting data for rainfed wheat

Rainfed wheat

Select crop: Rainfed wheat
Select aggregation level: Climate zones
Select yield indicator: Relative yield: \(\frac{Y_a}{Y_w} \times 100\%\)
Select variable: Mean value

Apply SPAM2005 crop mask: No

Legend:

<table>
<thead>
<tr>
<th>%</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>up to 10%</td>
<td>50% - 60%</td>
</tr>
<tr>
<td>10% - 20%</td>
<td>60% - 70%</td>
</tr>
<tr>
<td>20% - 30%</td>
<td>70% - 80%</td>
</tr>
<tr>
<td>30% - 40%</td>
<td>80% - 90%</td>
</tr>
<tr>
<td>40% - 50%</td>
<td>more than 90%</td>
</tr>
</tbody>
</table>

To view data details: Click on the map.

www.yieldgap.org
Crop yields slightly lower than the suggested 80% \( Y_p \)

- Small resource \( Y_g \) for all crops: high input levels

- Water limitation?
- Narrow rotations?

- Efficiency yield gap!
- Timeliness of operations?
- Delay previous crop (Mazzili et al., 2016)
- Soil trafficability (Droogers et al., 1996)
- Unfavourable weather (van Oort et al., 2012)
- Machinery constraints (Reidsma et al., 2015)

Silva et al., 2017. Ag. Systems
Yield improvement of Dutch winter wheat varieties on marine clay soils

<table>
<thead>
<tr>
<th>Observation</th>
<th>Trend</th>
<th>Formula of trendline, X=year – 1967</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variety</td>
<td>●</td>
<td>Y = 7.65 + 0.09X</td>
<td>87.9</td>
</tr>
<tr>
<td>Trial</td>
<td>△</td>
<td>Y = 4.91 + 0.25X – 0.002X²</td>
<td>80.2</td>
</tr>
<tr>
<td>Farm</td>
<td>X</td>
<td>Y = 4.72 + 0.18X – 0.002X²</td>
<td>66.2</td>
</tr>
</tbody>
</table>

Update of: Rijk et al., 2013.
Field Crops Research
Intercropping

Efficiencies are scale-dependent (see presentation Imke de Boer)

“Efficiency gaps, next to yield gaps, result in environmental impacts per unit area that are higher than desirable”

Global and local focus
A graphical presentation, in three steps: (i) NUE

- **NUE very high (NUE > 90%):** Risk of soil mining
- **NUE very low (NUE < 50%):** Risk of inefficient N use

**Possible targets**
- NUE = 90%
- NUE = 50%

Oene Oenema, Wageningen Univ.
A graphical presentation, in three steps: (ii) N output

**Possible targets**
- NUE = 90%
- NUE = 50%
- Desired minimum productivity (N output > 80 kg/ha/yr)

**N output, kg/ha/yr**
- NUE very high (NUE > 90%): Risk of soil mining
- NUE very low (NUE < 50%): Risk of inefficient N use

**N input, kg/ha/yr**

Oene Oenema, Wageningen Univ.
A graphical presentation, in three steps: (iii) N surplus

Possible targets

- NUE = 90%
- Desired maximum N surplus < 80 kg/ha/yr
- NUE = 50%
- Desired minimum productivity (N output > 80 kg/ha/yr)

NUE very high (NUE > 90%): Risk of soil mining

NUE very low (NUE < 50%): Risk of inefficient N use

Oene Oenema, Wageningen Univ.
Yield – Use efficiency - Surplus

P application and P uptake

Western Europe

Year
Kg ha$^{-1}$ yr$^{-1}$

P Uptake
P application

Sattari, Bouwman, Giller and Van Ittersum, 2012 - PNAS
Regional differences

Western Europe

Africa

Sattari, Bouwman, Giller and Van Ittersum, 2012 - PNAS
A learning curve!

W-Europe

Africa

Asia

Sattari, Bouwman, Giller and Van Ittersum, 2012 - PNAS
Intensification or Ecologisation?

Zhang et al., 2015. Nature
Organic vs Mainstream agriculture

Seufert and Ramankutty, 2017. Science Advances
How to ecologise ....

- Consider objectives, trade-off and re-design at different levels
- Diversify rotations
- Precision management in time and space (e.g. 4 Rs)
- Using organic inputs – organic matter and circularity
- Integrated pest management
Adding organic (fertilizer) inputs

- Meta-analysis of long-term experiments in Europe:
  - If macro nutrients (NPK) are in ample supply:
  - Mean additional yield effect of organic inputs is not significant (+1.4% ± 1.6)

- But...
Results – per crop type

-5% 0% 5% 10%
additional yield effect of organic matter input

wheat (31)
sugar beet (21)
potatoes (11)
maize (15)
barley (27)

Hijbeek et al., 2017. Plant and Soil
Expect trade-off....

Bos et al., 2017. Agricultural Systems
Expect trade-off....

Rotation A

- Cattle slurry plus min. fert.
- Pig slurry plus min. fert.
- Compost plus min. fert.
- Min. fert. only
- Break even line

Bos et al., 2017. Agricultural Systems
Drivers and barriers - compost

Hijbeek et al., 2017
Drivers and barriers - farmyard manure & compost

Hijbeek et al., 2017
Plant protection with naturally occurring predators
Plant protection with naturally occurring predators
Insect communities - pest control

Rusch et al. 2016 AGEE

Landscape cropping intensity (% arable land 1 km radius)

Natural pest control

Cereal aphids (no/100 straws)

With(out) Predator

+P - P

Rusch et al. 2016 AGEE
Concluderend

- Hoge opbrengsten en efficienties kunnen goed samengaan, maar ....
- De kunst is (ook) goede balans te vinden met emissies per hectare
- We boeken (nog steeds) vooruitgang
- Nadruk op intensiveren of ecologiseren afhankelijk van waar we zijn op de wereld
- Gebruik van organic inputs:
  - Geen wondermiddel
  - Niet zonder trade-off
  - Meer aandacht voor ‘drivers & barriers’ boeren
- Effect op veerkracht onzeker
Future harvest

Dank voor uw aandacht

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