Global Yield Gap Atlas – an agronomic database with local and global relevance

Martin van Ittersum – Plant Production Systems group
Questions of this symposium

- Should and could agricultural production be increased at the global scale?
- Where should agricultural productivity be increased?
- What are the existing limiting factors for increasing agricultural production?
- Which intensification pathways could and should be adopted?

- These questions require agronomic rigour!
FAO projection: +60% demand (2007-2050)
Tilman et al.: +100-110% crop yields
Five reasons why +60-110% by 2050 must be revisited

- FAO projection expressed in monetary value
- Baseline (2005-2010) is 10 years old
- Projections on drivers of demand (population and economic growth) need continuous update
- Demand increases => production increases?
- Projections are for the globe, but with huge regional differences

See also: Hunter et al., 2017. Bioscience.
## Population increase

<table>
<thead>
<tr>
<th>Continent</th>
<th>2015</th>
<th>2050</th>
<th>2100</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>7.4</td>
<td>9.7</td>
<td>11.2</td>
</tr>
<tr>
<td>Asia</td>
<td>4.4</td>
<td>5.3</td>
<td>4.9</td>
</tr>
<tr>
<td>Africa</td>
<td>1.2</td>
<td>2.5</td>
<td>4.4</td>
</tr>
<tr>
<td><strong>Sub-Saharan Africa</strong></td>
<td><strong>1.0</strong></td>
<td><strong>2.1</strong></td>
<td><strong>3.9</strong></td>
</tr>
<tr>
<td>North America</td>
<td>0.4</td>
<td>0.4</td>
<td>0.5</td>
</tr>
<tr>
<td>Latin America</td>
<td>0.6</td>
<td>0.8</td>
<td>0.7</td>
</tr>
<tr>
<td>Europe</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Oceania</td>
<td>0.04</td>
<td>0.06</td>
<td>0.07</td>
</tr>
</tbody>
</table>

United Nations, 2017
Meaning of increased global demand is region-specific!

Two extremes:

Sub-Saharan Africa’s demand will rise fastest because of population growth and dietary change => tripling production

Europe can (should?) play a leading role in developing circular food systems
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Motivation to start Global Yield Gap Atlas

1. Estimates of **extra crop production potential** in existing farmland and with available water resources

2. Support to **prioritize investment** in agricultural research and development and monitor impact

3. **Foundation** for narrowing yield gaps, estimate nutrient and water requirements, and for studies on climate change, land use, and environmental footprint

4. **Platform to integrate** biophysical and socio-economic factors

5. To develop a global database with agronomic rigour!
Global Yield Gap Atlas

62 countries, major food crops, accounting for 70, 84, 45% of rice, maize, and wheat

With University of Nebraska, ICRISAT, AfricaRice, CIMMYT and many national partners

- Major food crops in the world
- Global protocol with local application
- Local data and evaluation
- Strong agronomic foundation

www.yieldgap.org

- Co-financed by Bill and Melinda Gates Foundation
Yield potential, farm yield, and yield gaps

- Reaching 75-85% of yield potential is a reasonable target for farmers with access to inputs, markets, and extension services.
- Further yield increase is not cost-effective and/or environmentally sound.

**Crop grain yield (t/ha/year)**

- **Yield Potential**
  - Determined by:
    - Radiation
    - Temperature
    - [CO₂]
    - Cultivar
    - Rainfall & soil (in rainfed crops)

- **Farm yield**
  - Limited by:
    - Poor Fertility
    - Poor management
    - Insects, weeds
diseases

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*Modified from: van Ittersum and Rabbinge, Field Crops Research (1997)*
Global Yield Gap Atlas (www.yieldgap.org)

Broad usage in 2017: 30,000 users of website; 230,000 page-views; 4,500 downloads

<table>
<thead>
<tr>
<th>Sector</th>
<th>Downloads</th>
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</thead>
<tbody>
<tr>
<td>NGO’s/Foundations</td>
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<tr>
<td>Industry</td>
<td>235</td>
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<tr>
<td>Academia</td>
<td>2089</td>
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<tr>
<td>Government</td>
<td>452</td>
</tr>
<tr>
<td>Media</td>
<td>12</td>
</tr>
<tr>
<td>Individual (producer, consultant, extension)</td>
<td>2000</td>
</tr>
</tbody>
</table>
Yield and supporting data for rainfed maize

Rainfed maize

Select crop:
- Rainfed maize

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
- Yes

Legend:
- All classes
- Current classes

<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.
Yield and supporting data for 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: Yes

Legend:
- All classes
- Current classes

www.yieldgap.org
Questions of this symposium

- Should and could agricultural production be increased at the global scale?

- *Where should agricultural productivity be increased?*

- What are the existing limiting factors for increasing agricultural production?

- Which intensification pathways could and should be adopted?

- These questions require agronomic rigour!
Contribute to food security analysis

Can sub-Saharan Africa feed itself?


Plant Production Systems Group, Wageningen University, 6700 AK Wageningen, The Netherlands; Department of Agronomy and Horticulture, University of Nebraska, Lincoln, NE 68583-0915; International Crops Research Institute for the Semi-Arid Tropics, 00623 Nairobi, Kenya; Wageningen Environmental Research, Wageningen University & Research, 6700 AA, Wageningen, The Netherlands; Environment and Production Technology Division, International Food Policy Research Institute, Washington, DC 20006-1002; Africa Rice Center, Sustainable Productivity Enhancement Program, 01 BP 2031, Cotonou, Benin; Centre for Crop Systems Analysis, Wageningen University, 6700 AK Wageningen, The Netherlands; Jomo Kenyatta University of Agriculture and Technology, 00200 Nairobi, Kenya; International Institute of Tropical Agriculture, Tamale, Ghana; AGRHYMET Regional Centre, BP 11011 N’iamey, Niger; Department of Soil Science, Federal University of Technology Minna, P.M.B. 65 Gidan-Kwano, Niger State, Nigeria; Crop Science Department, University of Zimbabwe, MP167 Mount Pleasant, Harare, Zimbabwe; National Agricultural Research Laboratories, Kampala Nabweru 7065, Uganda; Institut d’Economie Rurale, BP 258 Bamako, Mali; National Irrigation Commission, Ministry of Water and Irrigation, 14473 Dar es Salaam, The United Republic of Tanzania; Institut de l’Environnement et de Recherches Agricoles, 04 BP: 8645 Ouagadougou 04, Ouagadougou, Burkina Faso; and International Maize and Wheat Improvement Centre, Addis Ababa, Ethiopia

Van Ittersum et al., 2016. PNAS
Growth in population and cereal demand - 2050

A factor 3.4 increase!

Van Ittersum et al., 2016 (PNAS)
Yield and supporting data for rainfed maize

Select crop:
Rainfed maize

Select aggregation level:
Climate zones

Select yield indicator:
- Relative yield: $\frac{Y_a}{Y_w} \times 100\%$

Select variable:
Mean value

Apply crop mask: No

Legend:
- All classes
- Current classes

To view data details: Click on the map.
Can SSA feed itself? - cereals

Van Ittersum et al., 2016. PNAS
Required trend change maize yields

![Graph showing required trend change in maize yields compared to current trend and potential yield.](#)
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Actual and potential water productivity – rainfed maize

www.yieldgap.org
Water productivity gaps (rainfed conditions)
Water or non-water limiting factors?

Rattalino Edreira, Guilpart, Sadras, Cassman, Van Ittersum, Schils, Grassini, Agricultural and Forest Meteorology, 2018
Estimating nutrient requirements - maize

www.yieldgap.org

Ten Berge, De Vries, Van Loon, Hijbeek, Rattallino Edreira and Van Ittersum, 2018 (In review)
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Decomposing yield gaps

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

Crop inputs (x)

Yield gap

Technology yield gap

Resource yield gap

Efficiency yield gap

Actual yield

Three contrasting case studies

- **Mixed farming in Southern Ethiopia**
  - Sample: 200 farms
  - Year: 2012
  - Farm size: < 2.5 ha
  - Crops: Maize in Hawassa and wheat in Asella

- **Rice farming in Central Luzon, Philippines**
  - Sample: 100 farms
  - Year: 1966-2012
  - Farm size: 1.7 ha
  - Crops: Rice (wet season and dry season)

- **Arable farming in the Netherlands**
  - Sample: 175 farms
  - Year: 2008 - 2012
  - Farm size: ~60 ha
  - Crops: Wheat, barley, potato, sugar beet, onion

*Silva et al., in preparation*
Overview of crop yield gaps

- **Southern Ethiopia**: Large yield gap due to efficiency and technology yield gaps.
- **Central Luzon, Philippines**: Medium yield gap due to efficiency, resource, and technology yield gaps.
- **The Netherlands**: Small yield gap due to efficiency and technology gaps.

Silva et al., 2017. Ag. Systems
Interventions to narrow yield gap(s)

Yield (tons/ha)

Potential yield
Feasible yield
Economic yield
Technical efficient yield
Actual yield

Yield gap

Technology Yield gap
Economic Yield gap
Allocative Yield gap
Technical efficiency yield gap

Main causes
- Agricultural innovation system and broader institutional, technological, economic and social factors
- Transaction and transportation costs
- Knowledge and financial constraints, risk issues and information asymmetries
- Suboptimal crop management caused by knowledge, skills and information gaps.

Policies
- Investment in applied agricultural research and development programs
- Investment in rural roads
- Policies to decrease transaction costs
- Credit & insurance
- Expand agro-dealer networks
- Support market information
- Land tenure systems
- Smart input subsidies
- Improve extension services
- Stimulate knowledge transfer from best practice to average farmers

Sliva et al., 2017
Van Dijk et al., 2017
Future harvest

Thank you for your attention!

Merci to MAK!IT


References on understanding yield gaps