Sustainable intensification: the fine line between myopia and utopia

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

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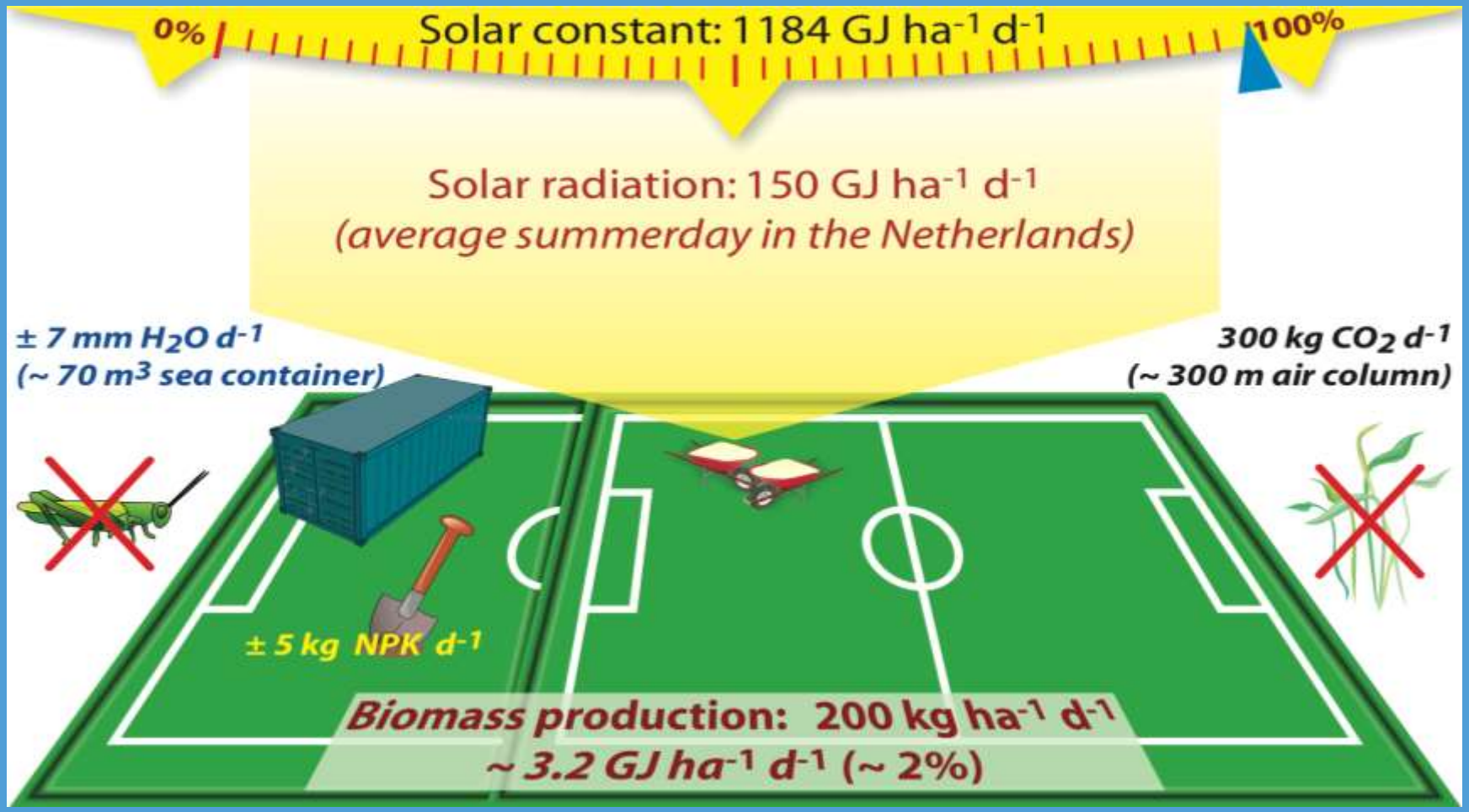
What is agriculture?

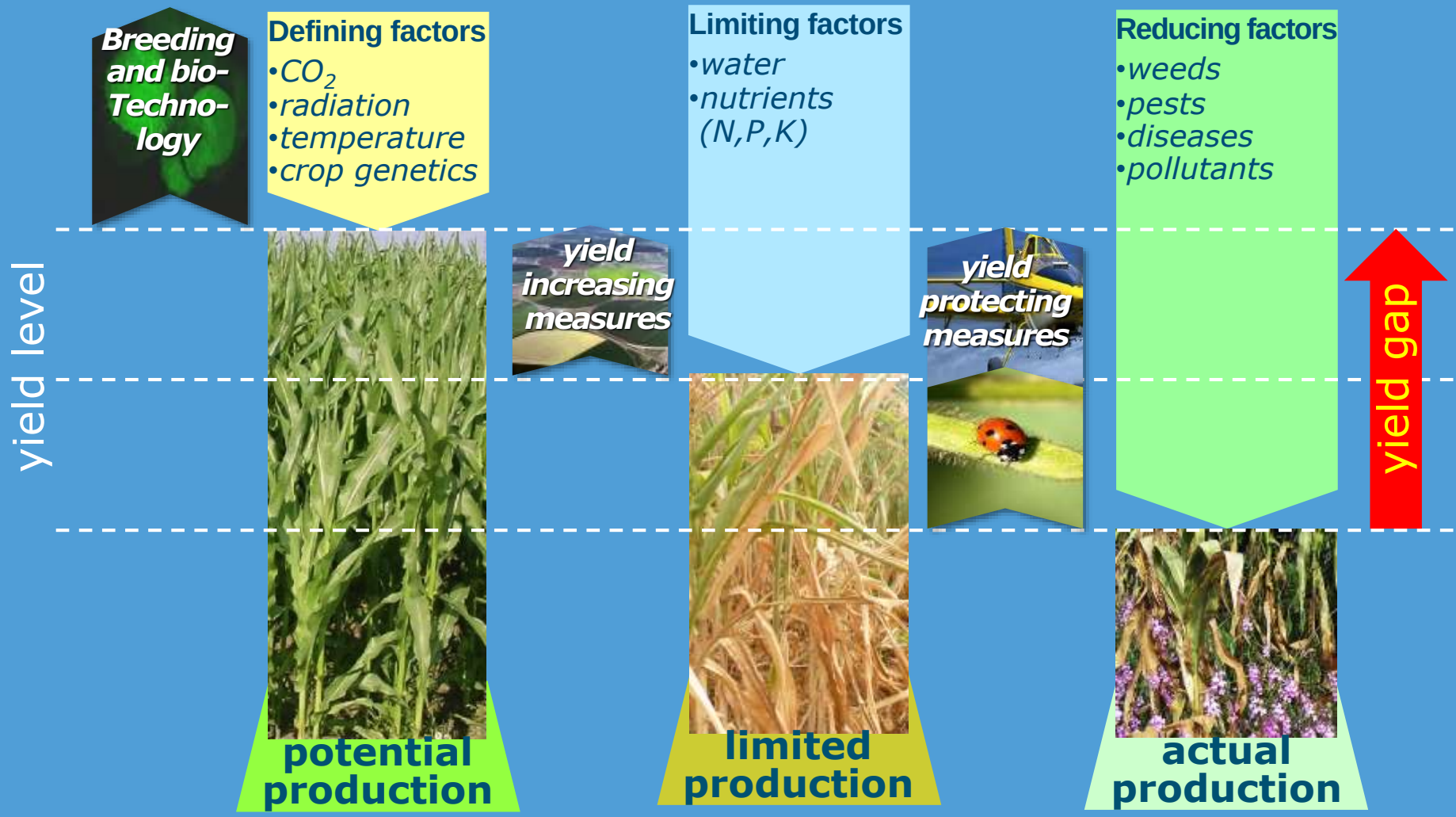
Human activity in which energy from the sun is used for the production of sugars through the growth of plants in soil

This is true for all forms of agriculture: traditional and modern

Crop production



Production-ecological principles & practice



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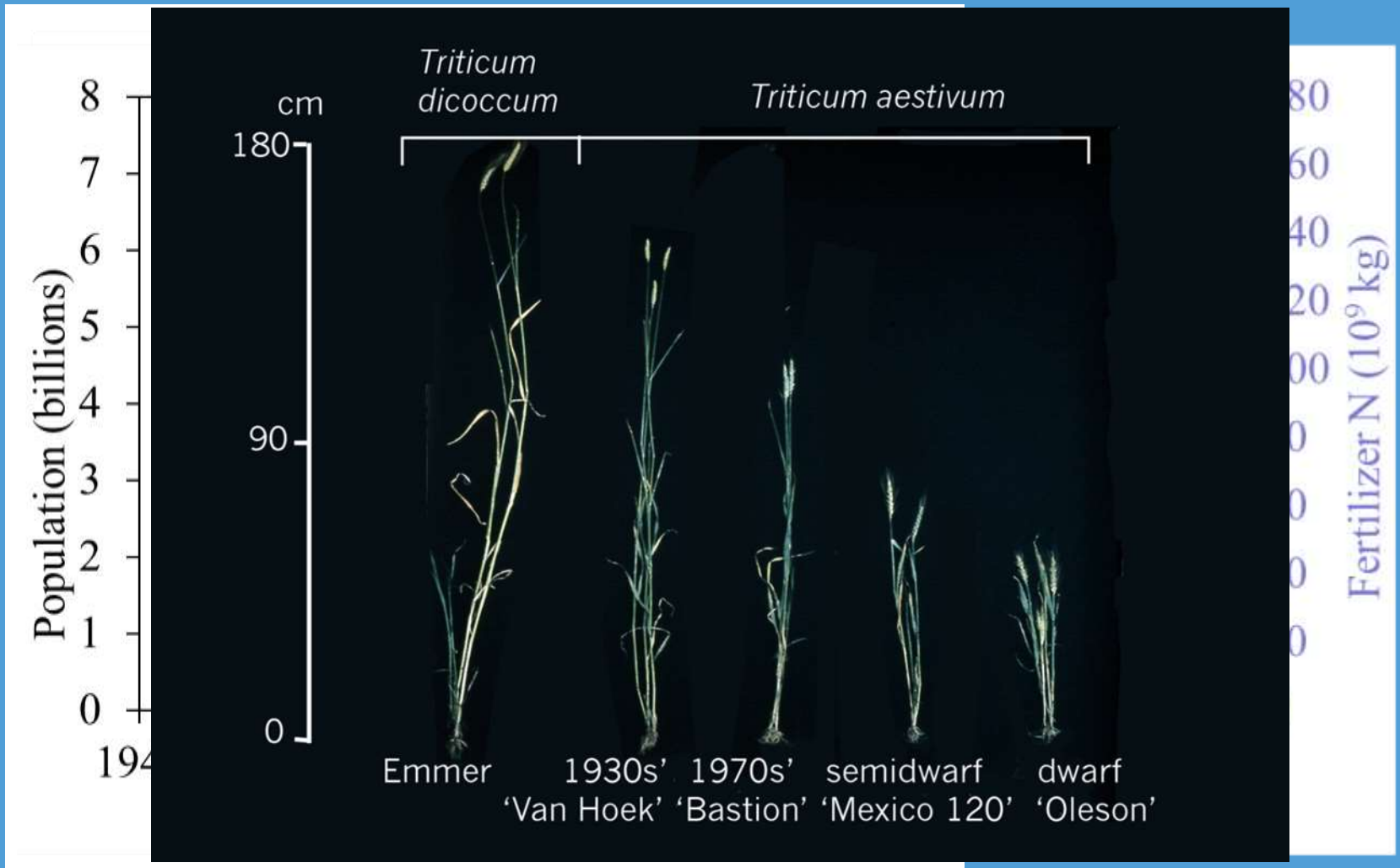
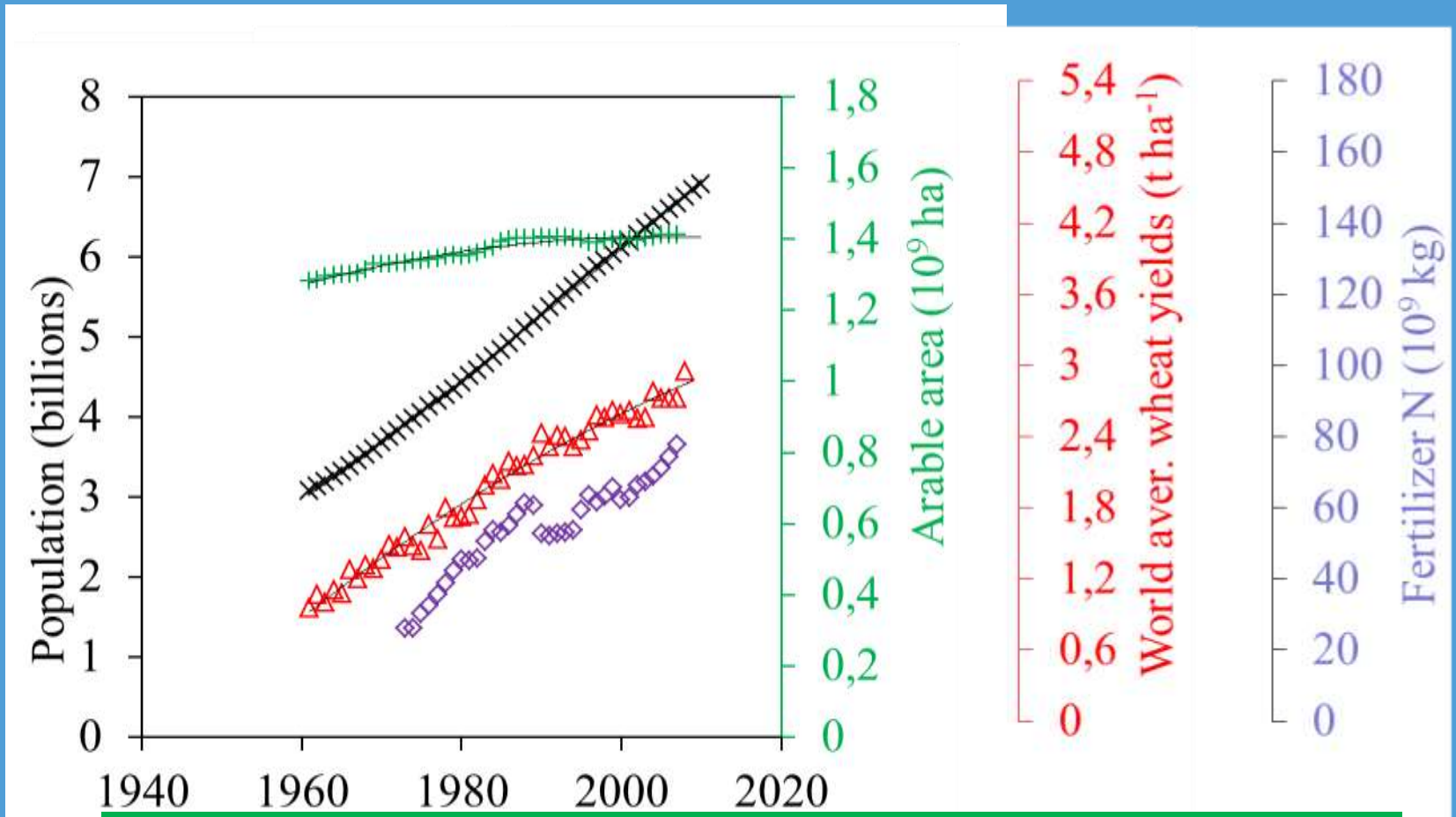
Van Ittersum and Rabbinge, 1997
Slide: Harrie Lovenstein

Looking back: 1960-2015



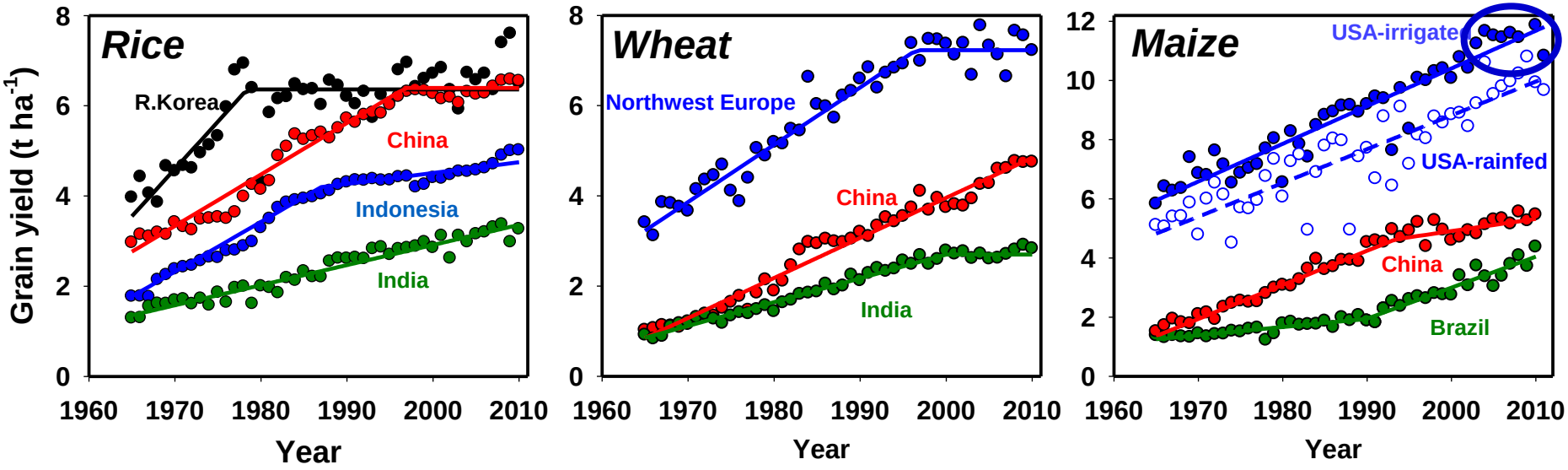
Updated from Evans, 1998



But conditions in 2017 very different than in 1960

Updated from Evans, 1998

Slack in cereal yield increases?



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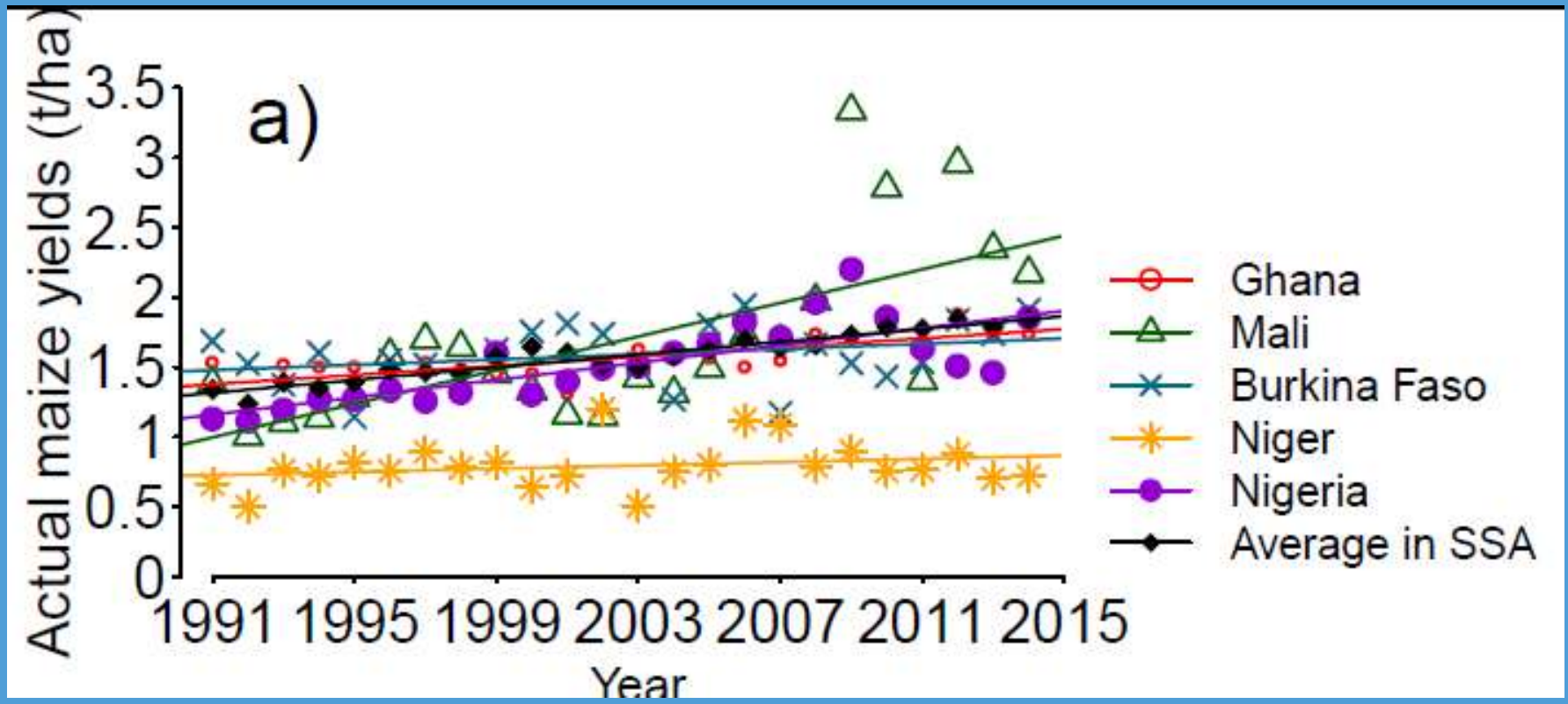
For quality of life

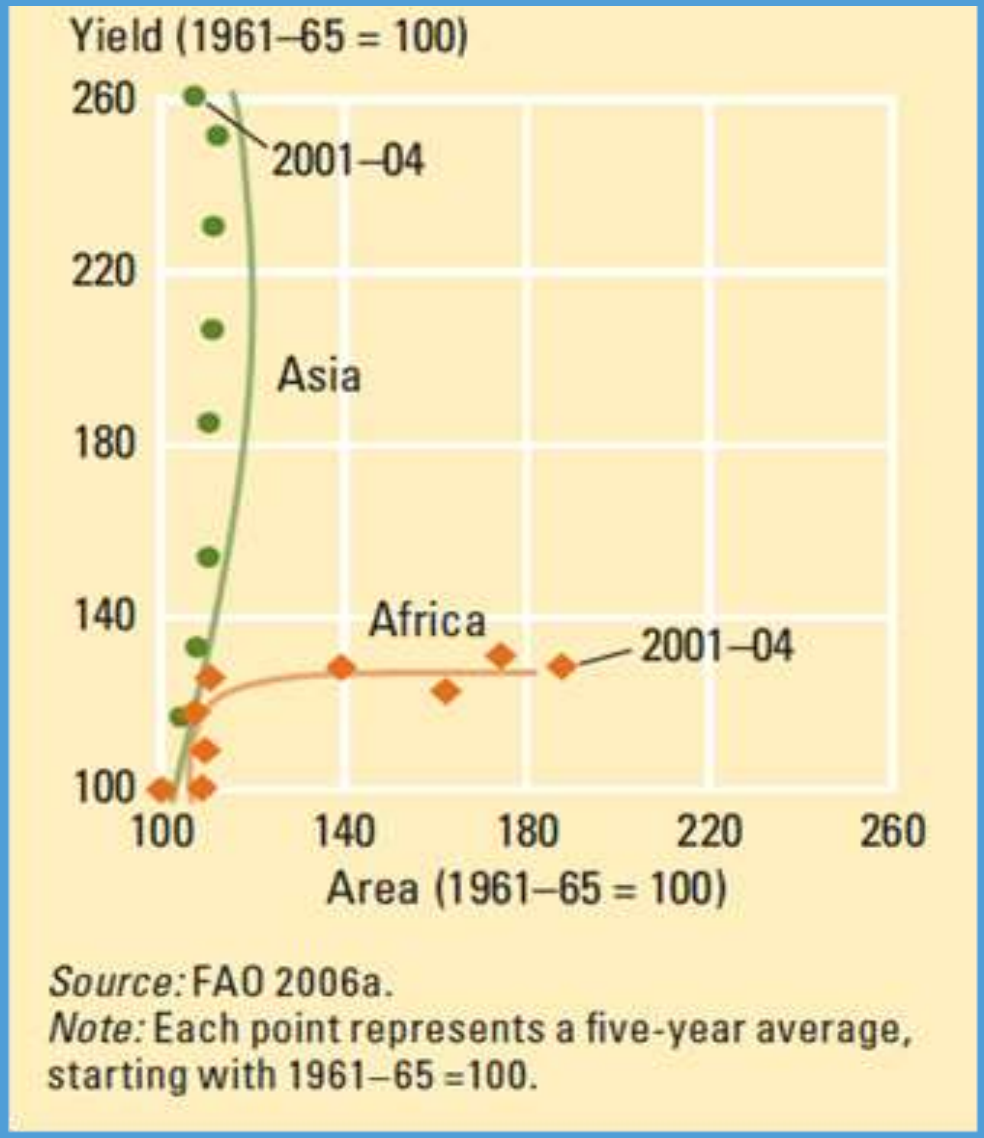
Cassman, 1999; Cassman et al., 2010; Grassini et al., 2011

Slack in cereal yield increases?



FAO and Van Ittersum et al., 2016

The green revolution in Asia and Africa



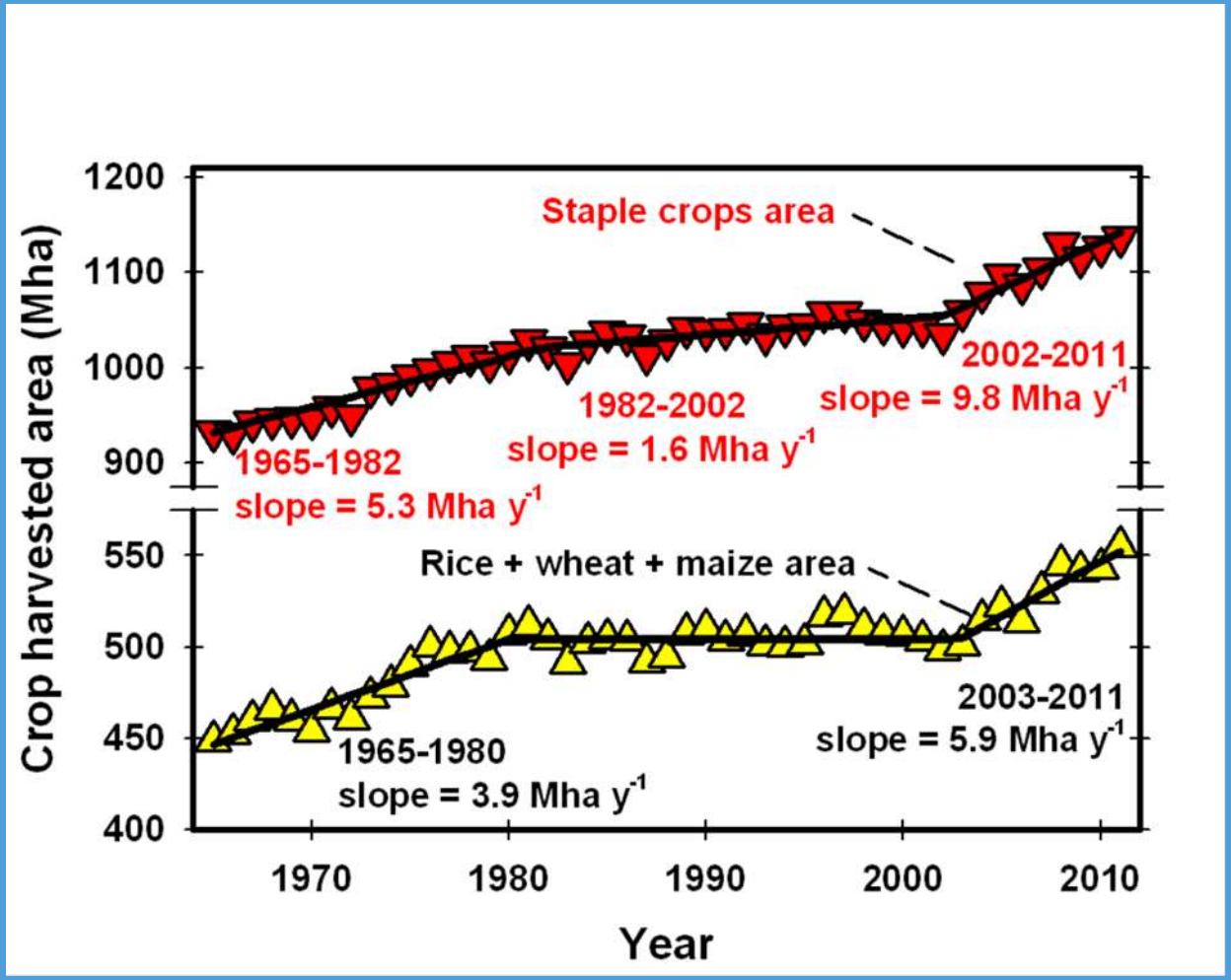
Source: FAO 2006a.
Note: Each point represents a five-year average, starting with 1961–65 =100.

Trends arable land area – Sub-Saharan Africa (2004-2013)

Arable land area 2010 in million ha	Arable land area increase 2004-2013 in million ha
5.8	1.6
4.6	0.7
6.4	1.4
15.2	1.8
33.0	-1.0 (ns)
14.6	2.8
5.5	0.5
11.9	4.0
6.7	1.0
3.5	0.8
107.0	**13.6 (14%)**

Source: FAOSTAT

Increase in global crop areas



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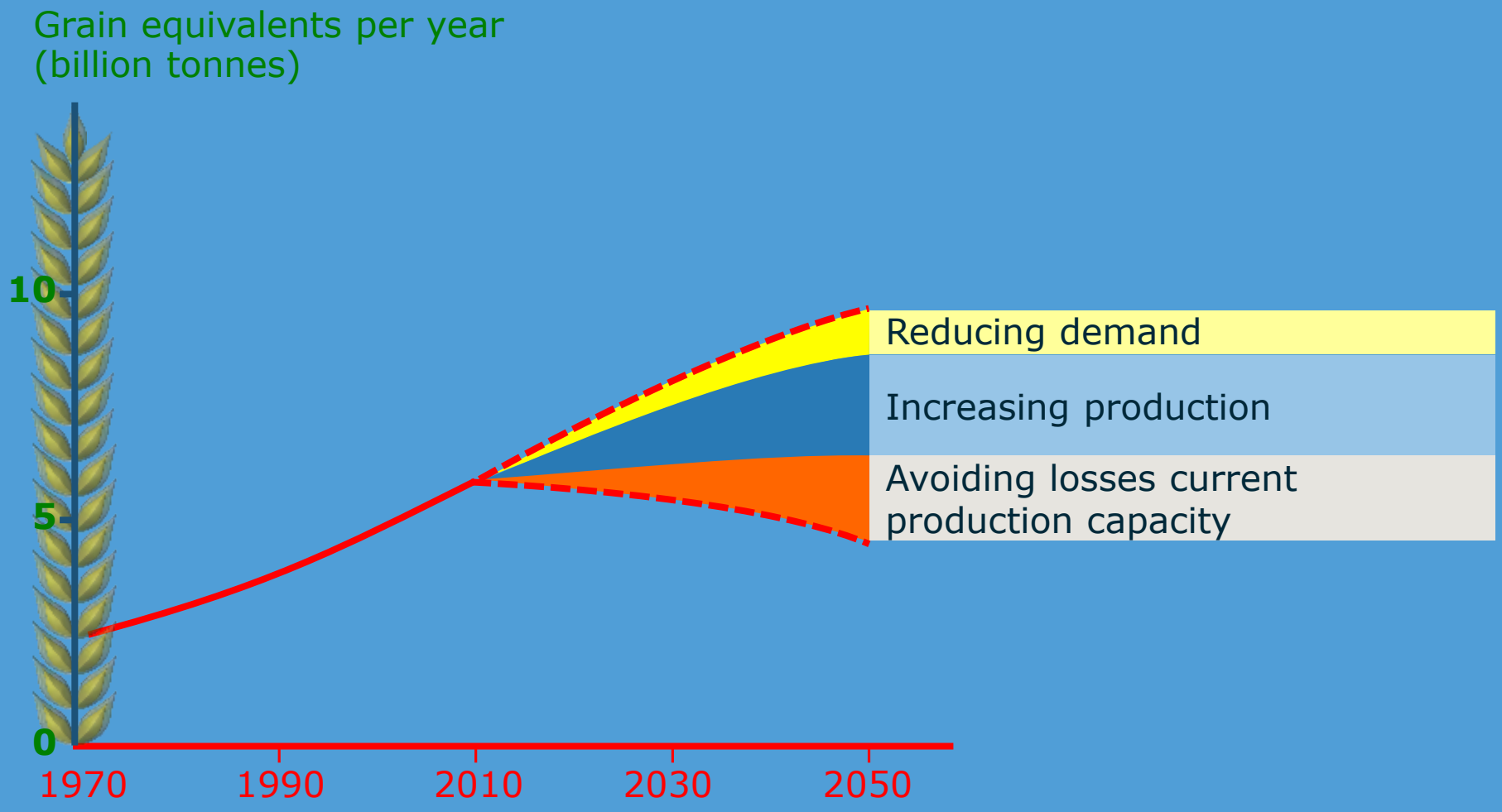
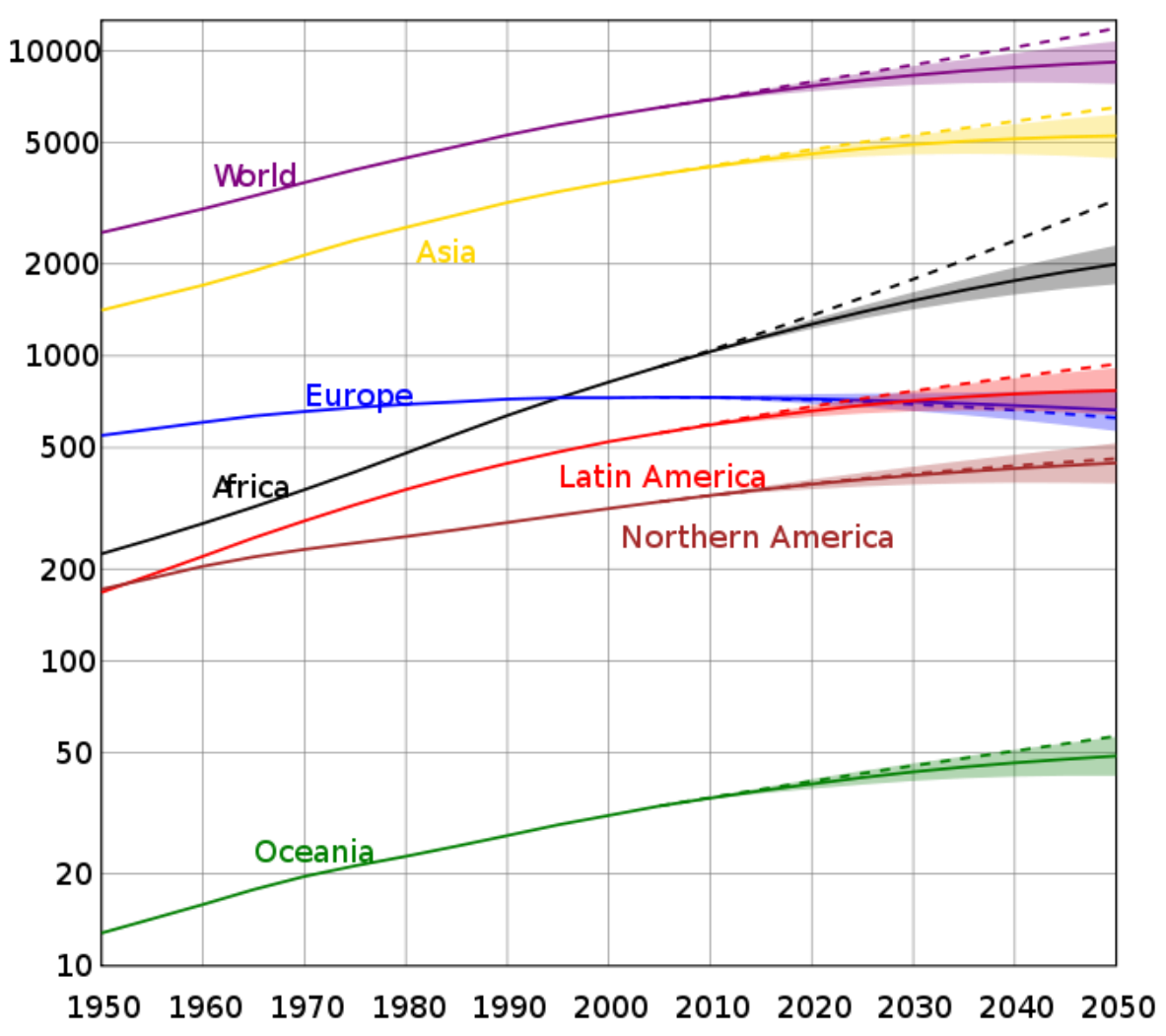
Grassini et al., 2013

Looking ahead: Pathways to increase availability

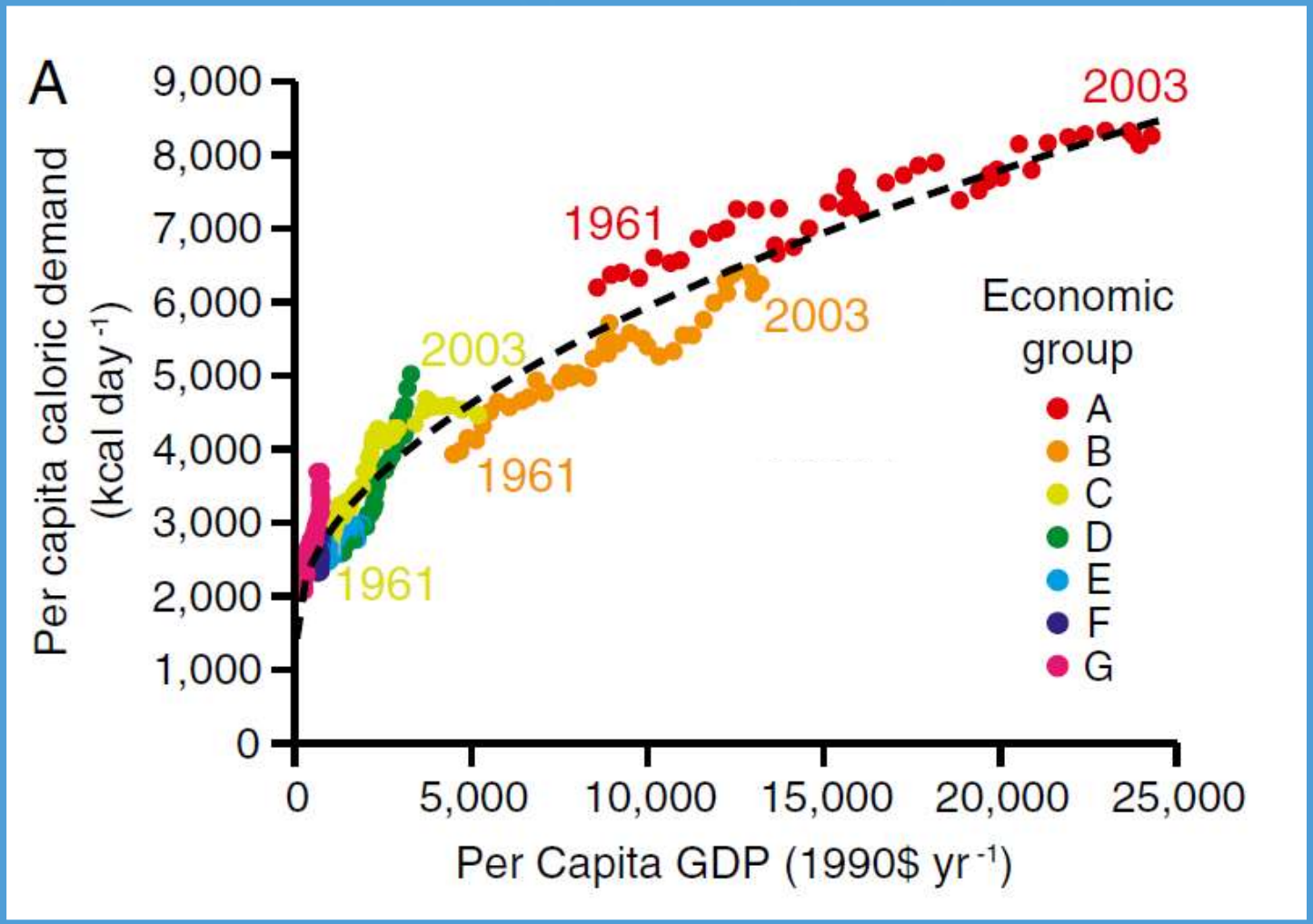


after Keating et al., 2014. Global Food Security

Population growth



Demand versus income (per capita)

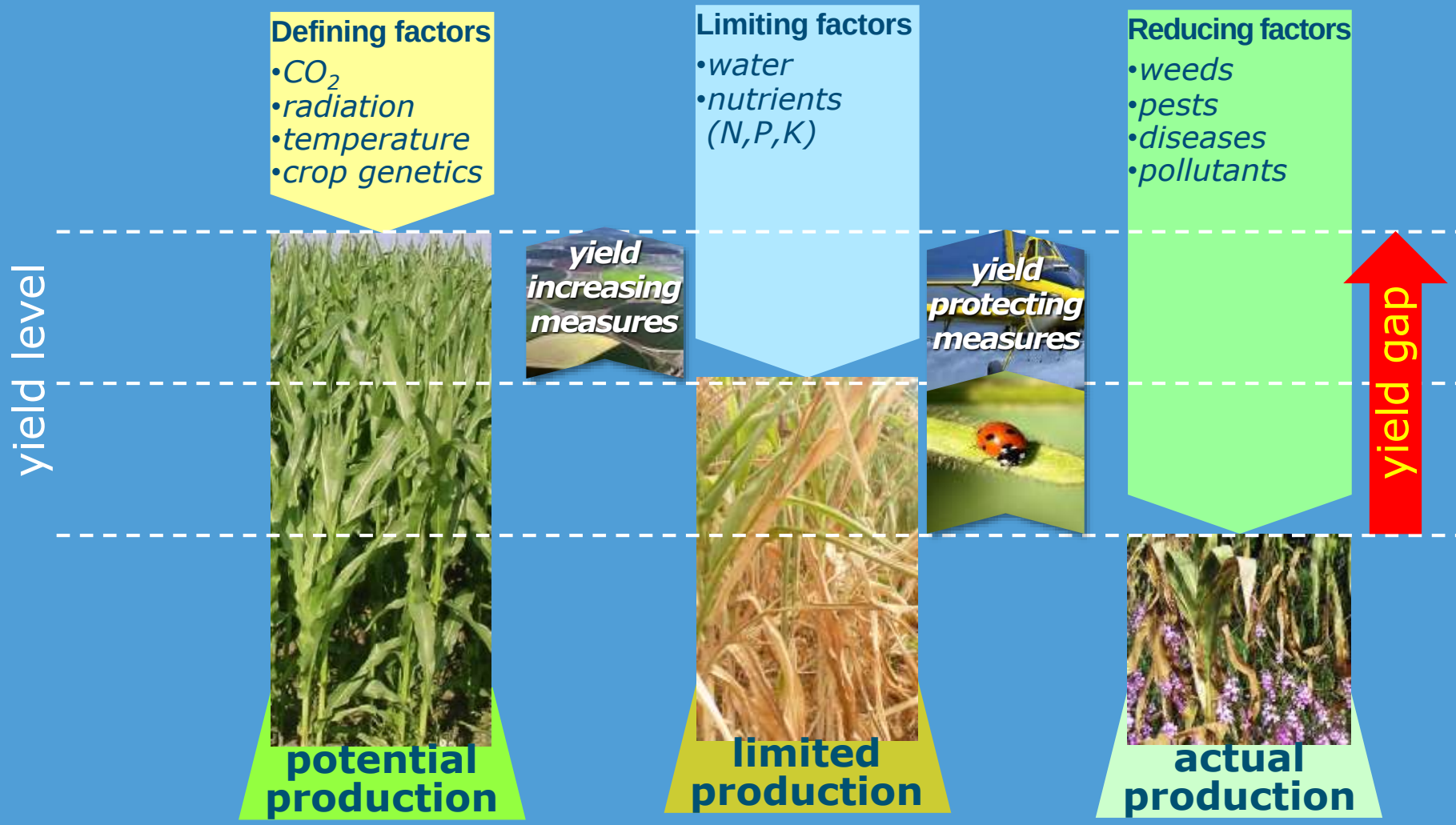


Tilman et al., 2011 (PNAS)

The need for extra food is very region-specific

So, it is crucial to know where production can be increased and how

Production-ecological principles & practice



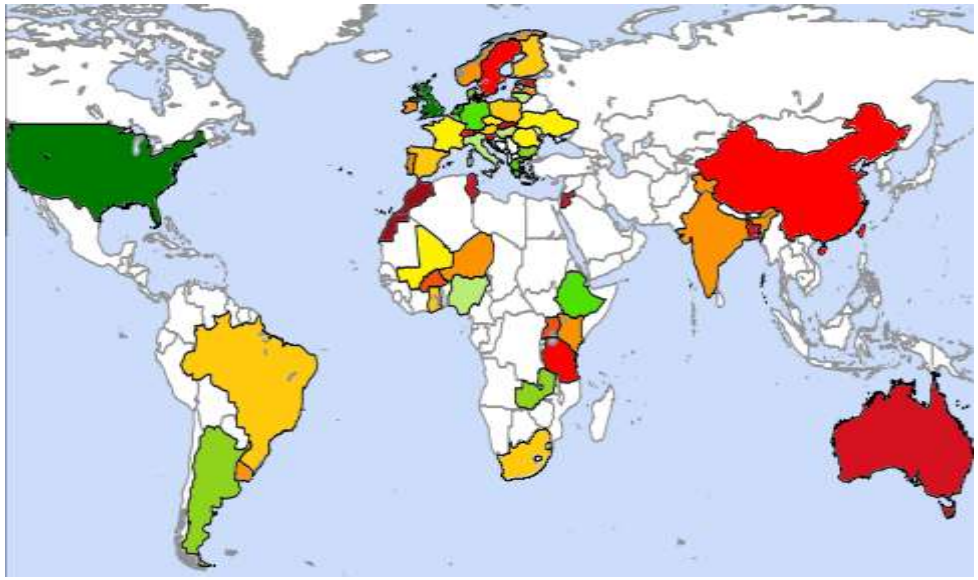
Van Ittersum and Rabbinge, 1997
Slide: Harrie Lovenstein

Yield gap analysis

Photo: Ken Giller

Global Yield Gap Atlas

Global Yield Gap Atlas



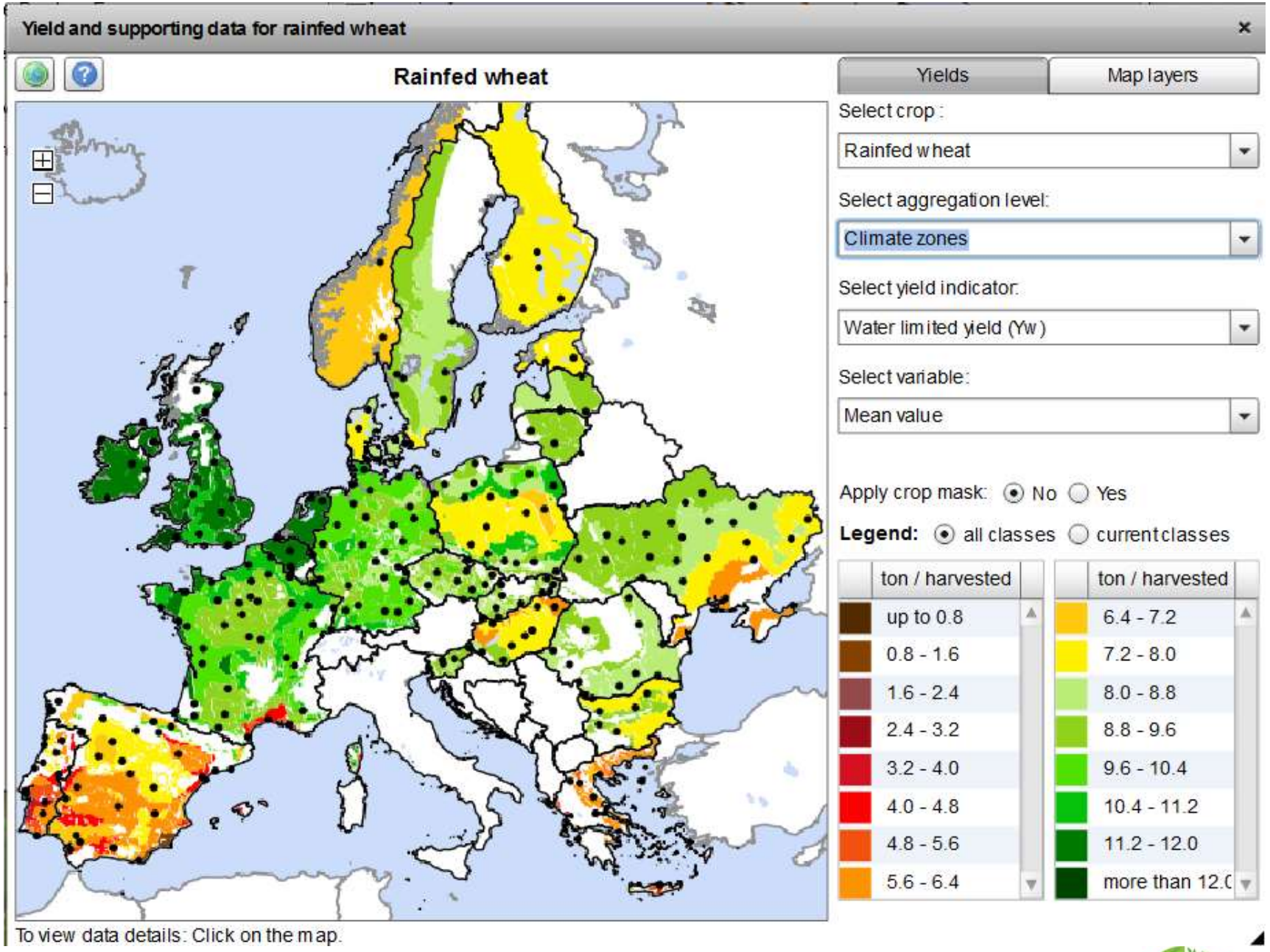
www.yieldgap.org

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

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

- Co-financed by Bill and Melinda Gates Foundation

Global Yield Gap Atlas


Yield and supporting data for rainfed wheat
Rainfed wheat
Yields
Map layers
Select crop :
Rainfed wheat
Select aggregation level:
Climate zones
Select yield indicator:
Water limited yield (Yw)
Select variable:
Mean value
Apply crop mask: No Yes
Legend: all classes current classes
ton / harvested
up to 0.8
0.8 - 1.6
1.6 - 2.4
2.4 - 3.2
3.2 - 4.0
4.0 - 4.8
4.8 - 5.6
5.6 - 6.4
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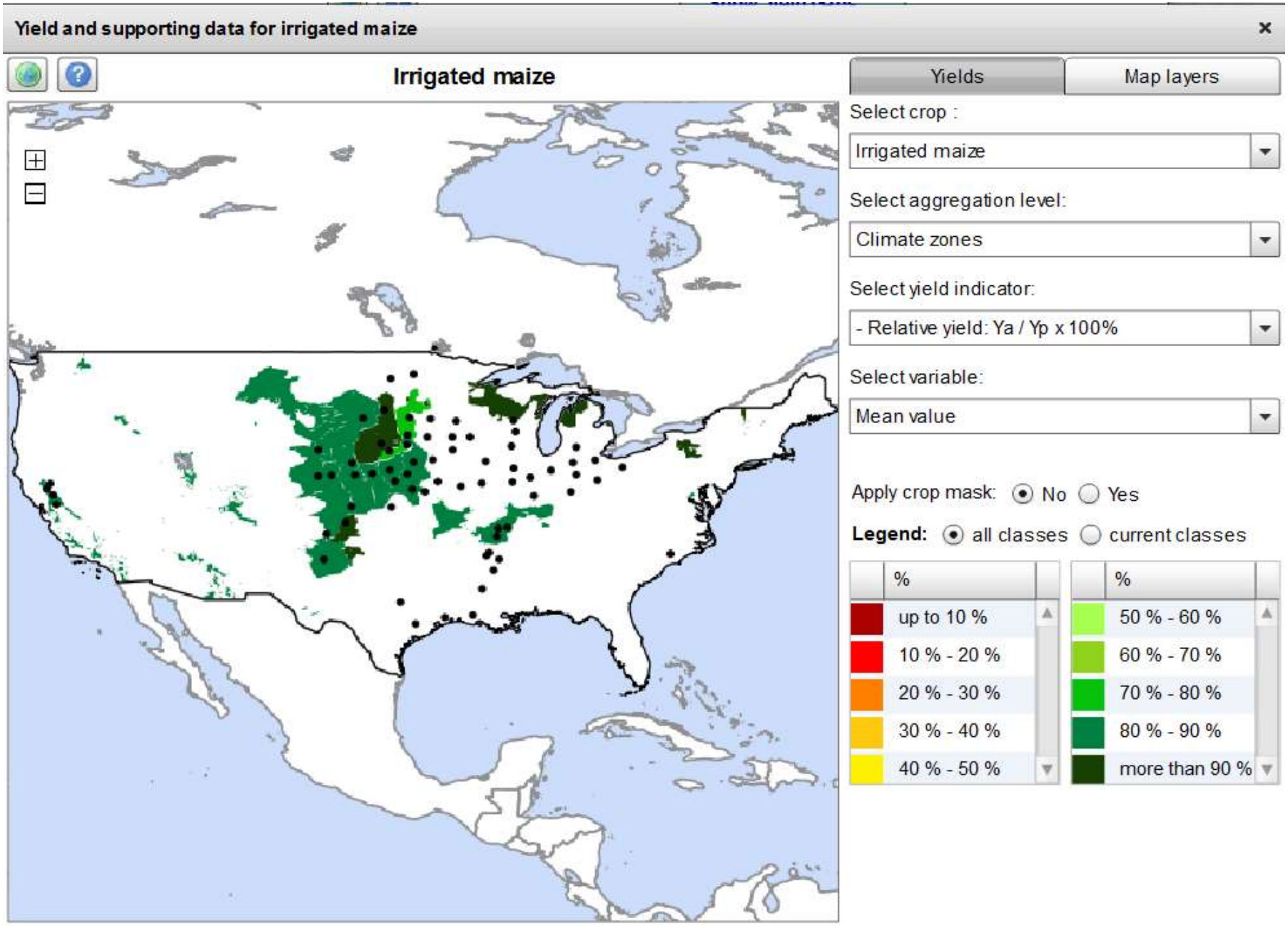
6.4 - 7.2
7.2 - 8.0
8.0 - 8.8
8.8 - 9.6
9.6 - 10.4
10.4 - 11.2
11.2 - 12.0
more than 12.0
To view data details: Click on the map.

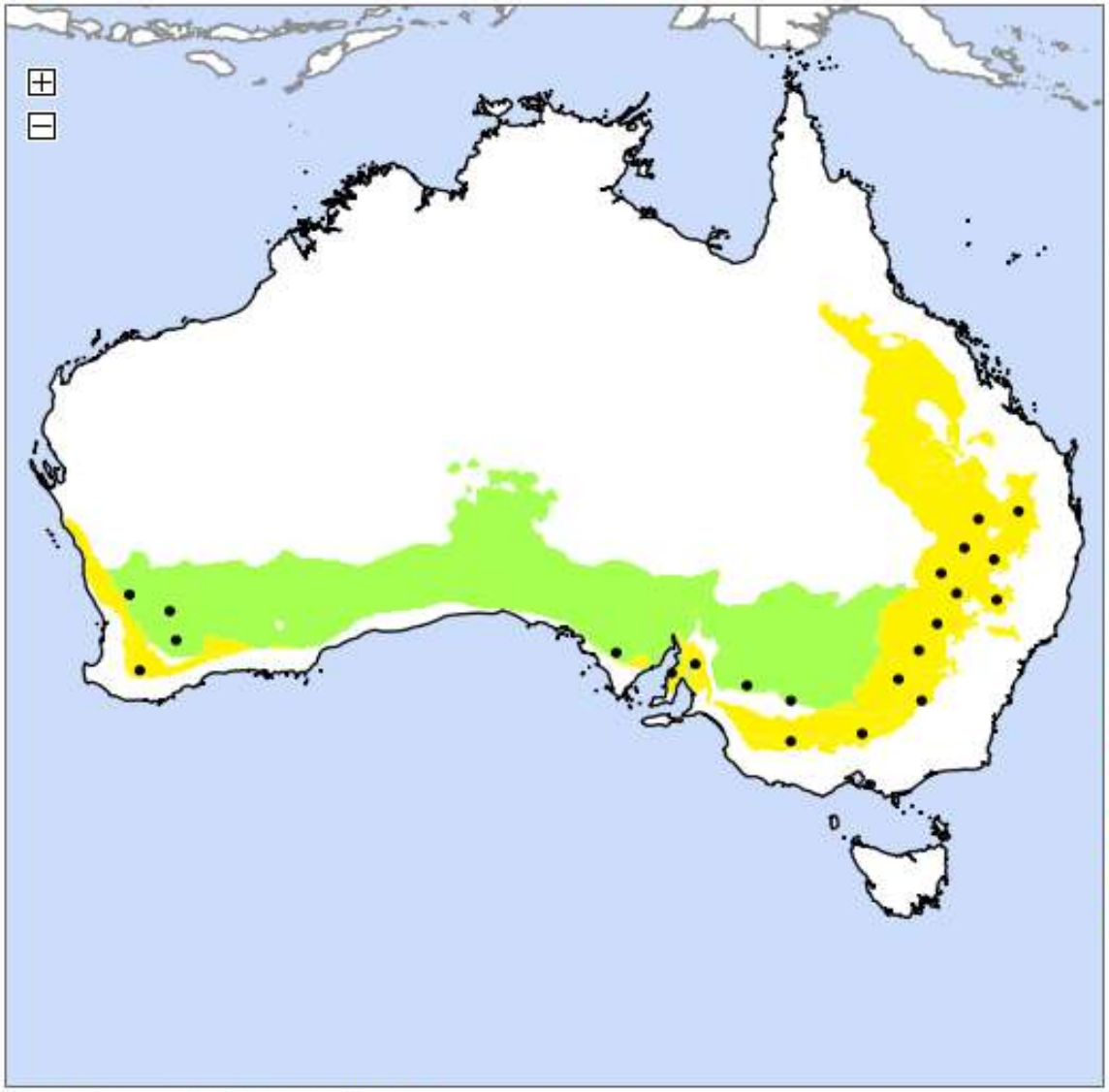


www.yieldgap.org

Global Yield Gap Atlas

Yield and supporting data for rainfed wheat

Rainfed wheat



Yields | Map layers

Select crop :

Rainfed wheat

Select aggregation level:

Climate zones

Select yield indicator:

- Relative yield: Ya / Yw x 100%

Select variable:

Mean value

Apply crop mask: (•) No ( ) Yes

Legend: (•) all classes ( ) current classes

%	%
up to 10 %	50 % - 60 %
10 % - 20 %	60 % - 70 %
20 % - 30 %	70 % - 80 %
30 % - 40 %	80 % - 90 %
40 % - 50 %	more than 90 %

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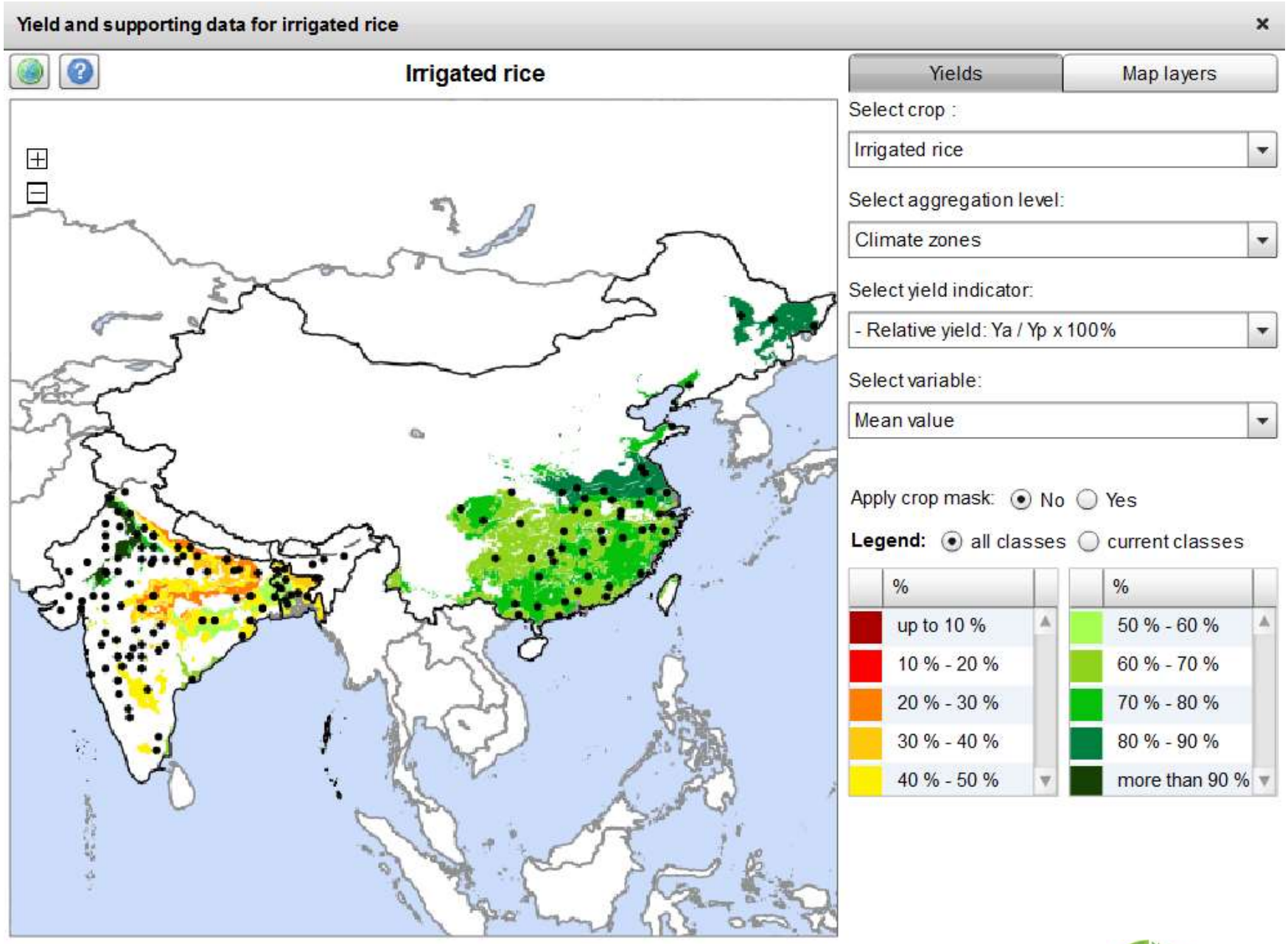

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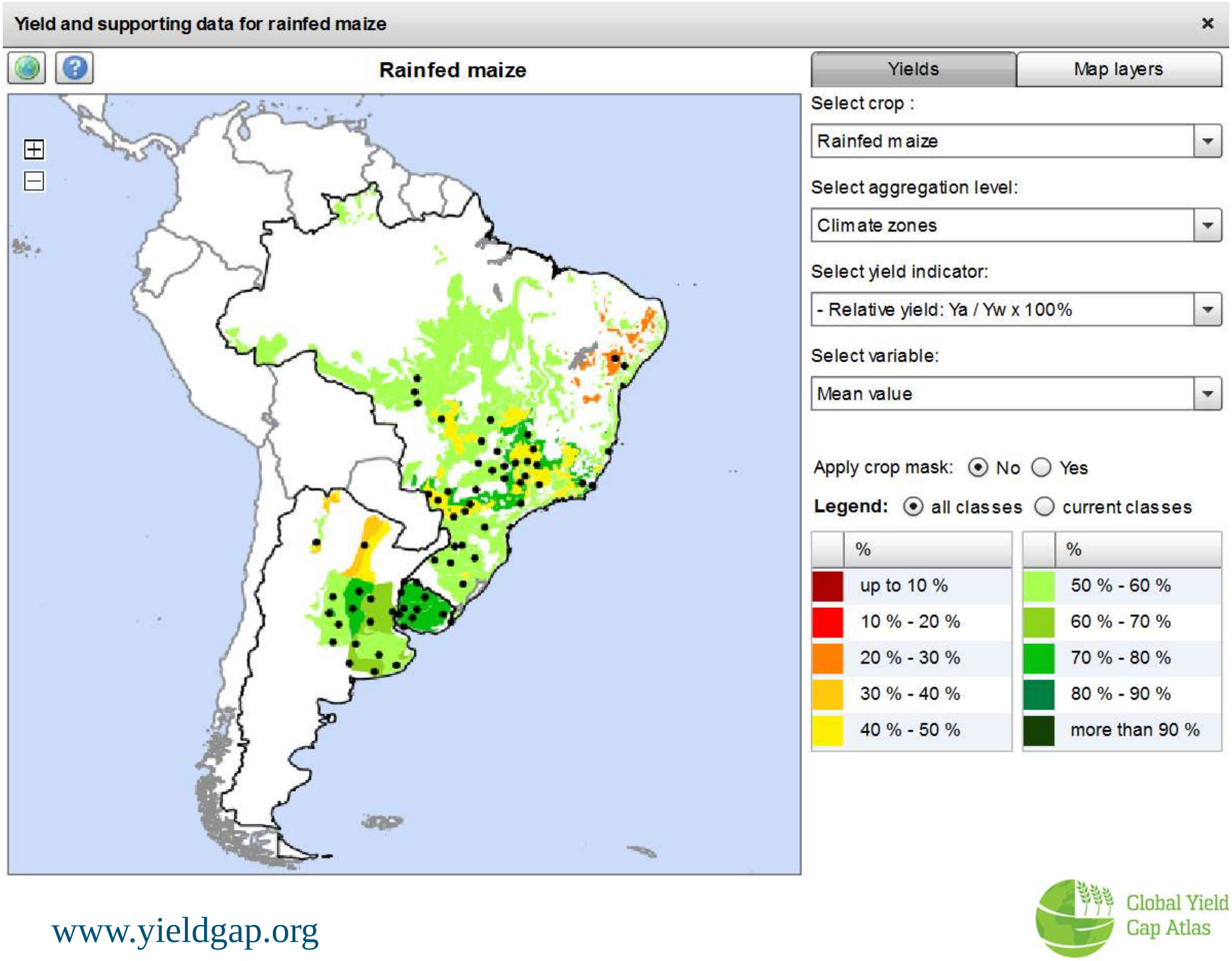
Global Yield Gap Atlas



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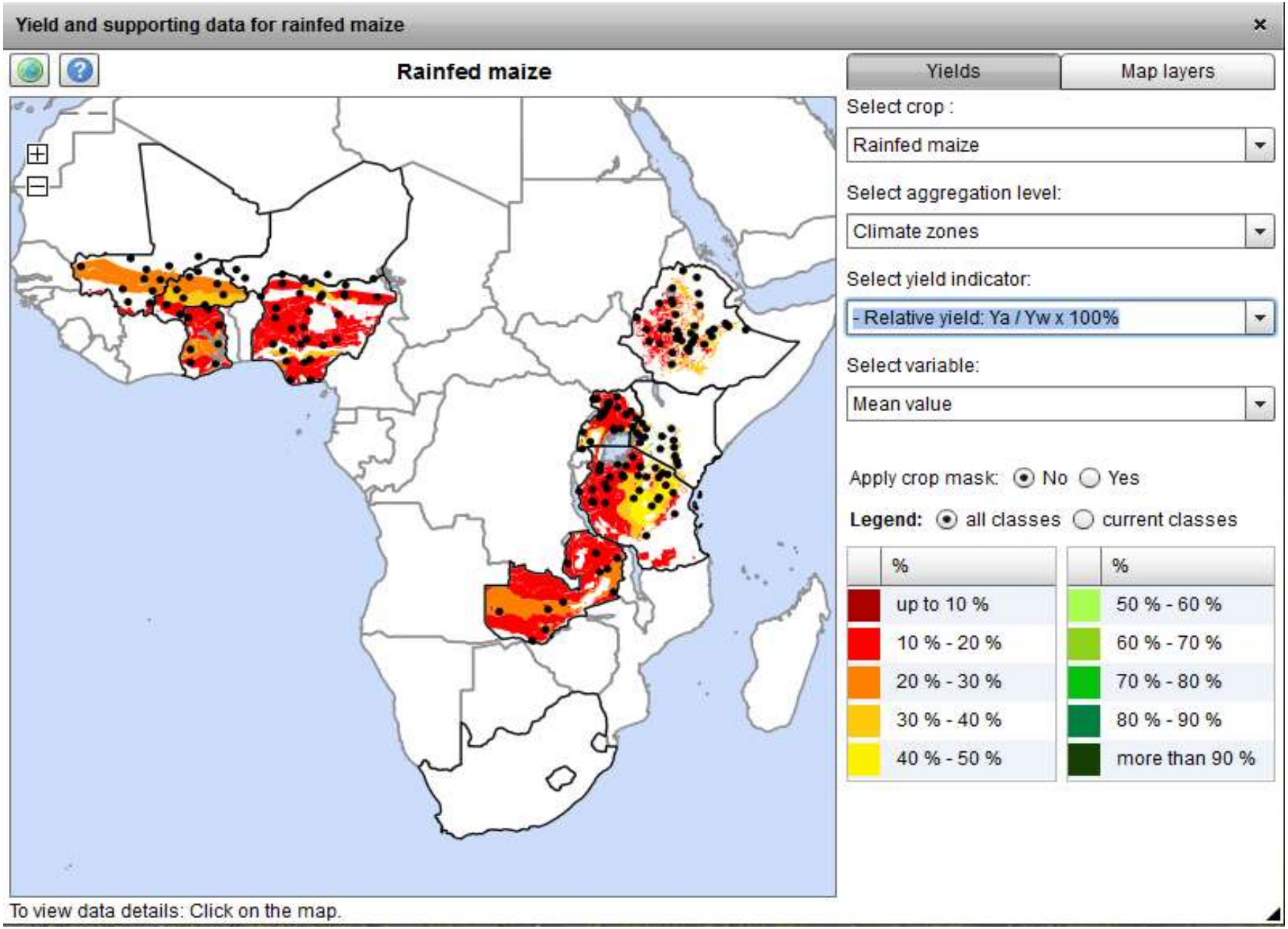
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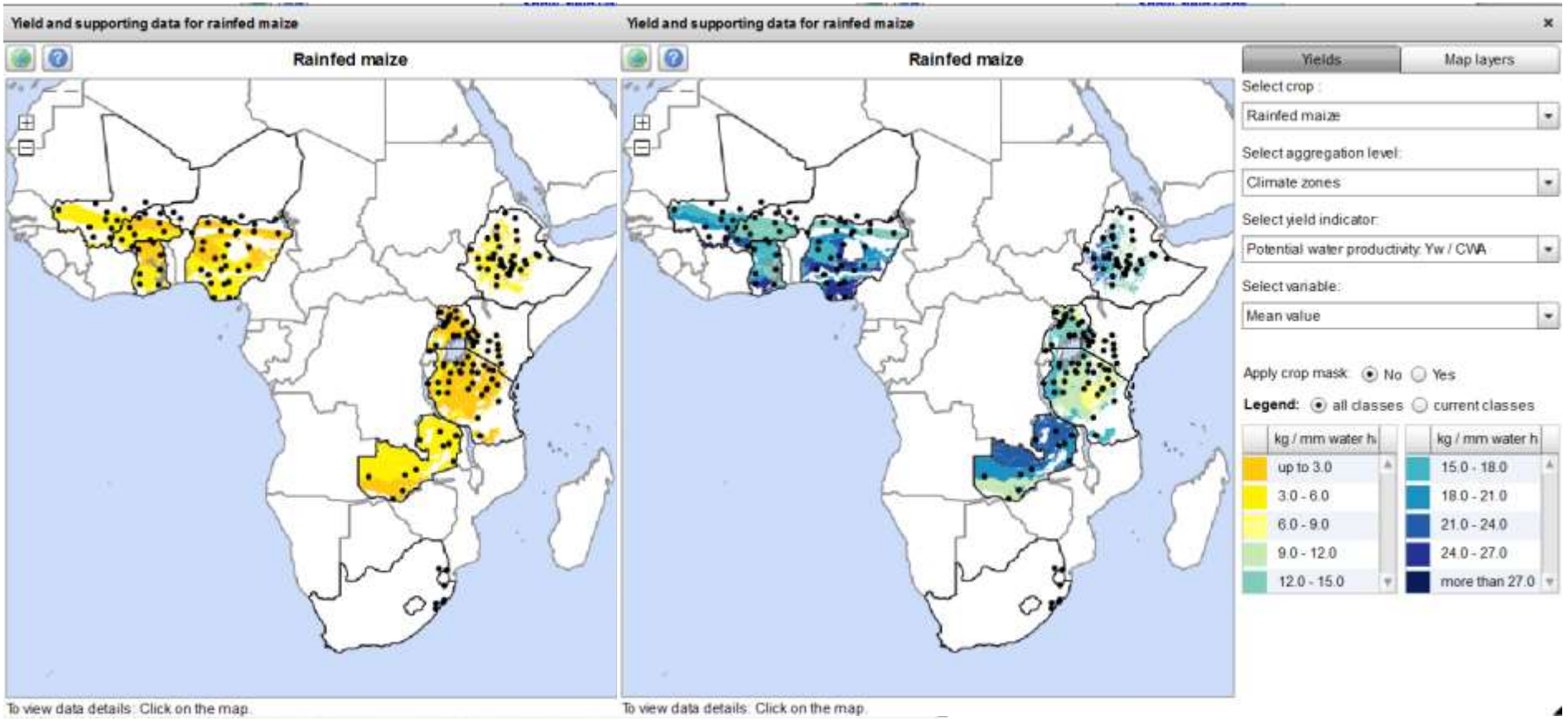
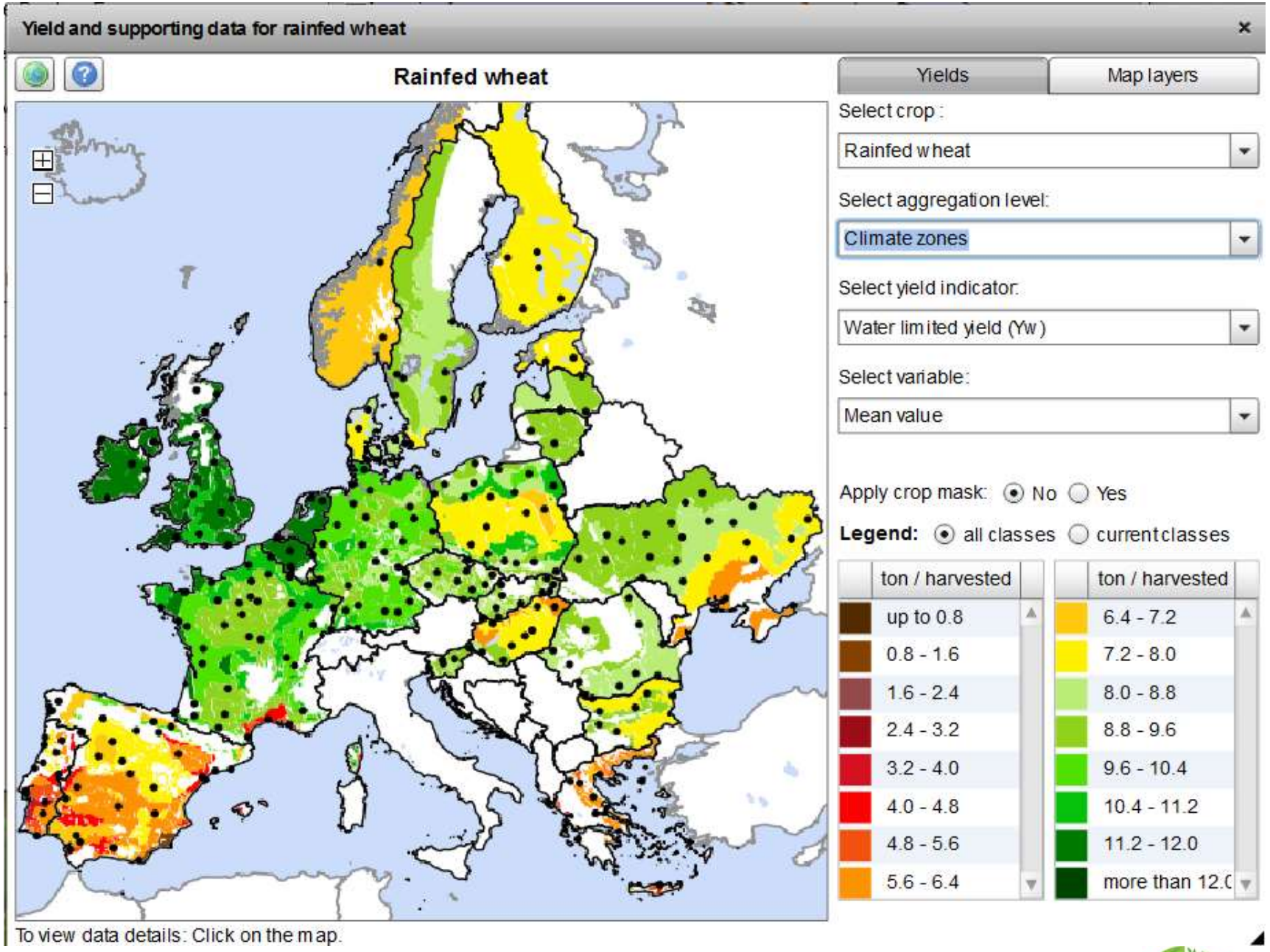
Actual and potential water productivity

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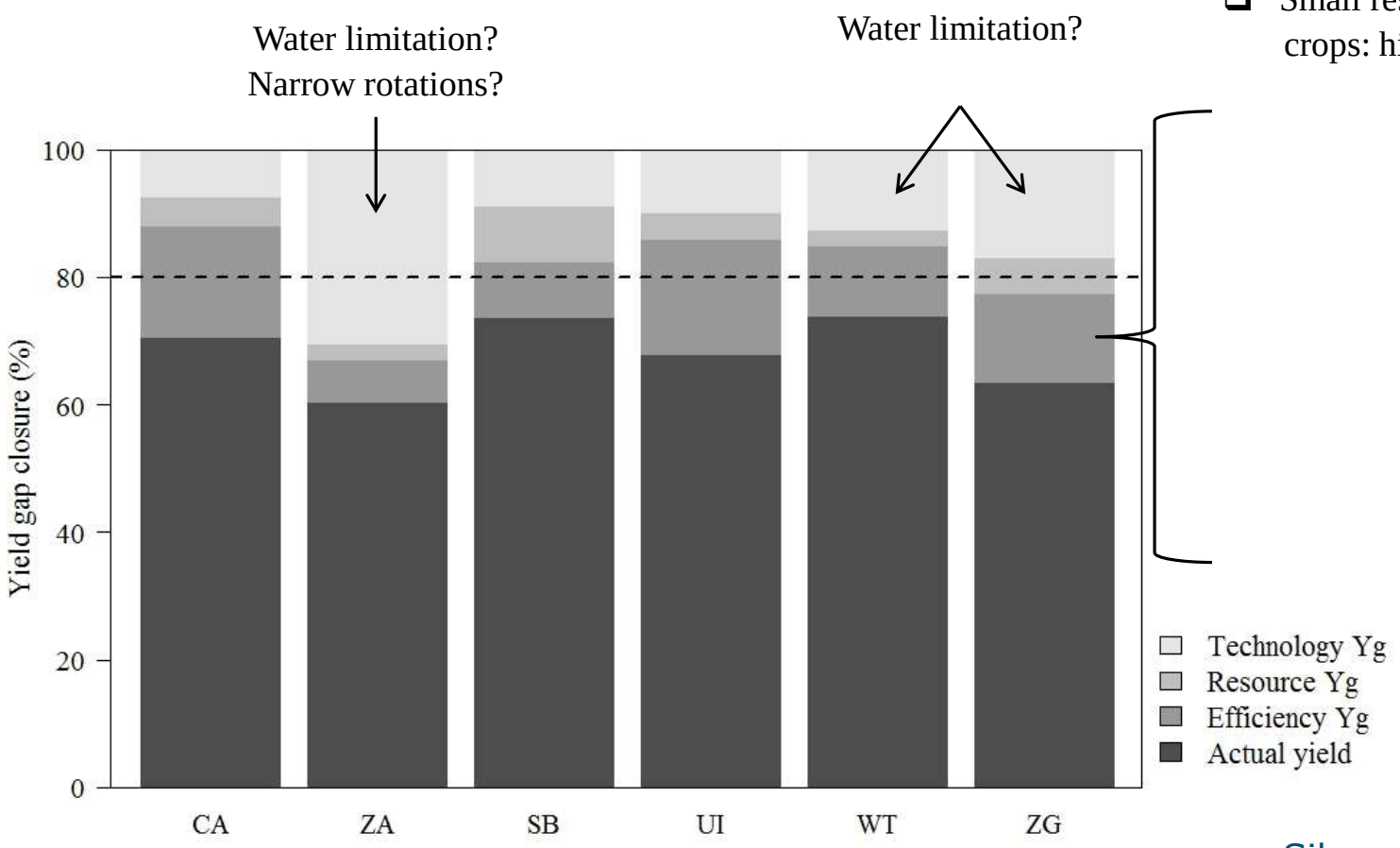
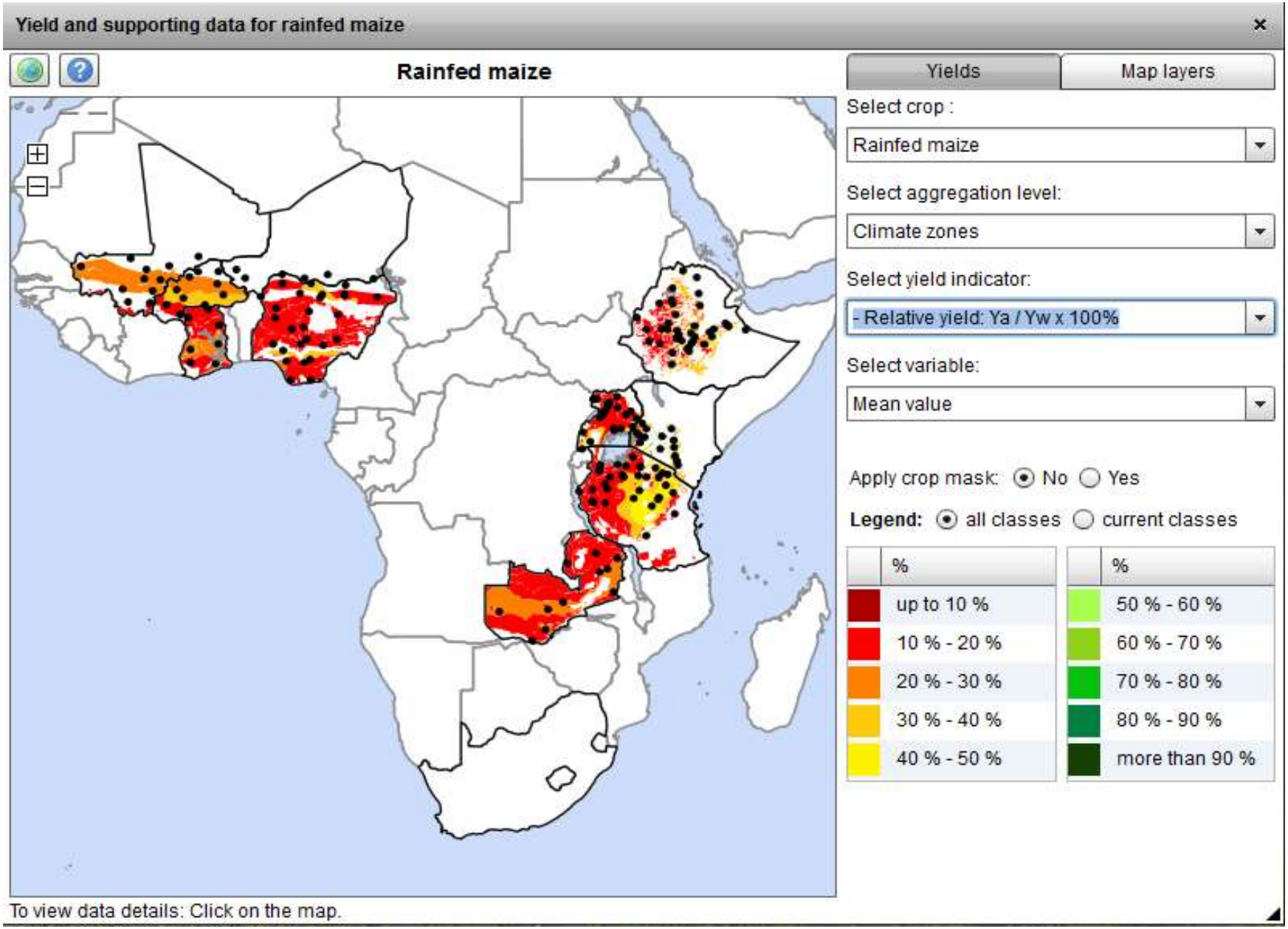
Magnitude of yield gaps for major arable crops in NLs

- Crop yields slightly lower than the suggested 80% Yw
- Small resource Yg for all crops: high input levels



Silva et al., 2017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Global Yield Gap Atlas

Can sub-Saharan Africa feed itself?

Martin van Ittersum, Lenny van Bussel – Plant Production Systems group
Patricio Grassini, Ken Cassman – University of Nebraska-Lincoln
GYGA team, including ten country agronomists from SSA

PNAS14964–14969 | PNAS | December 27, 2016 | vol. 113 | no. 52

University of Nebraska Lincoln

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WaterforFood
ROBERT B. DAUGHERTY INSTITUTE
University of Nebraska

ICRISAT
Science with a human face

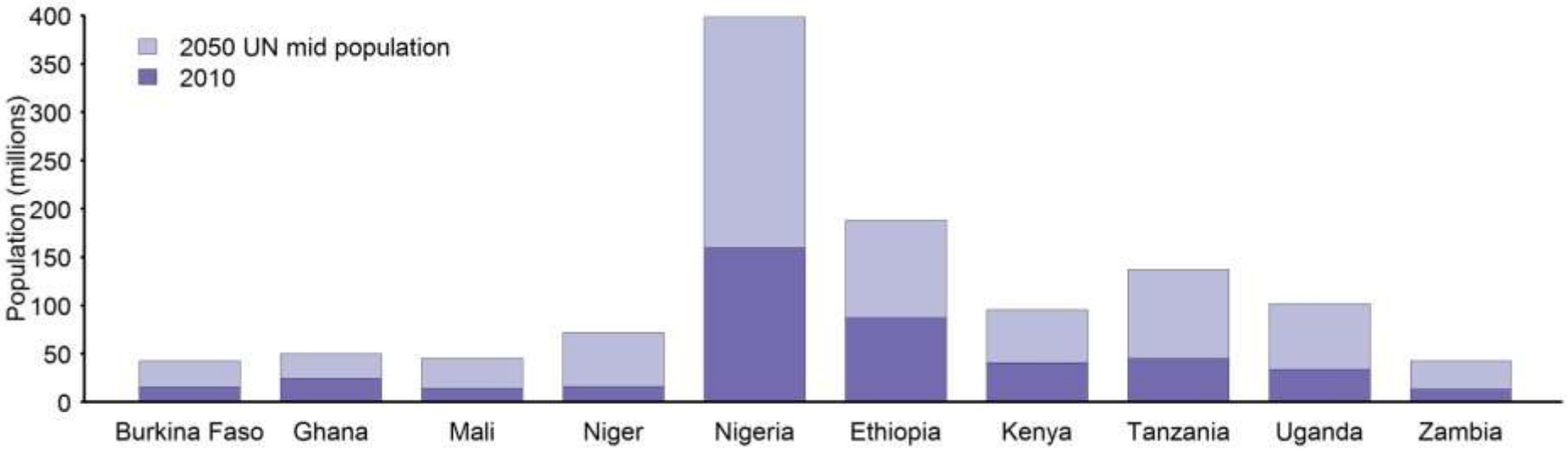
Growth in population and cereal demand - 2050

Country	Population 2010 (million)	Population 2050 (million)	% Population increase
Burkina Faso	16	41	256
Ghana	24	46	192
Mali	14	45	321
Niger	16	69	431
Nigeria	159	440	277
Ethiopia	87	188	216
Kenya	41	97	237
Tanzania	45	129	287
Uganda	33	104	315
Zambia	13	44	338

UN, 2012 and IMPACT, 2012 (and 2015)

Global Yield Gap Atlas

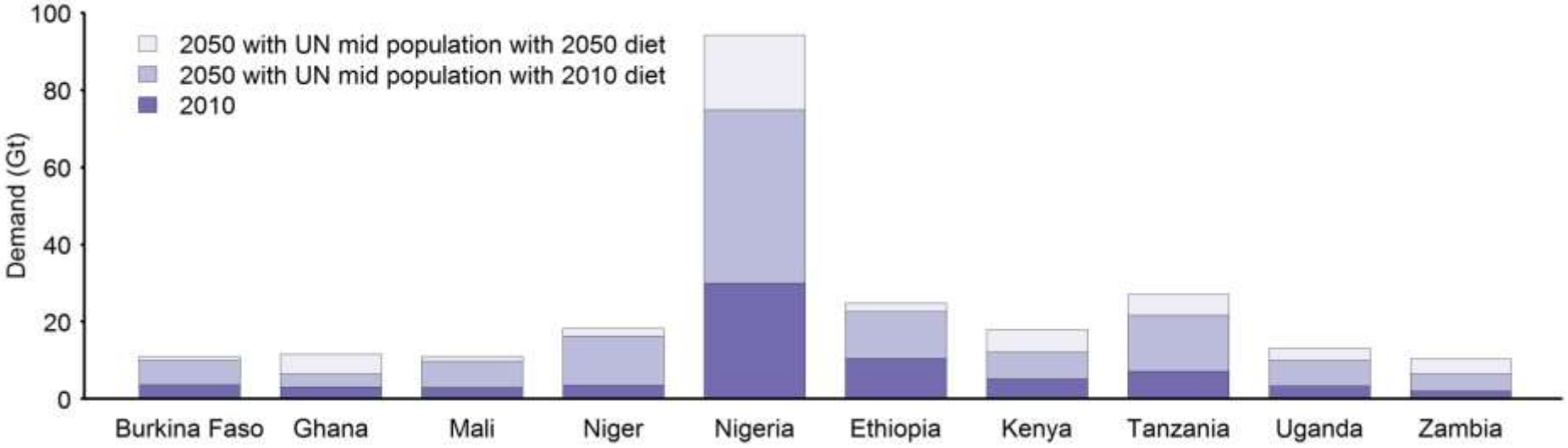
Growth in population 2050



From 0.45 to 1.2 billion (2.6 times)

Global Yield Gap Atlas

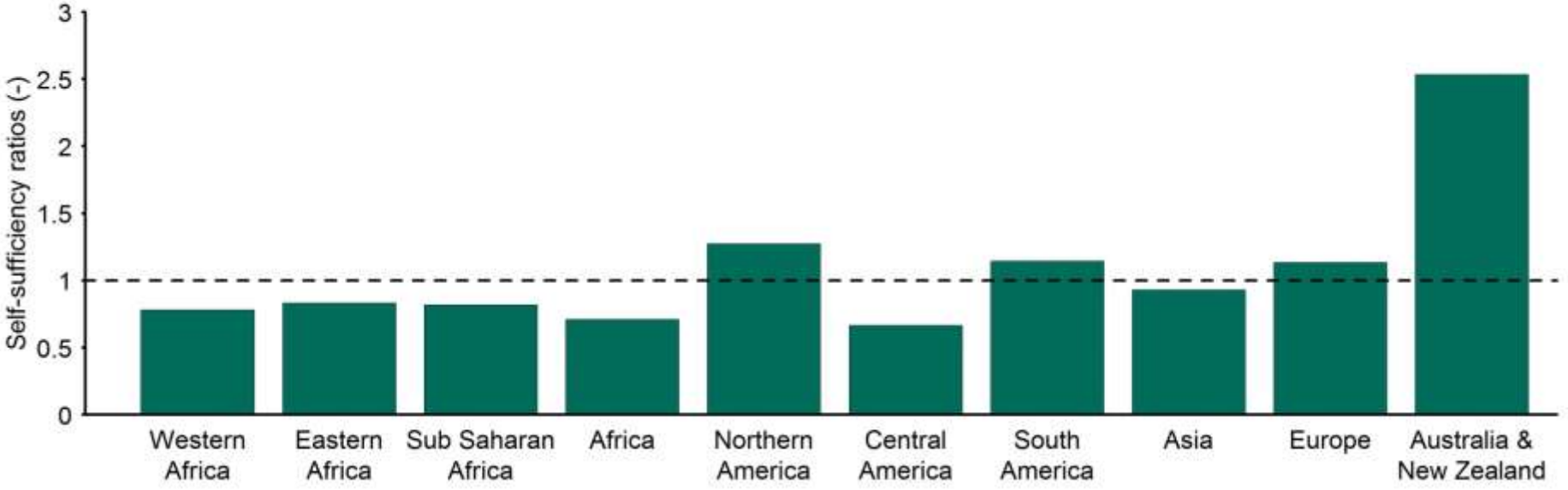
Growth in population and cereal demand - 2050



A factor 3.4 increase!

Global Yield Gap Atlas

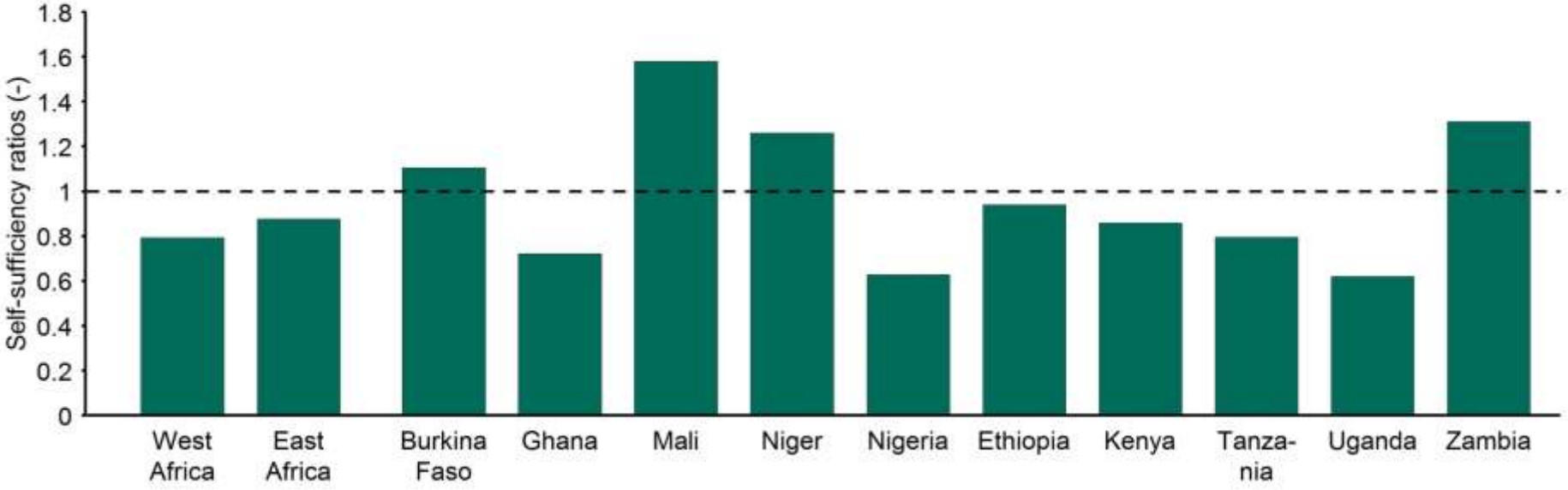
Current self-sufficiency ratios cereals - 2010



Source: FAOstat

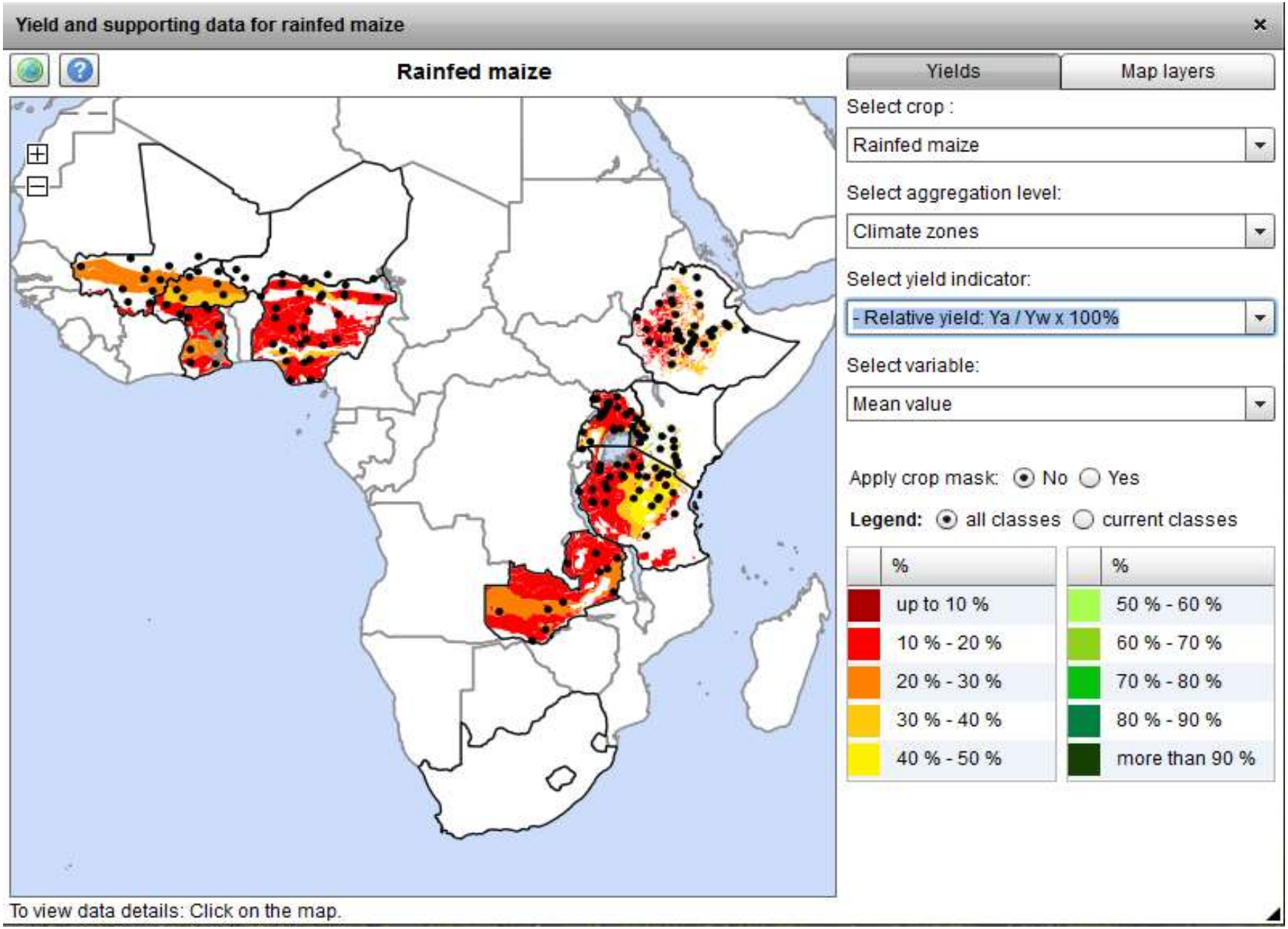
Global Yield Gap Atlas

Current self-sufficiency cereals SSA - 2010



Source: IMPACT model

Global Yield Gap Atlas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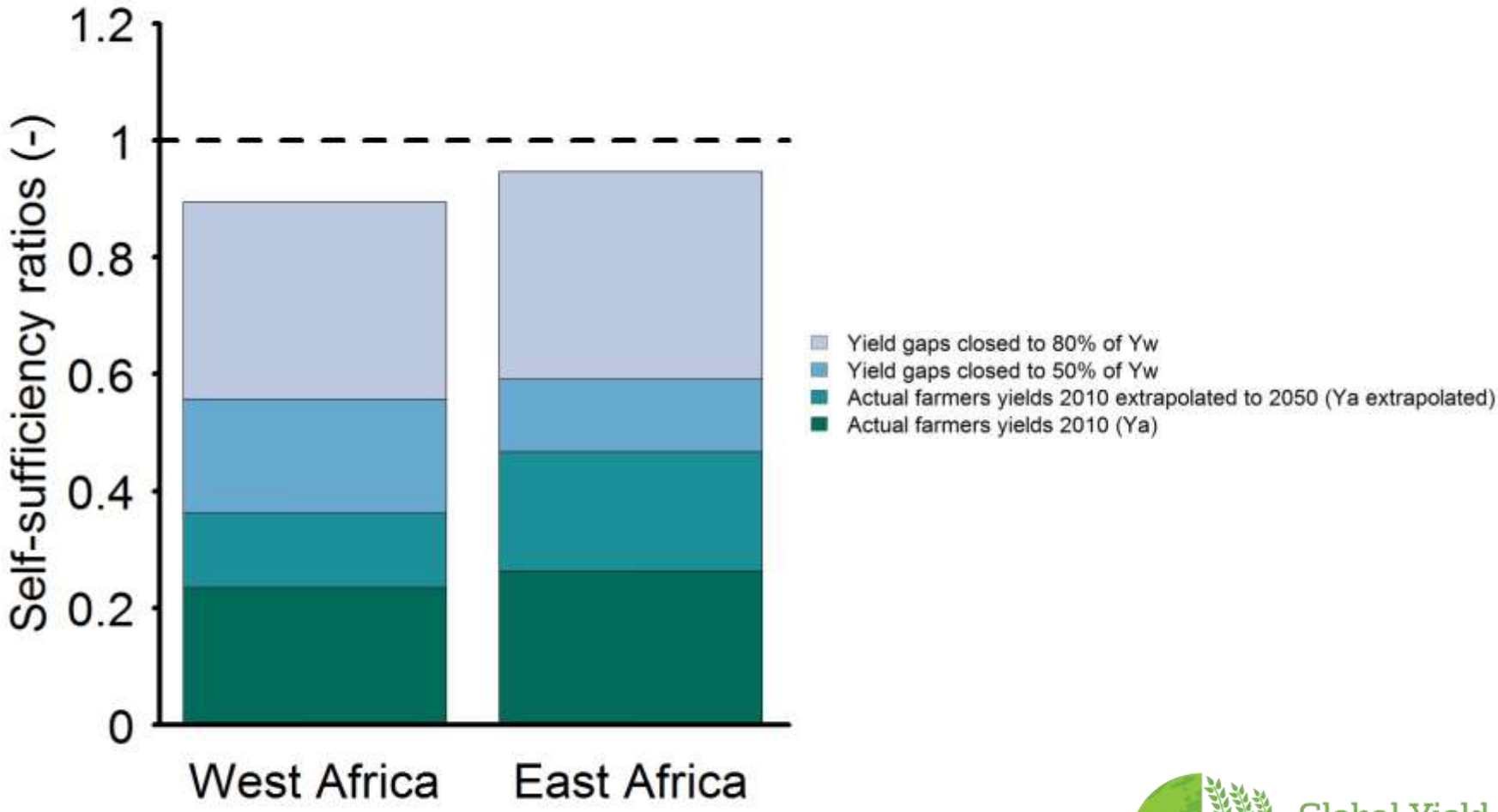
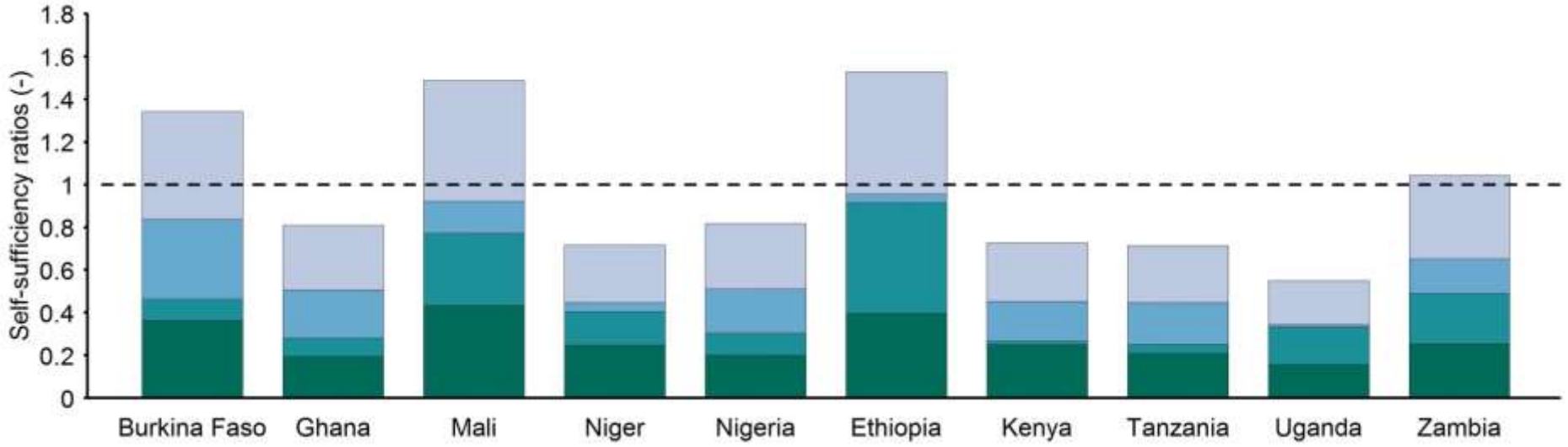
West and East Africa aggregated



Global Yield Gap Atlas

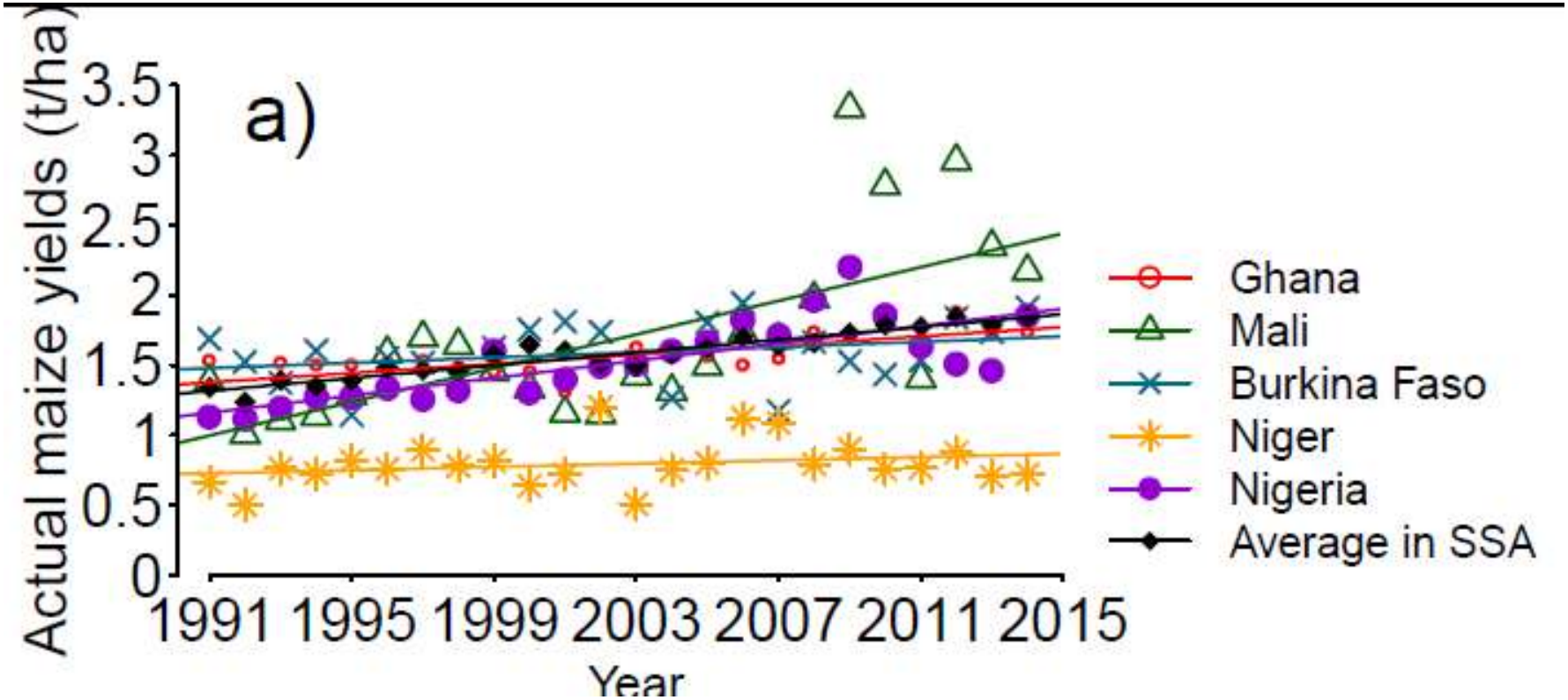
Self-sufficiency 2050: 10 countries



Yield gaps closed to 80% of Yw
Yield gaps closed to 50% of Yw
Actual farmers yields 2010 extrapolated to 2050 (Ya extrapolated)
Actual farmers yields 2010 (Ya)

Global Yield Gap Atlas

Yield progress in SSA (maize)



FAO and Van Ittersum et al., in press

Global Yield Gap Atlas

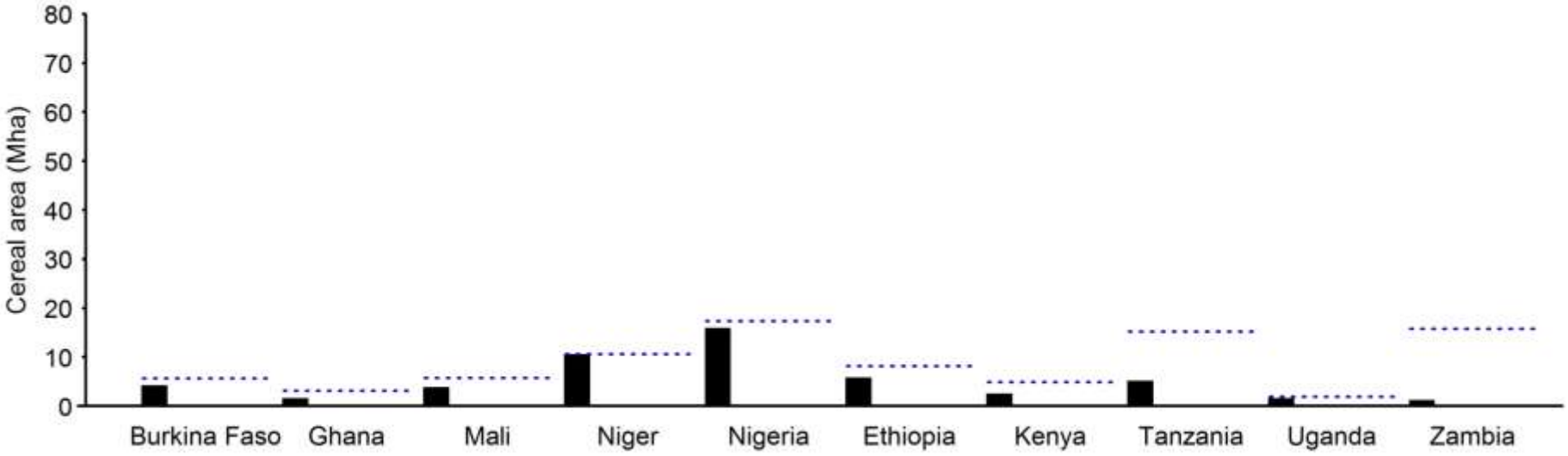
Historical maize yield increases (kg/ha/year)

Country	1961-1990	1991-2013
Argentina	68	131
Brazil	25	122
China	107	56
Ethiopia	n.a.	79
France	130	61
Ghana	0.7	17
India	15	48
Indonesia	43	130
Kenya	26	6
Nigeria	21	39
Spain	168	196
USA	112	111

FAOSTAT

Global Yield Gap Atlas

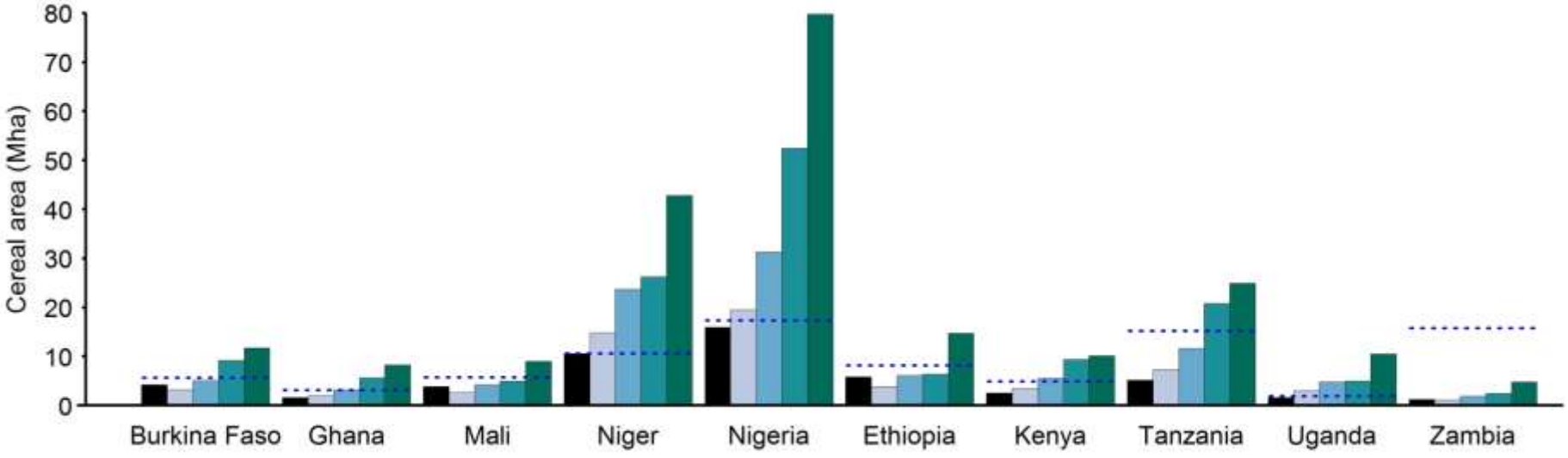
Current and potentially available cereal area



Based on: Chamberlin et al., 2014

Global Yield Gap Atlas

Current and potentially available cereal area



- Yield gaps closed to 80% of Yw
- Yield gaps closed to 50% of Yw
- Actual farmers yields 2010 extrapolated to 2050 (Ya extrapolated)
- Actual farmers yields 2010 (Ya)

Global Yield Gap Atlas


shutterstock

Conclusions – to reach self-sufficiency

- Increasing cereal yields from 20% to 50% of Yw:
  - doubling of annual yield increases
  - 80% increase in cereal areas
- Increasing cereal yields to 80% of Yw:
  - annual yield increases of ca. 130-140 kg
- Increased cropping intensity and irrigation will help
- A regional approach to food self-sufficiency seems essential, but even then...

Global Yield Gap Atlas

If a successful intensification is not achieved ....

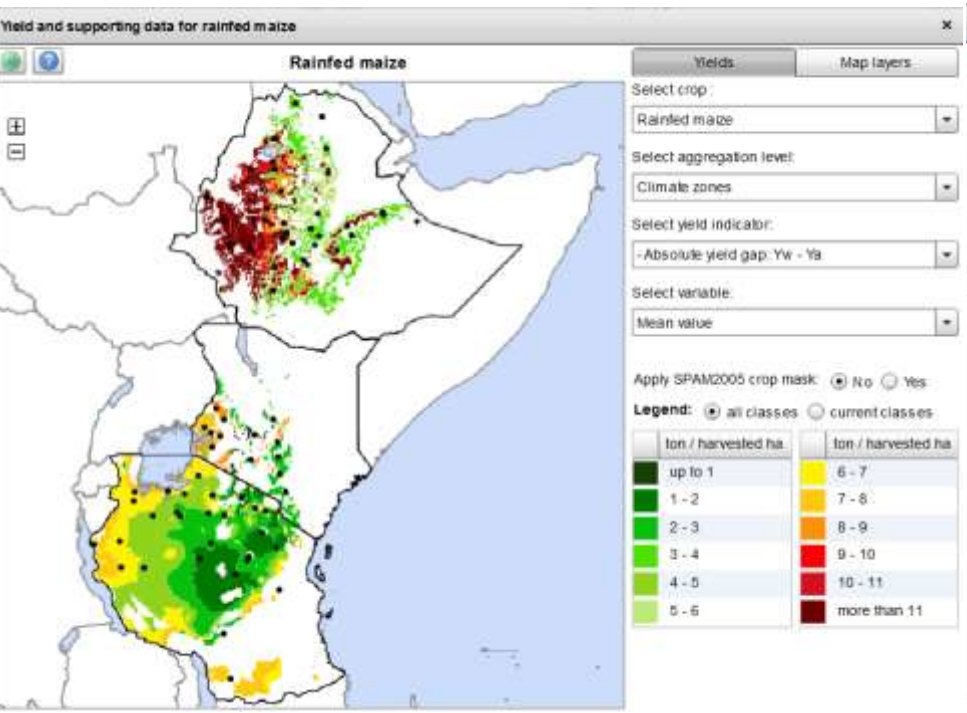
The consequences in terms of:

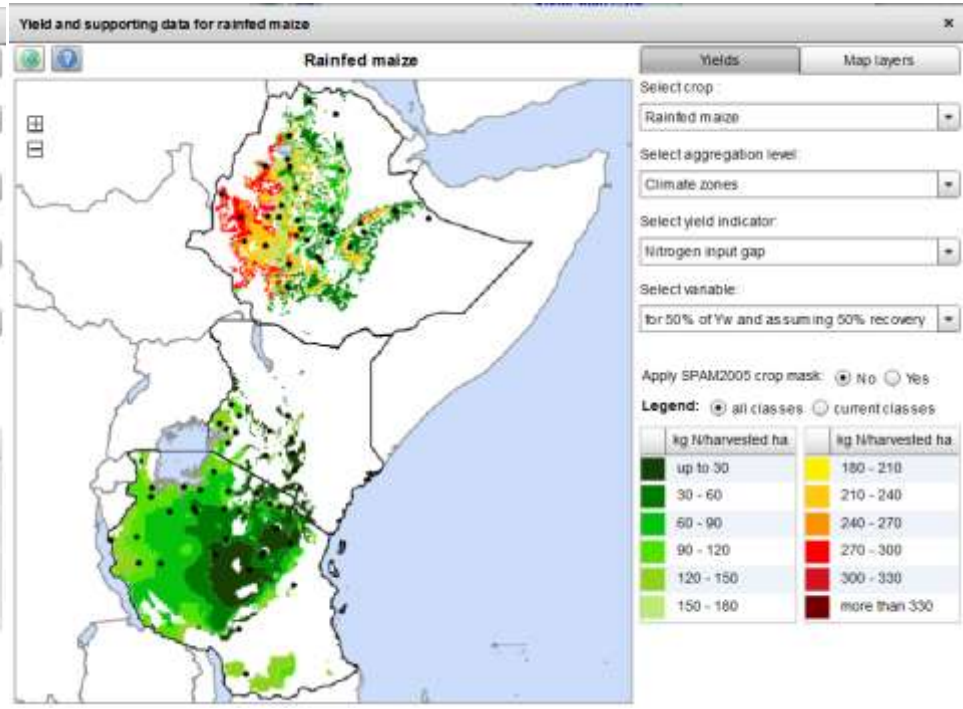
- cereal self-sufficiency and/or
- area expansion (GHG, biodiversity!)

will be huge!

Global Yield Gap Atlas

From yield gaps to nutrient gaps





www.yieldgap.org

Global Yield Gap Atlas

And what about Sustainable intensification?

Global Yield Gap Atlas

Reducing GHG emissions and/or intensity

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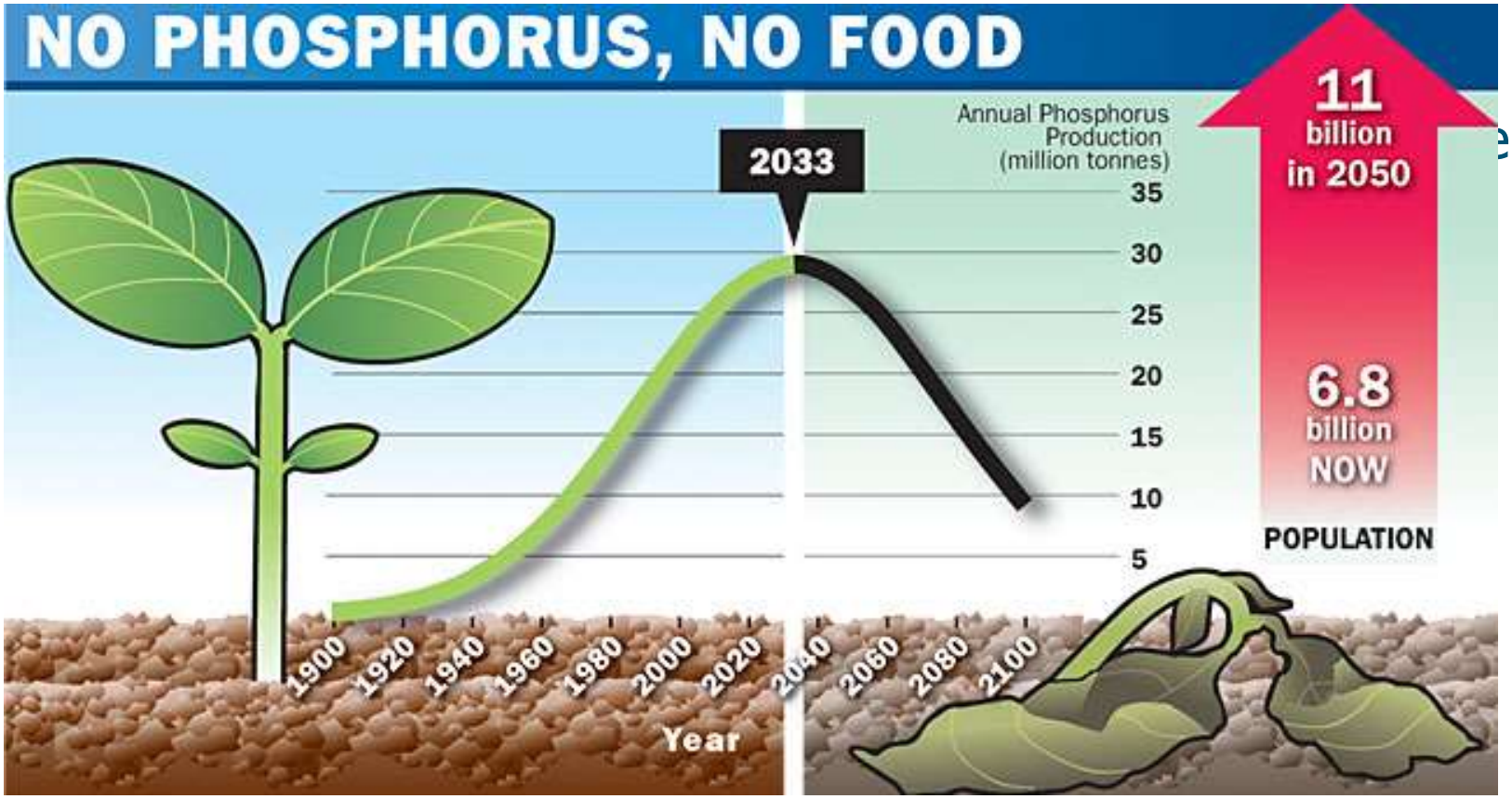
Efficient, or better, circular use of finite resources



Weekly TimesNow,
21 September 2009

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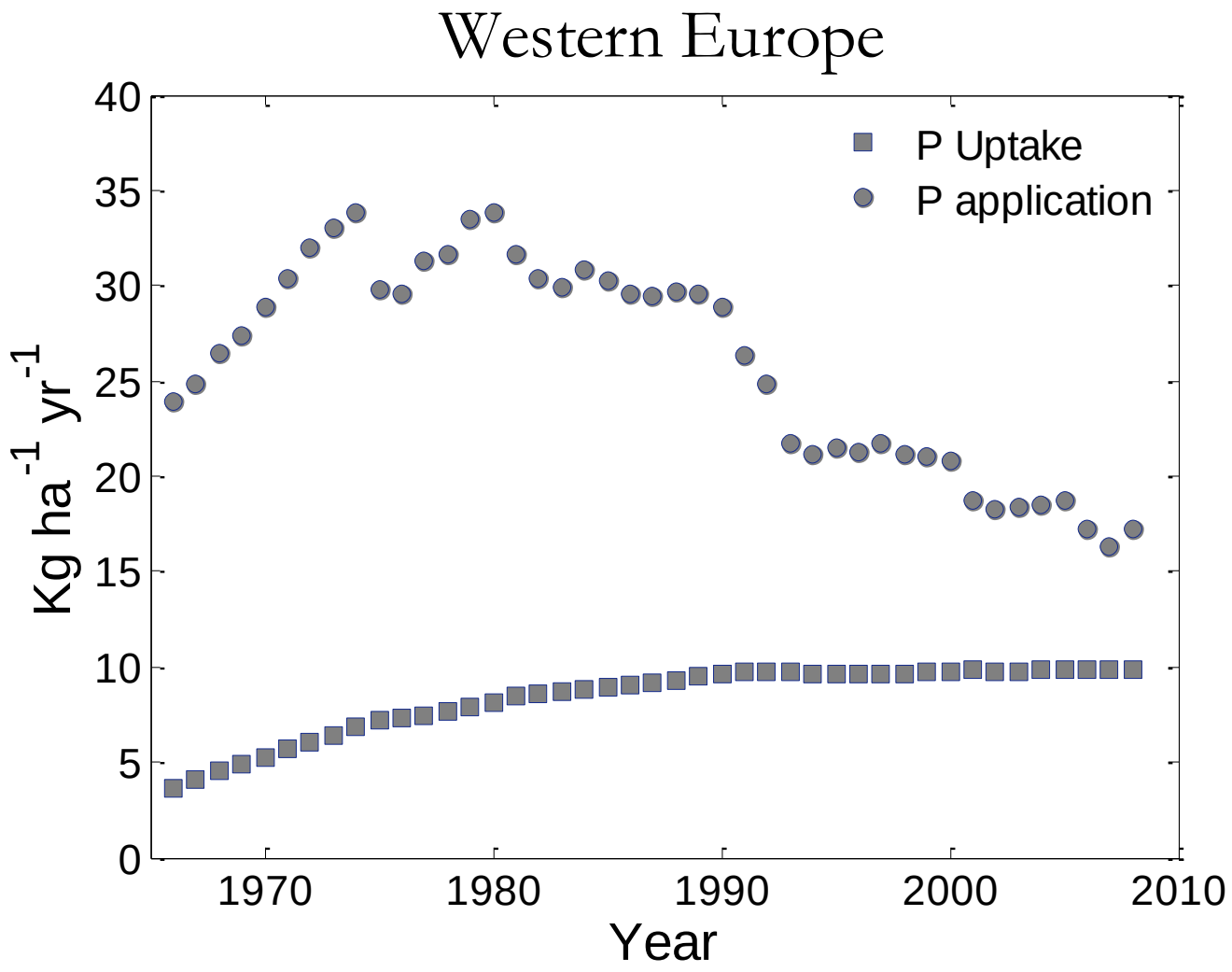
P application and P uptake



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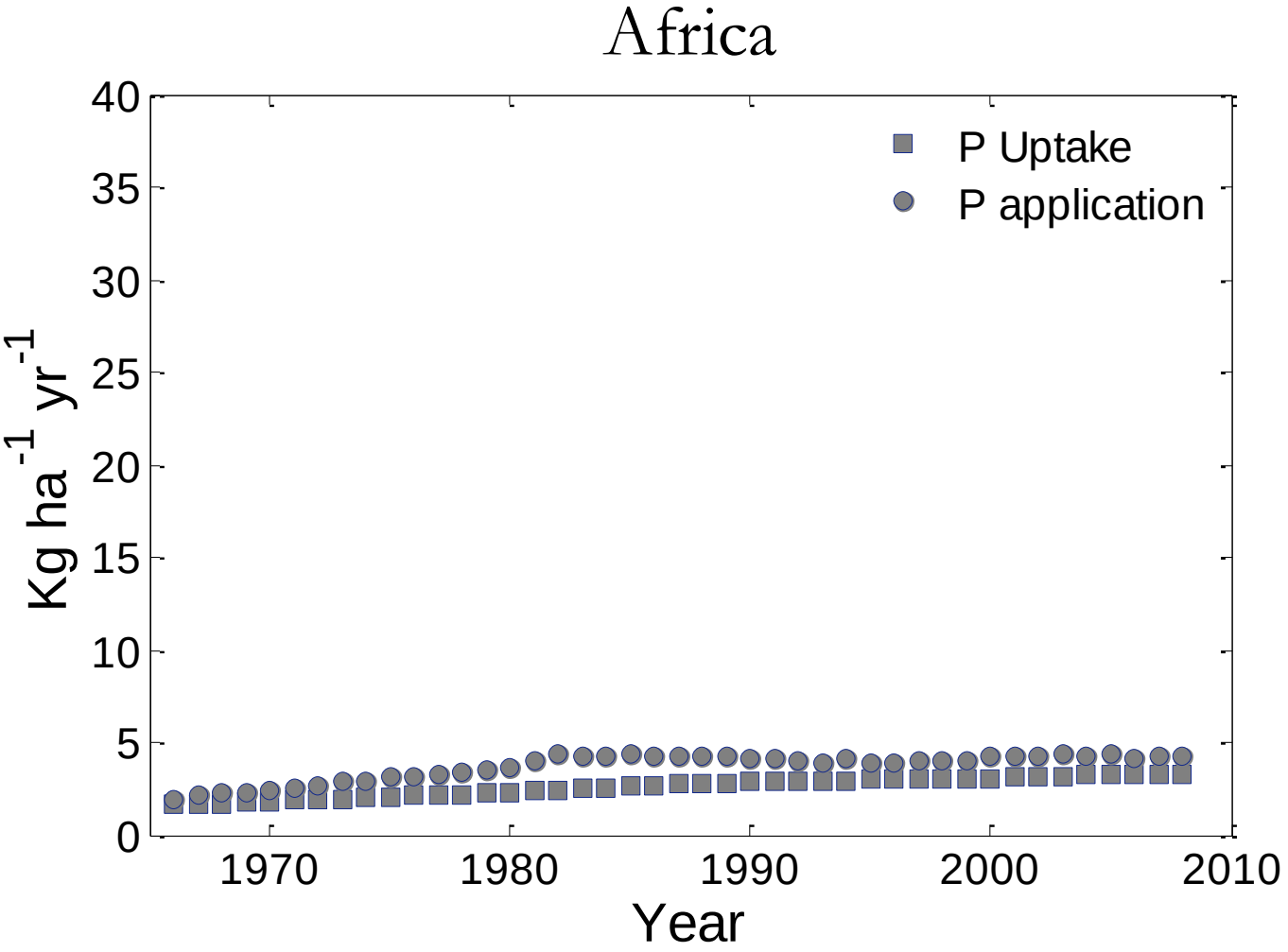
Sattari, Bouwman, Giller and Van Ittersum, 2012 - PNAS

P application and P uptake



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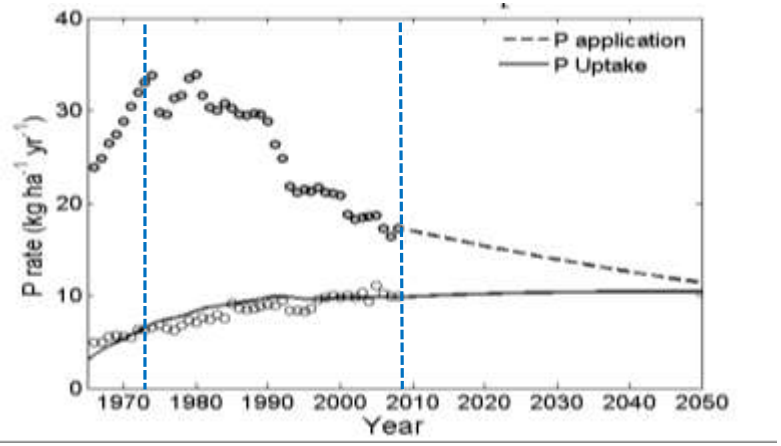
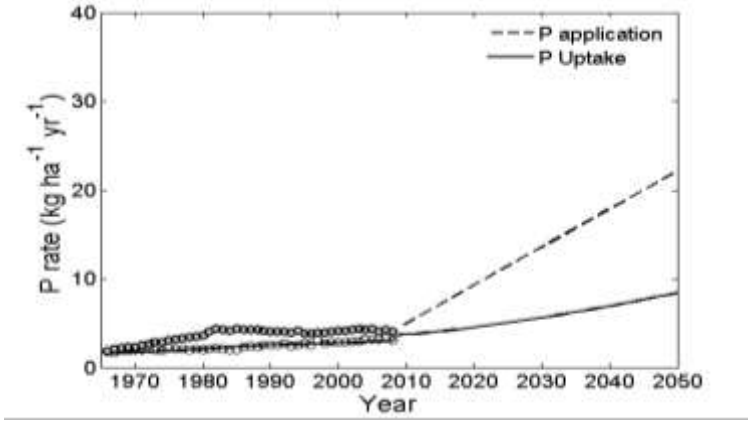
Sattari, Bouwman, Giller and Van Ittersum, 2012 - PNAS

A learning curve!

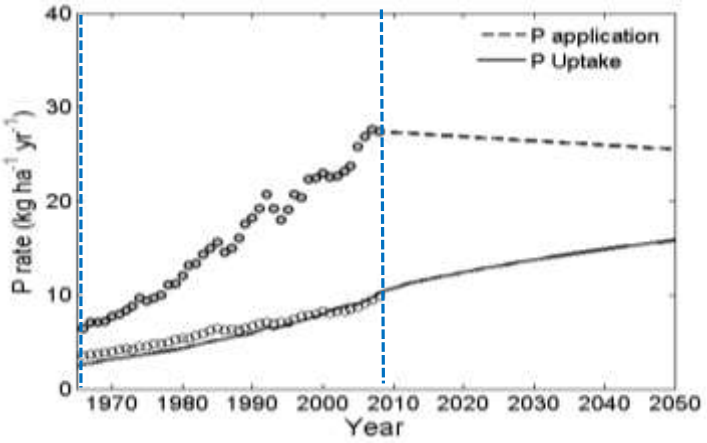
W-Europe



Africa



Asia



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

Experimental farm De Marke

Research (demonstrate) whether:

it is possible to produce milk at a ‘normal production intensity: 12,000 kg milk/ha’ without violating environmental targets

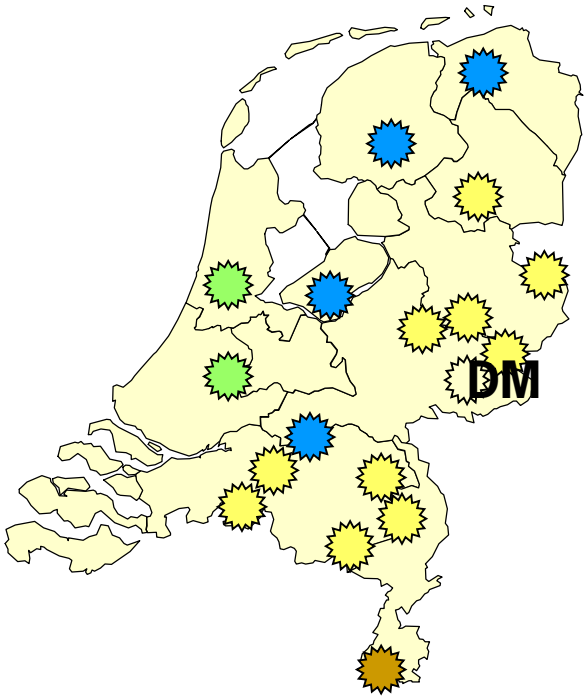
16 pilot farms

clay

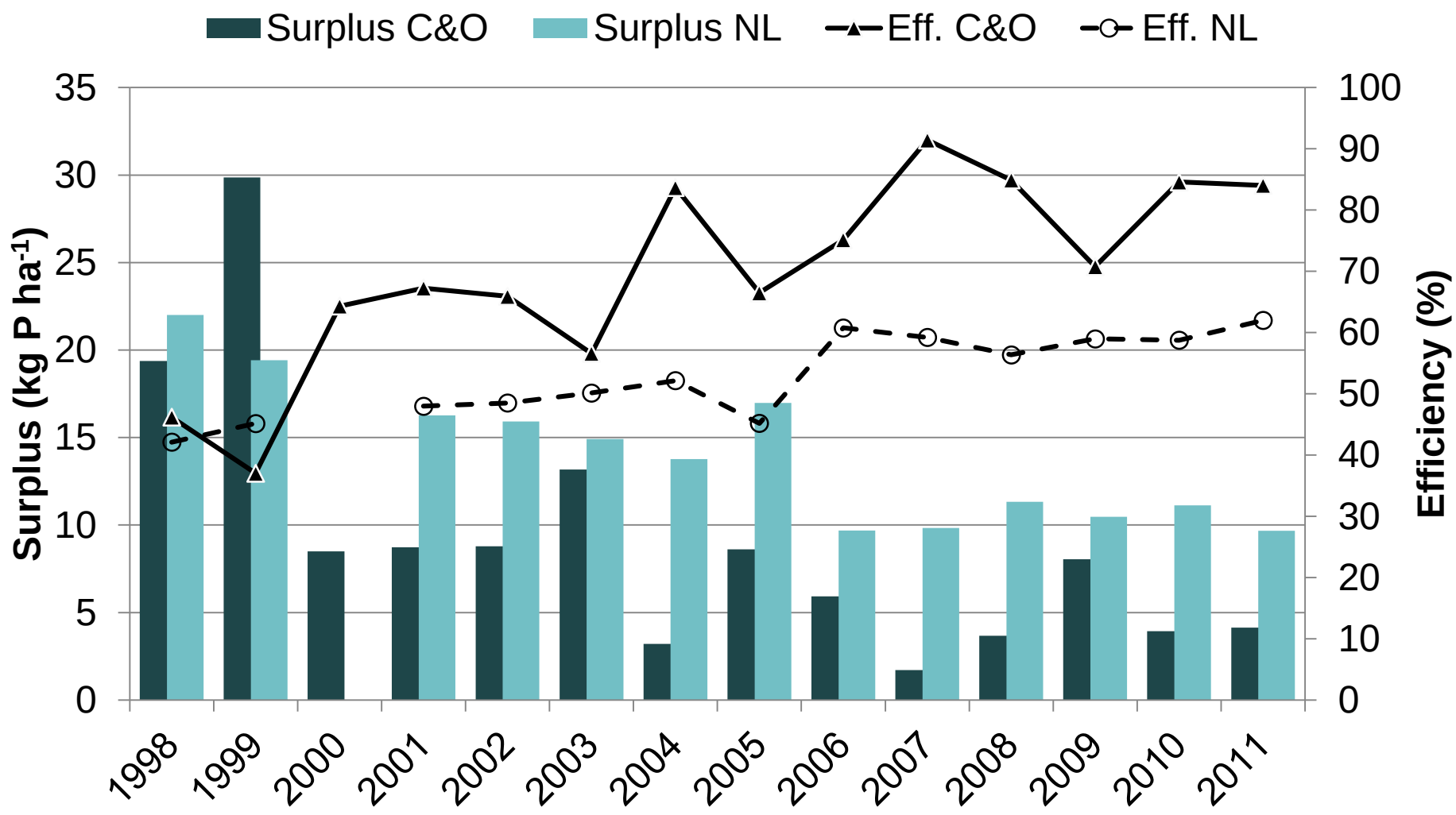
peat

sand

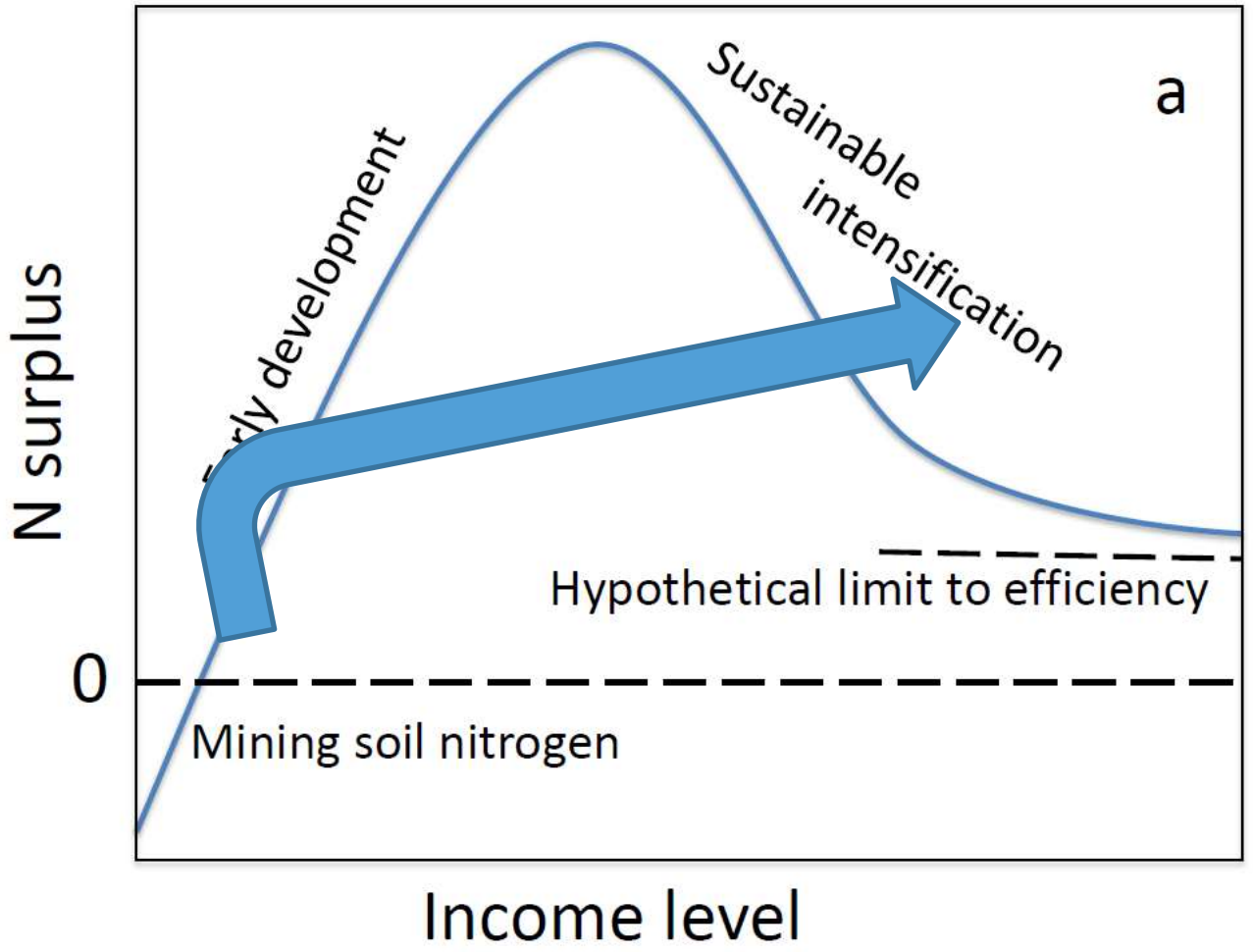
loess



Surplus and efficiency of phosphorus (P) at whole farm level



The challenge: tunnelling through



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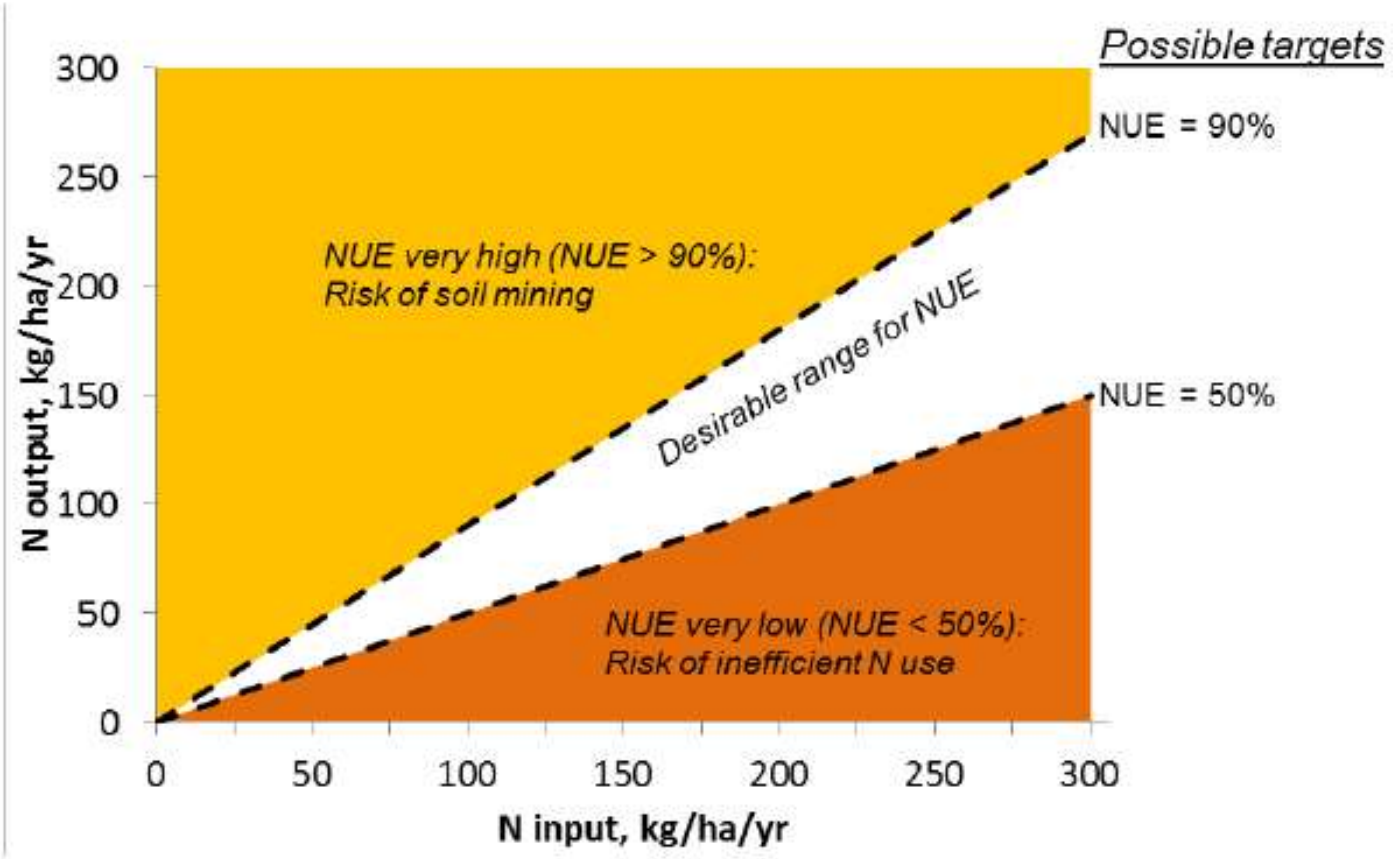
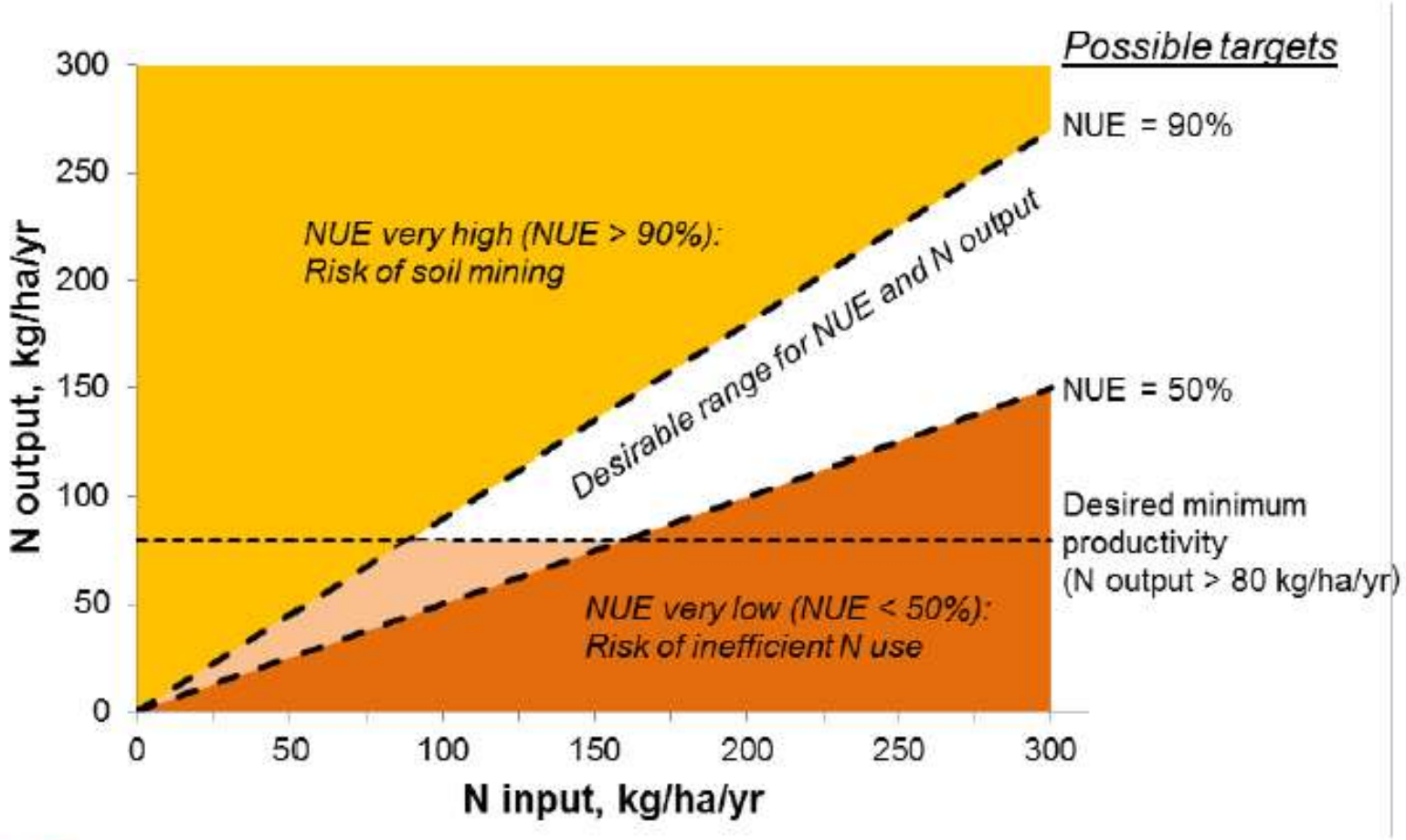
Zhang et al., Nature, 2015

A graphical presentation, in three steps: (i) NUE



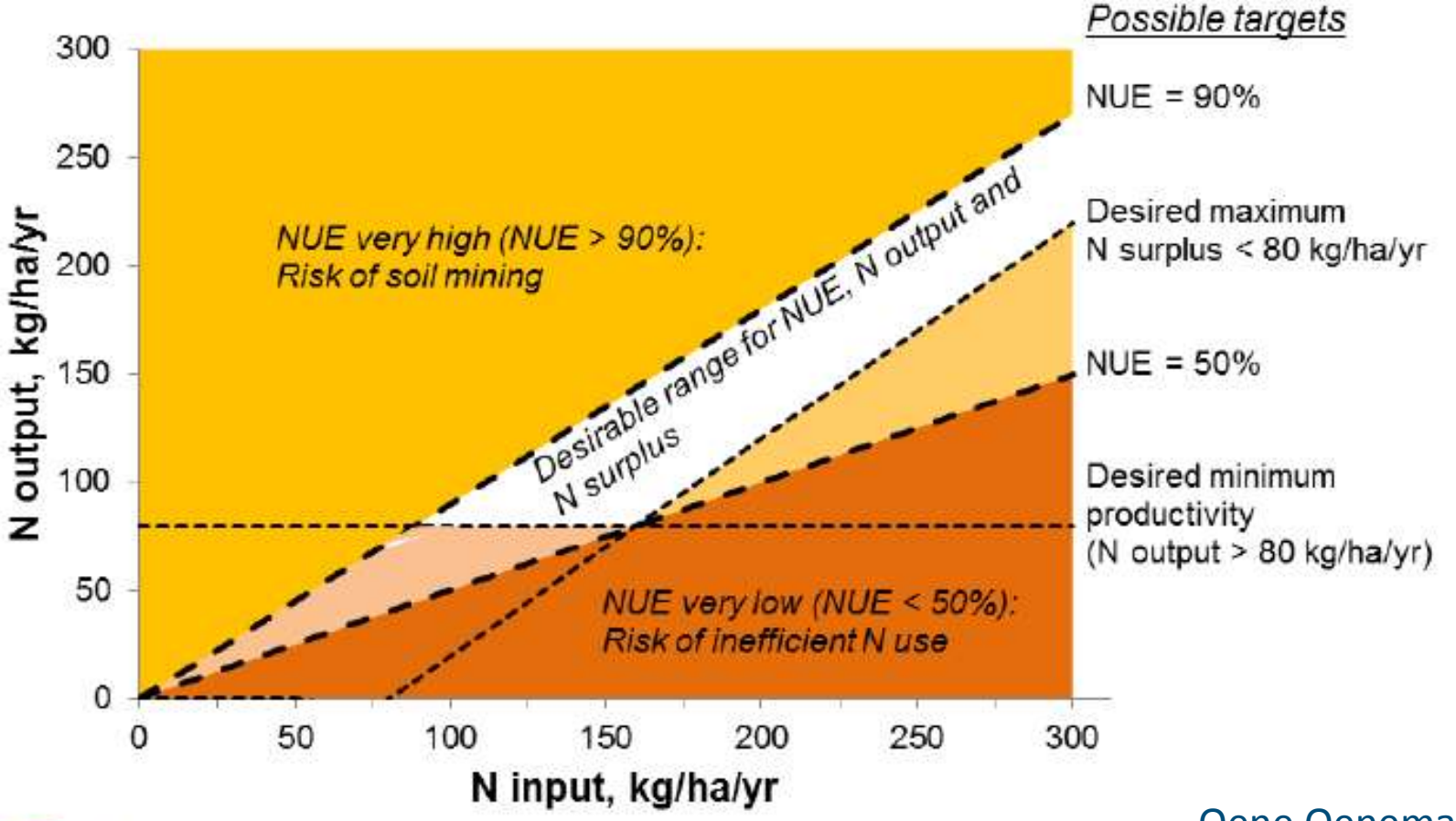
Oene Oenema,
Wageningen Univ.

A graphical presentation, in three steps: (ii) N output



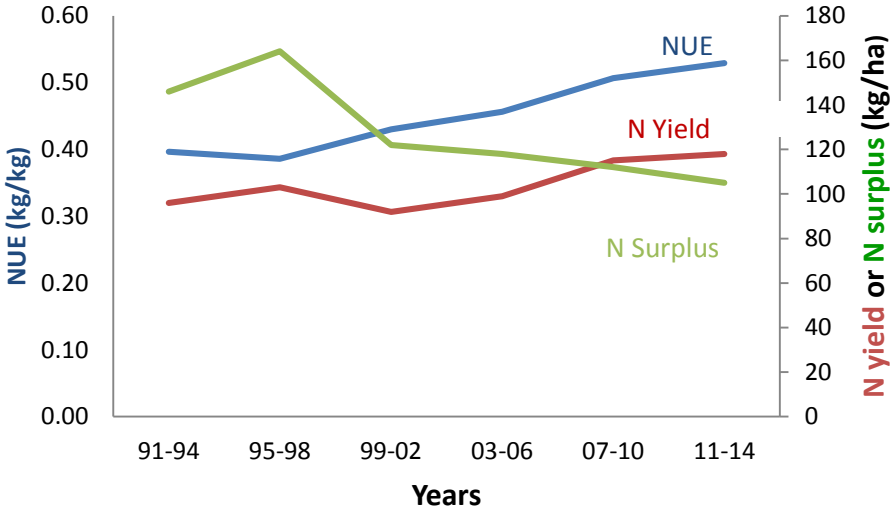
Oene Oenema, Wageningen Univ.

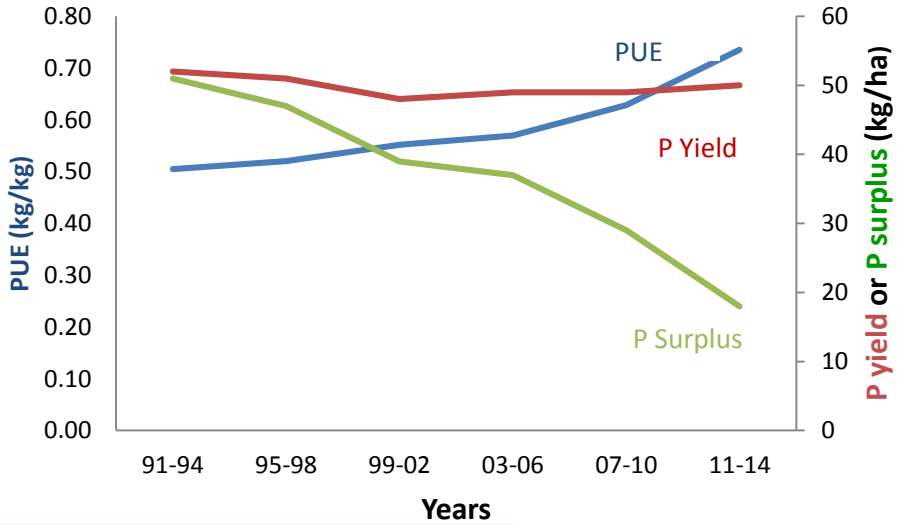
A graphical presentation, in three steps: (iii) N surplus



Oene Oenema,
Wageningen Univ.

Yield – Use efficiency - Surplus





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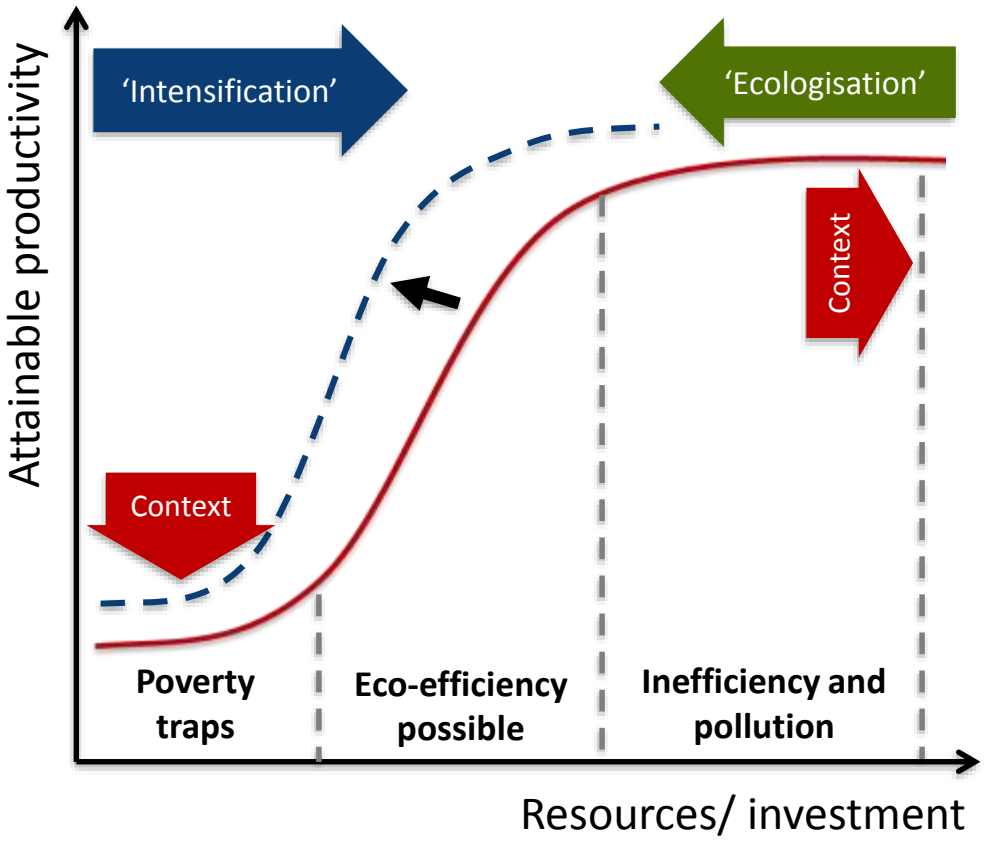
Prins, H., C. Daatselaar & T. de Koeijer (2016) Bemesting en bodemoverschotten van stikstof en fosfaat 1991-2014. Evaluatie Meststoffenwet 2016: deelrapport vraag 2 en vraag 10 ex post. Wageningen Economic Research.

Intensification or Ecologisation?



'Ecologisation':
How to maintain productivity while reducing dependence on fossil fuels?

'Intensification':
How to increase productivity in a sustainable, affordable way?

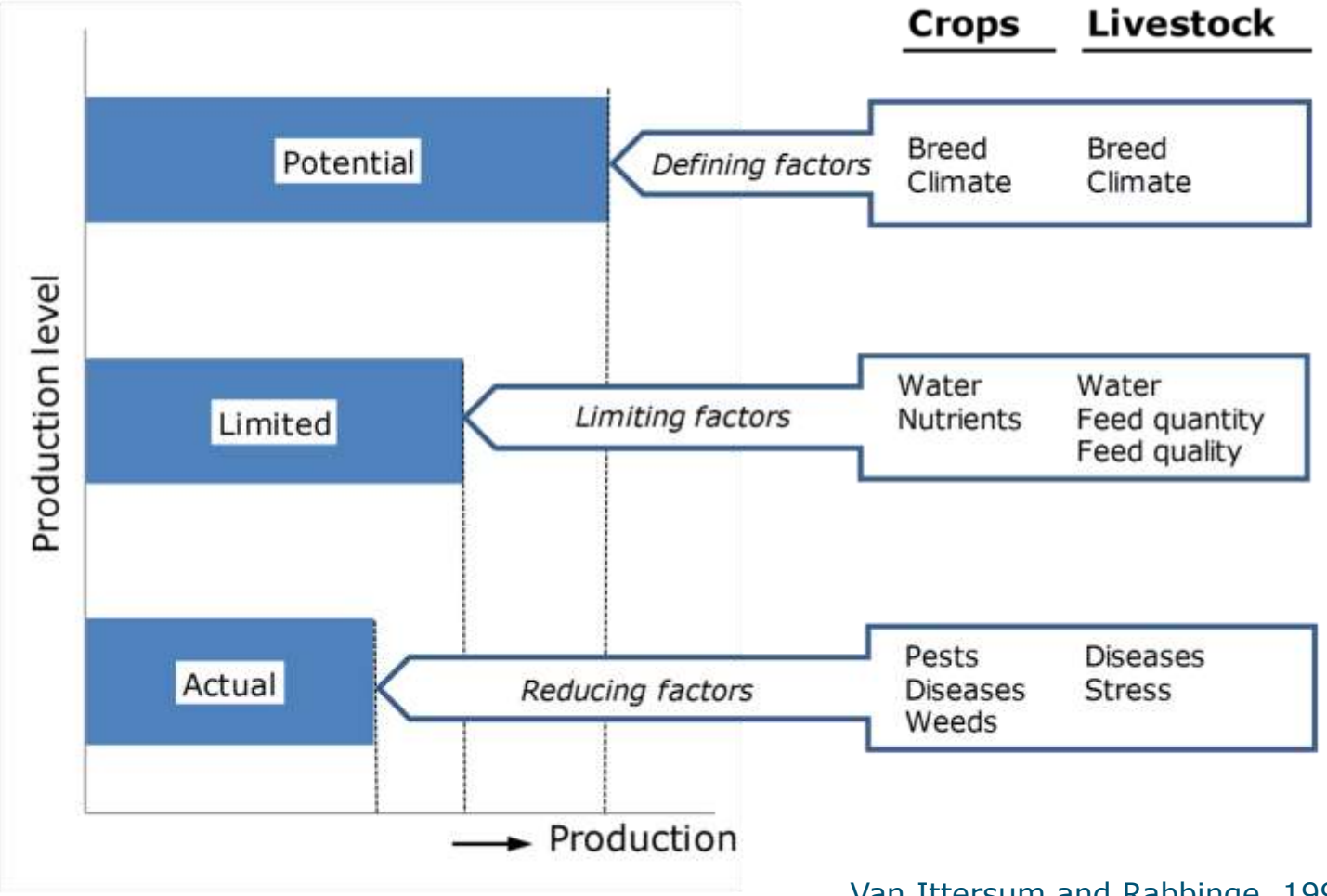
Towards an ecological intensification of world agriculture - Tittonell (2013)

Future harvest

Thank you for your attention!


SUSTAINABLE DEVELOPMENT GOALS
1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE AND JUSTICE
17 PARTNERSHIPS FOR THE GOALS
SUSTAINABLE DEVELOPMENT GOALS

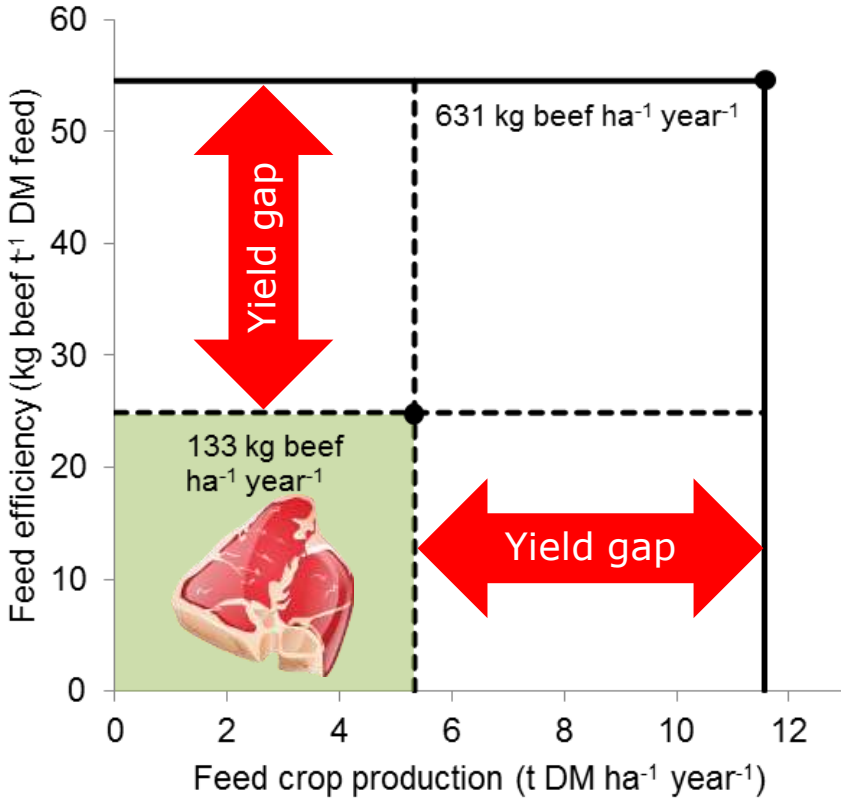
‘Yield gap analysis’ for Livestock systems



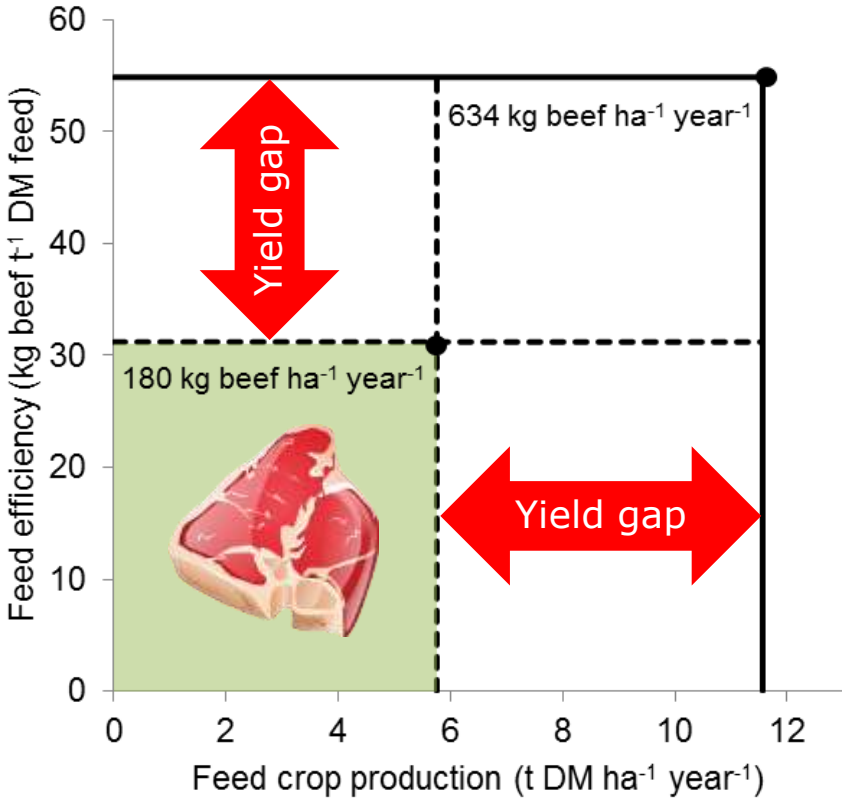
Van Ittersum and Rabbinge, 1997; Van de Ven et al, 2003;
Van der Linden et al., 2015

Yield gap analysis for crop-livestock systems

5% concentrates, 95% grass-based



18% concentrates, 82% grass-based



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For quality of life

Van der Linden *et al.*, 2015
Data: Reseaux d'Elevage Charolais, 2012