Sustainable intensification: the fine line between myopia and utopia

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

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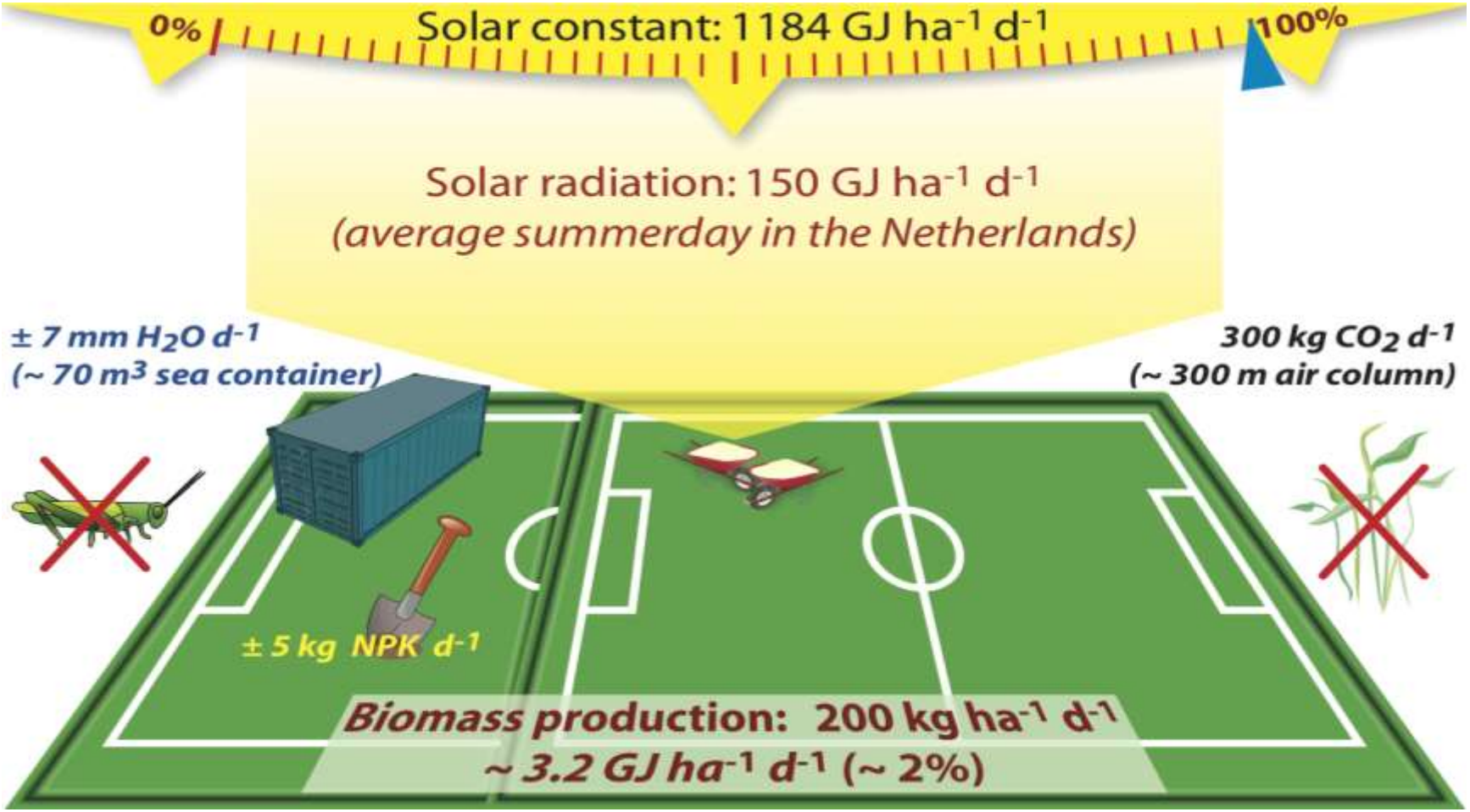
What is agriculture?

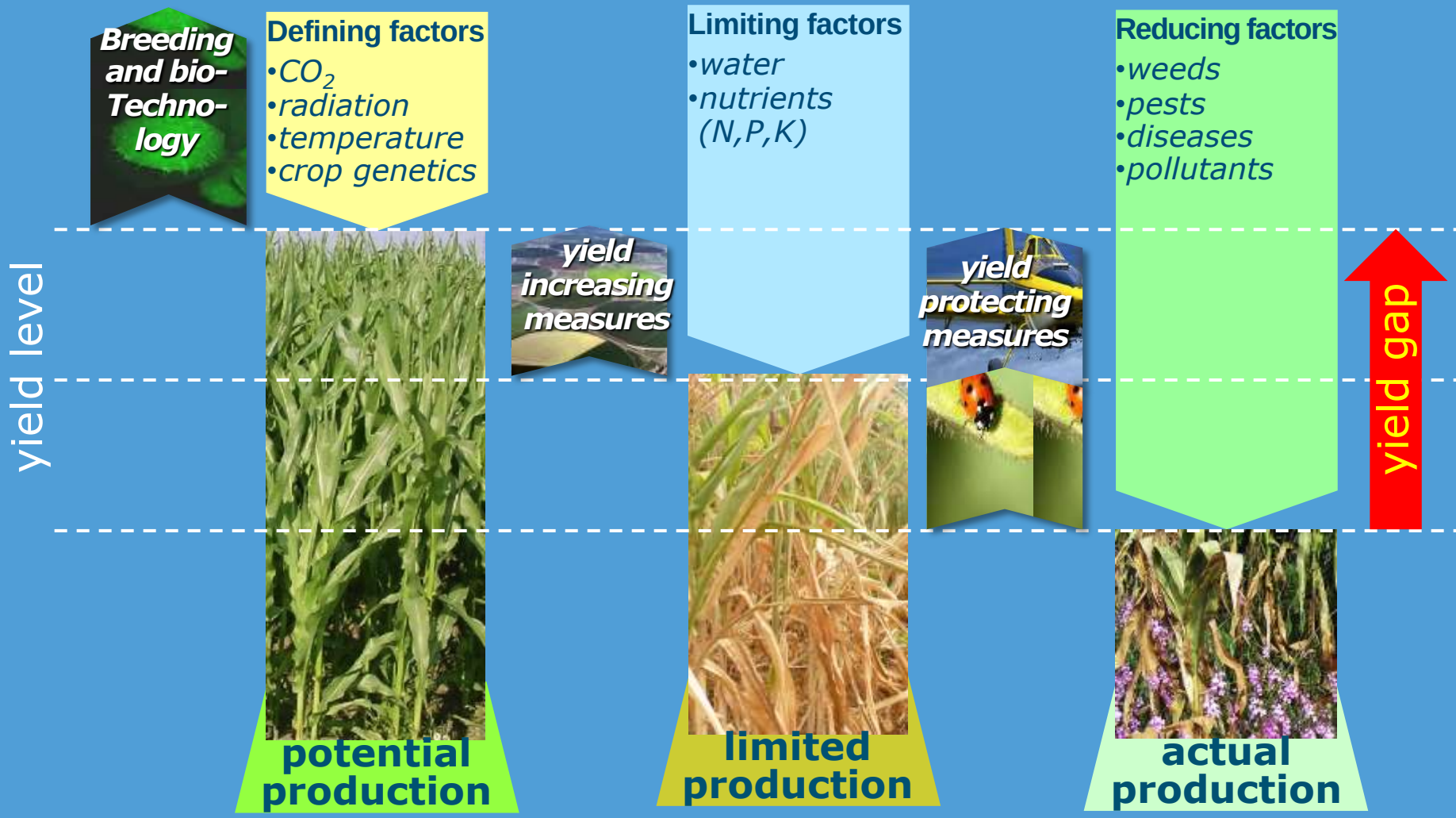
Human activity in which energy from the sun is used for the production of sugars through the growth of plants in soil

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

Plant production



Production-ecological principles & practice



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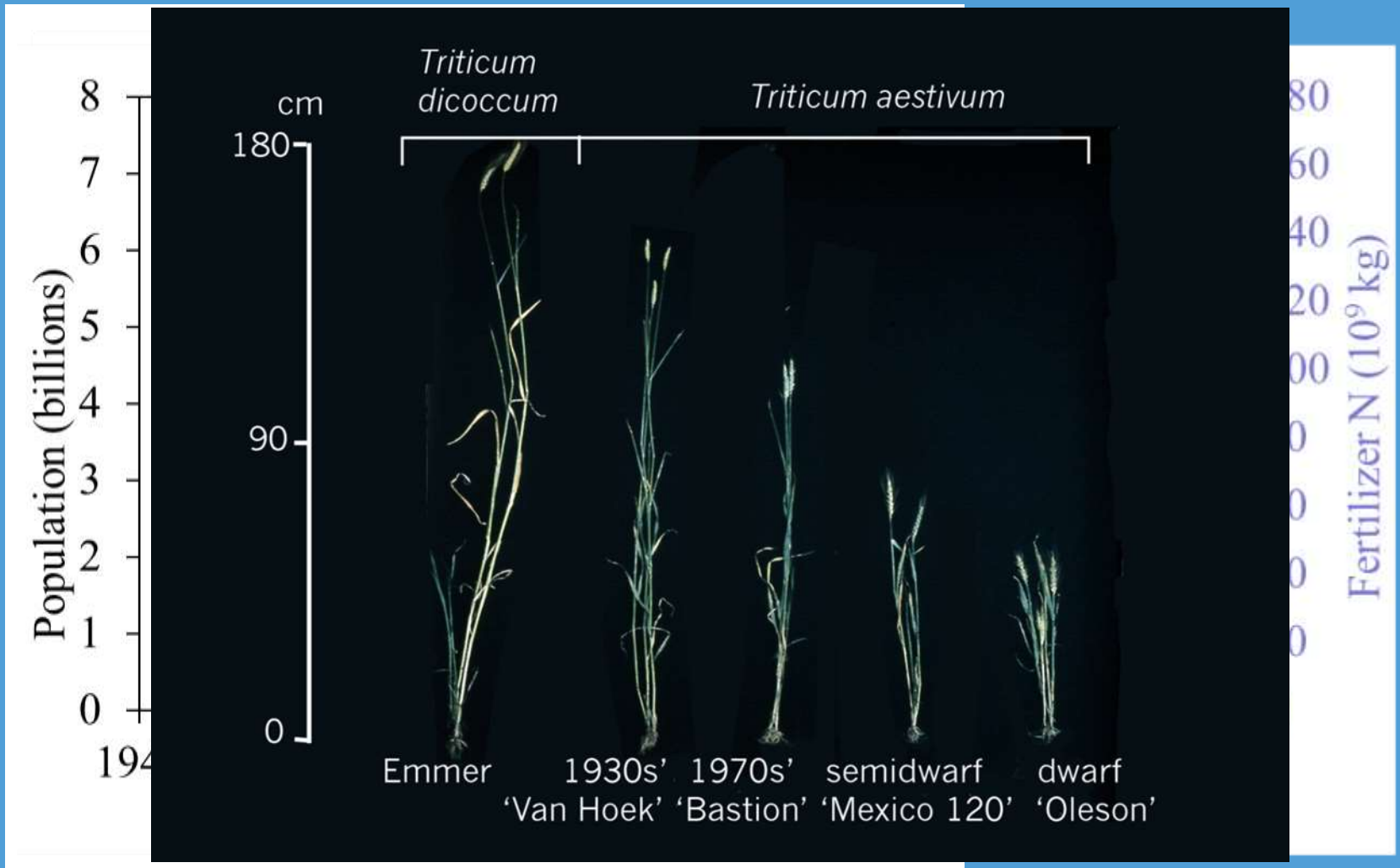
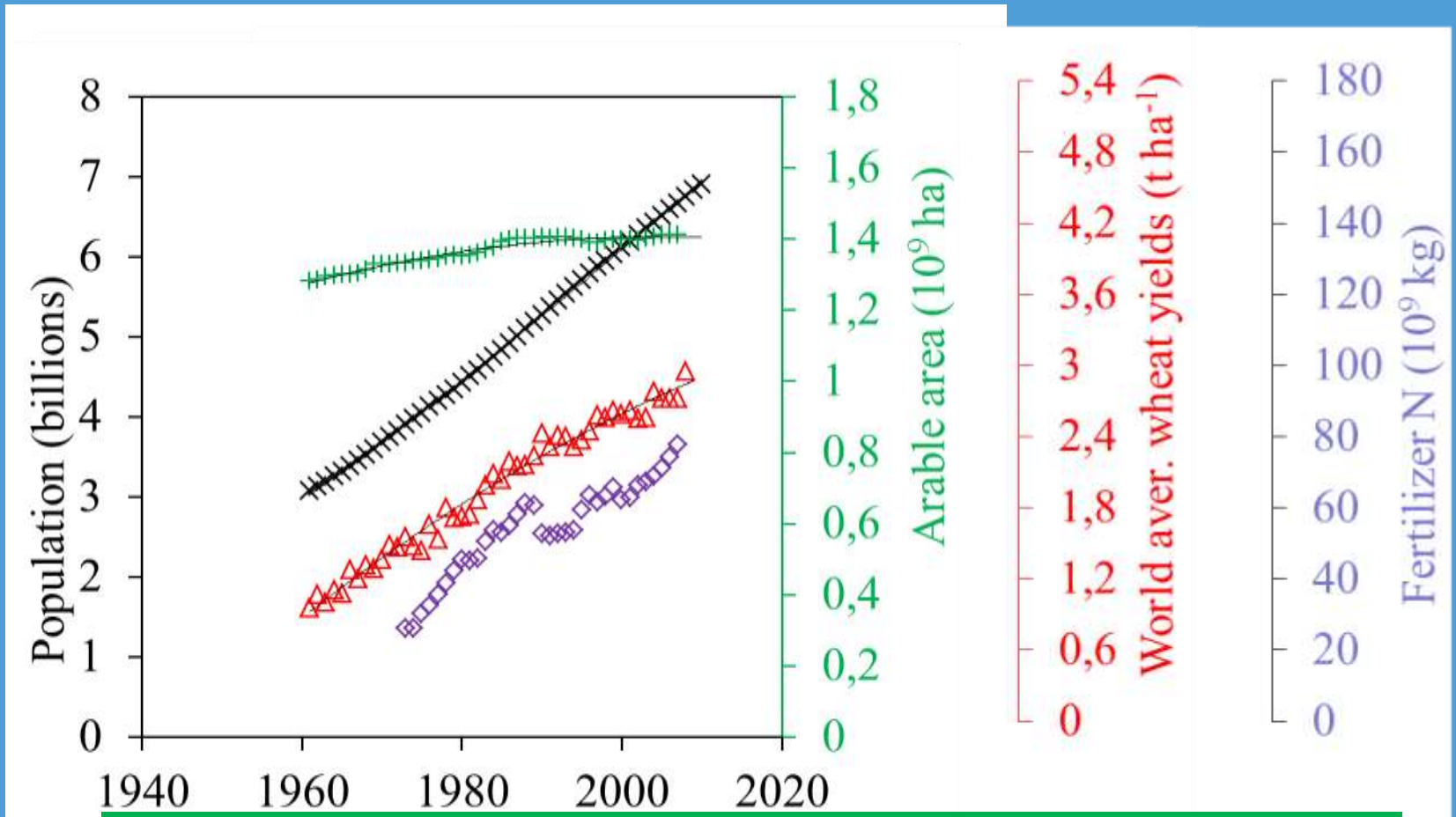
Slide from Harrie Lovenstein – Wageningen University

Looking back: 1960-2010



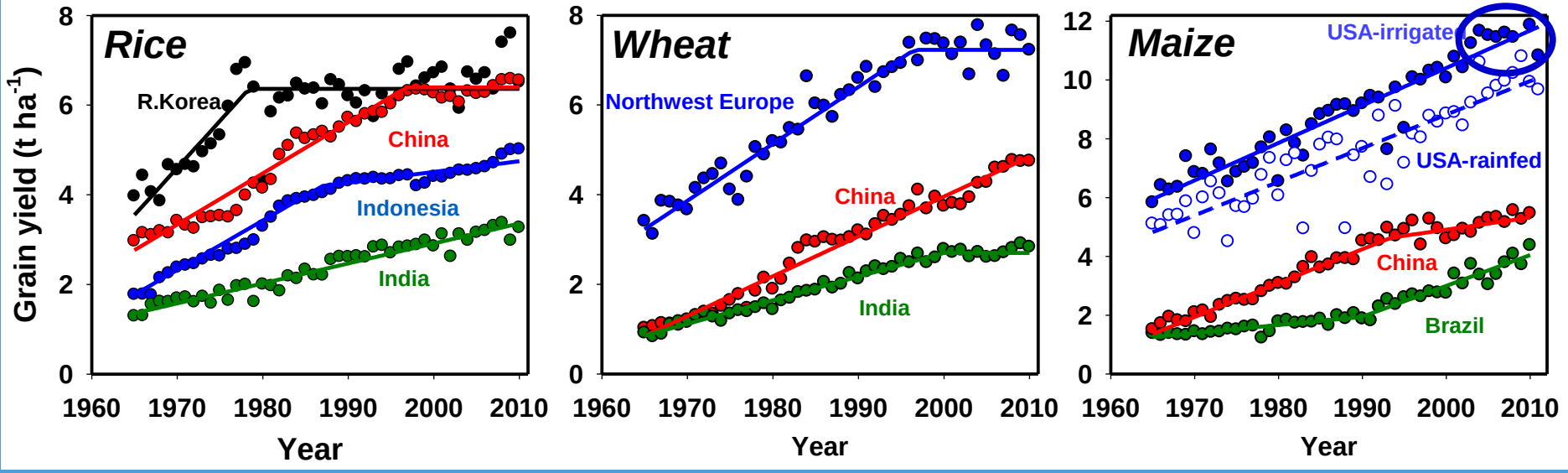
Updated from Evans, 1998



But conditions in 2016 very different than in 1960

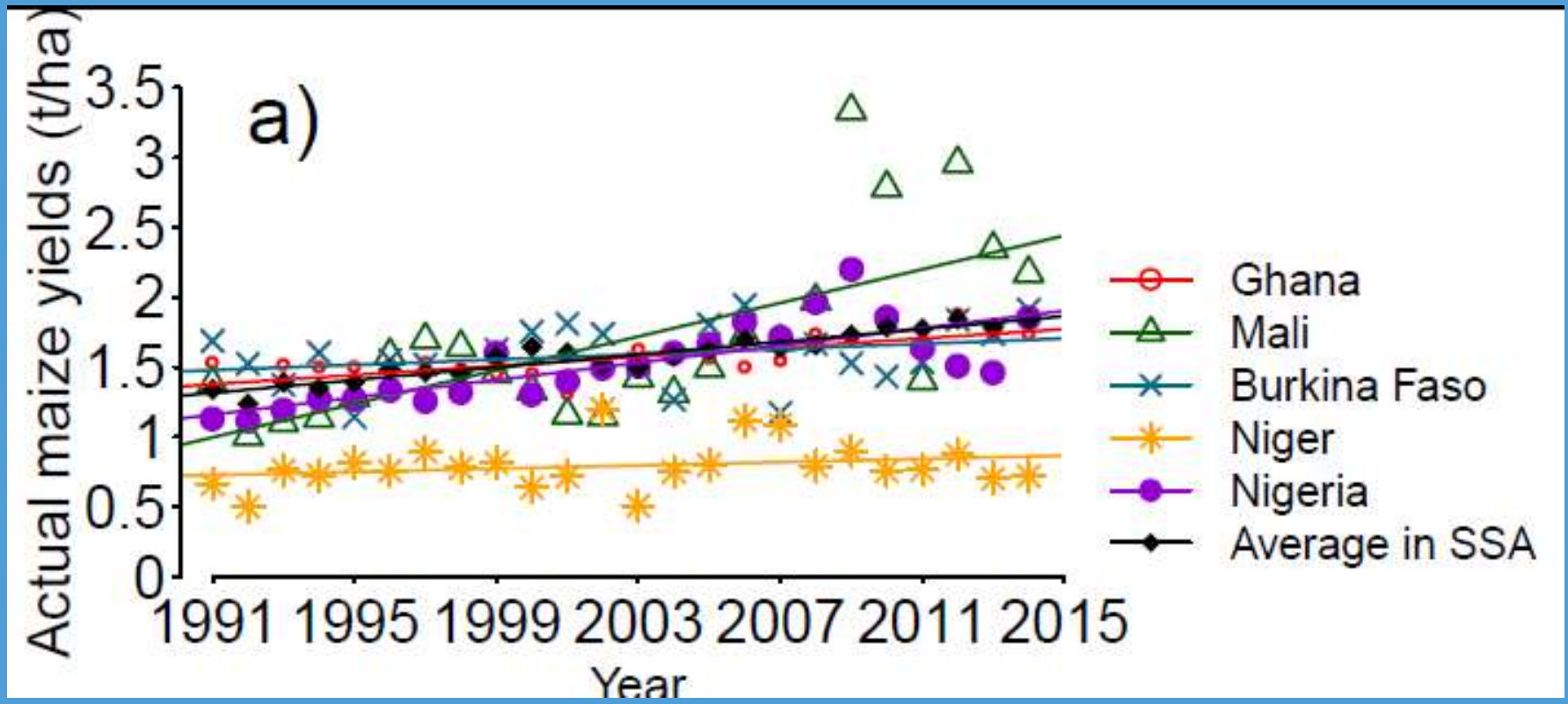
Updated from Evans, 1998

Slack in cereal yield increases?



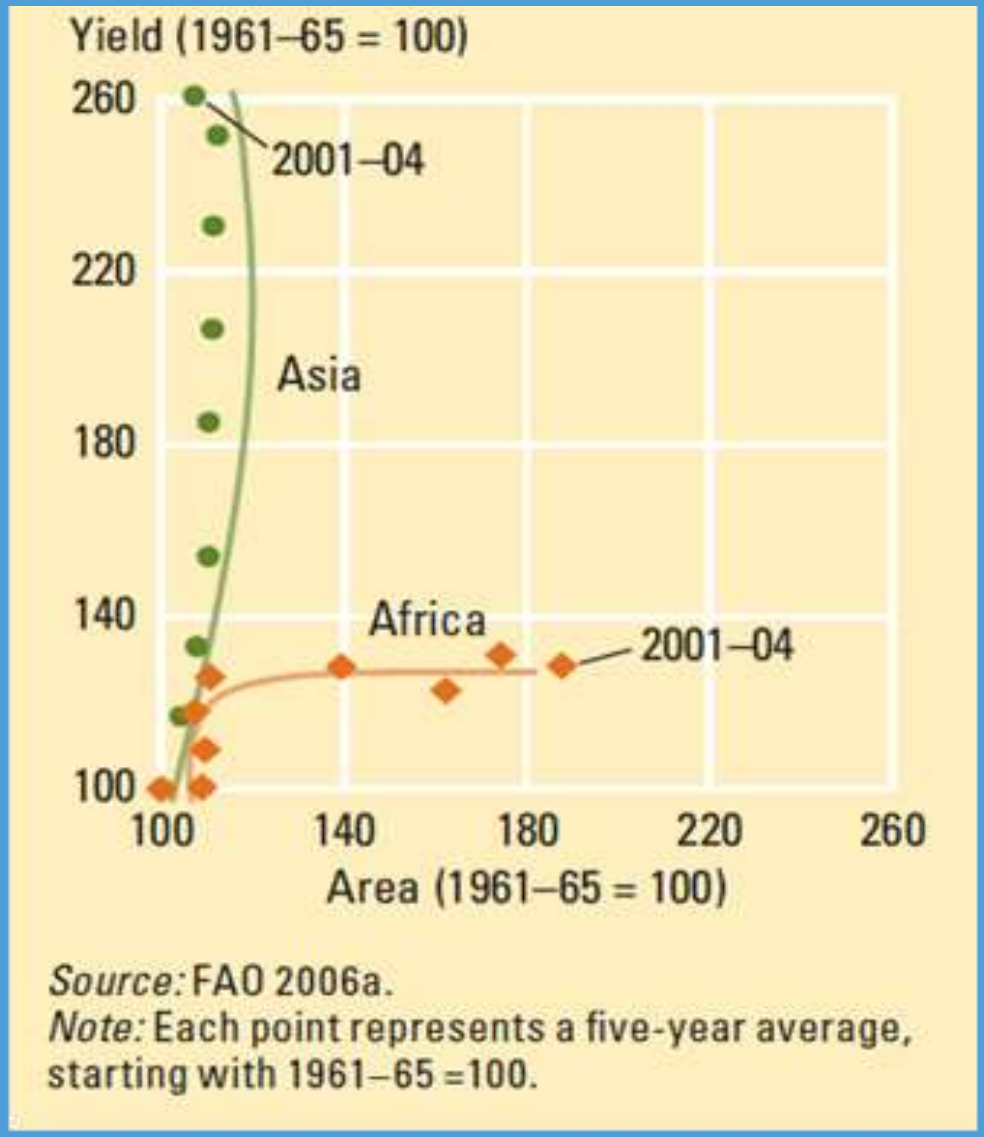
Cassman, 1999; Cassman et al., 2010; Grassini et al., 2011

Slack in cereal yield increases?



FAO and Van Ittersum et al., in press

The green revolution in Asia and Africa



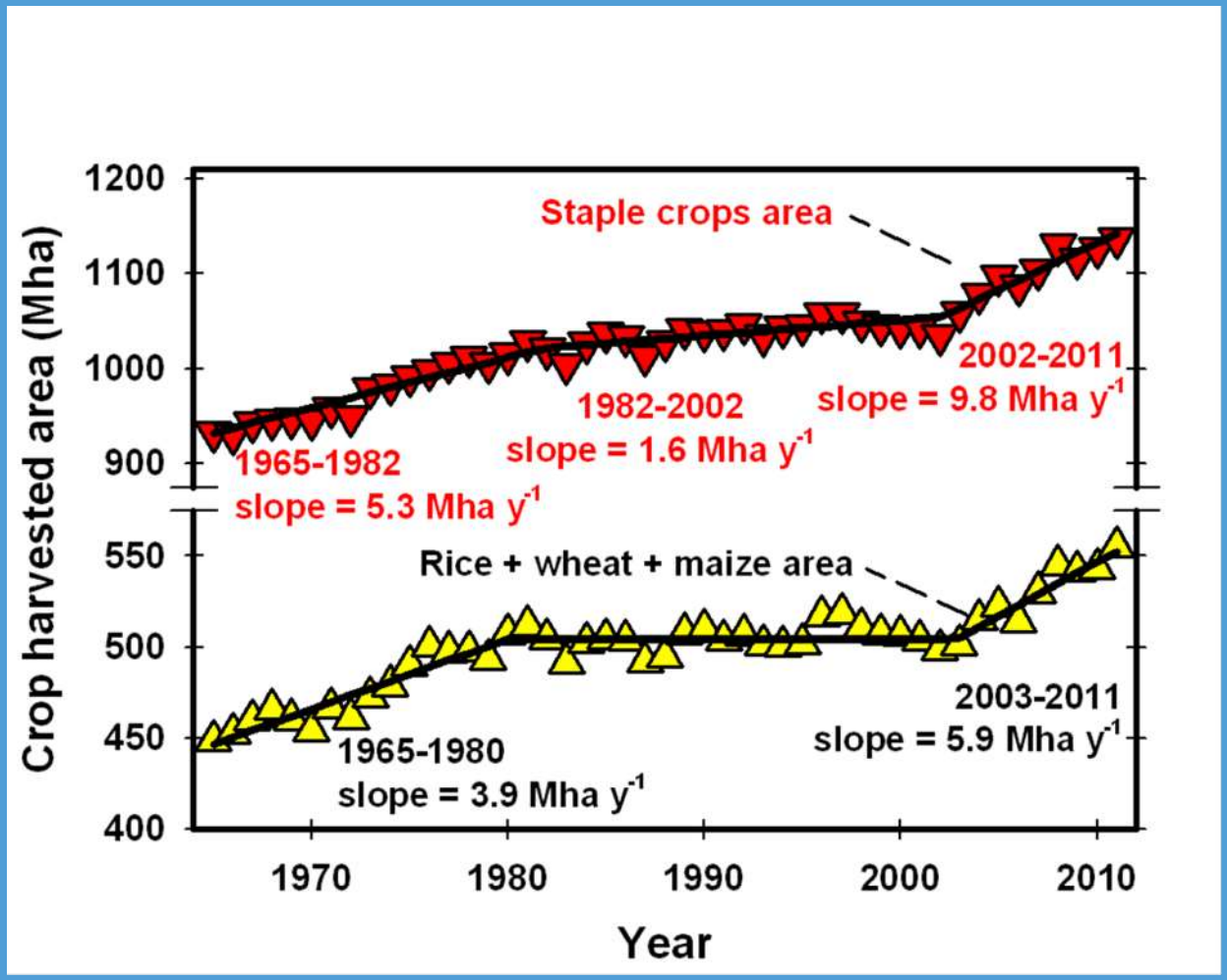
Source: FAO 2006a.
Note: Each point represents a five-year average, starting with 1961–65 =100.

Trends arable land area – Sub-Saharan Africa (2002-2012)

Country	Arable land area 2010 in million ha	Arable land area increase 2002-2012 in million ha
Burkina Faso	5.8	1.4
Ghana	4.6	0.7
Mali	6.4	1.8
Niger	15.2	1.8
Nigeria	33.0	0.2 (ns)
Ethiopia	14.6	5.0
Kenya	5.5	0.6
Tanzania	11.6	4.9
Uganda	6.7	1.4
Zambia	3.5	1.0
Total	**107.4**	**18.7 (17%)**

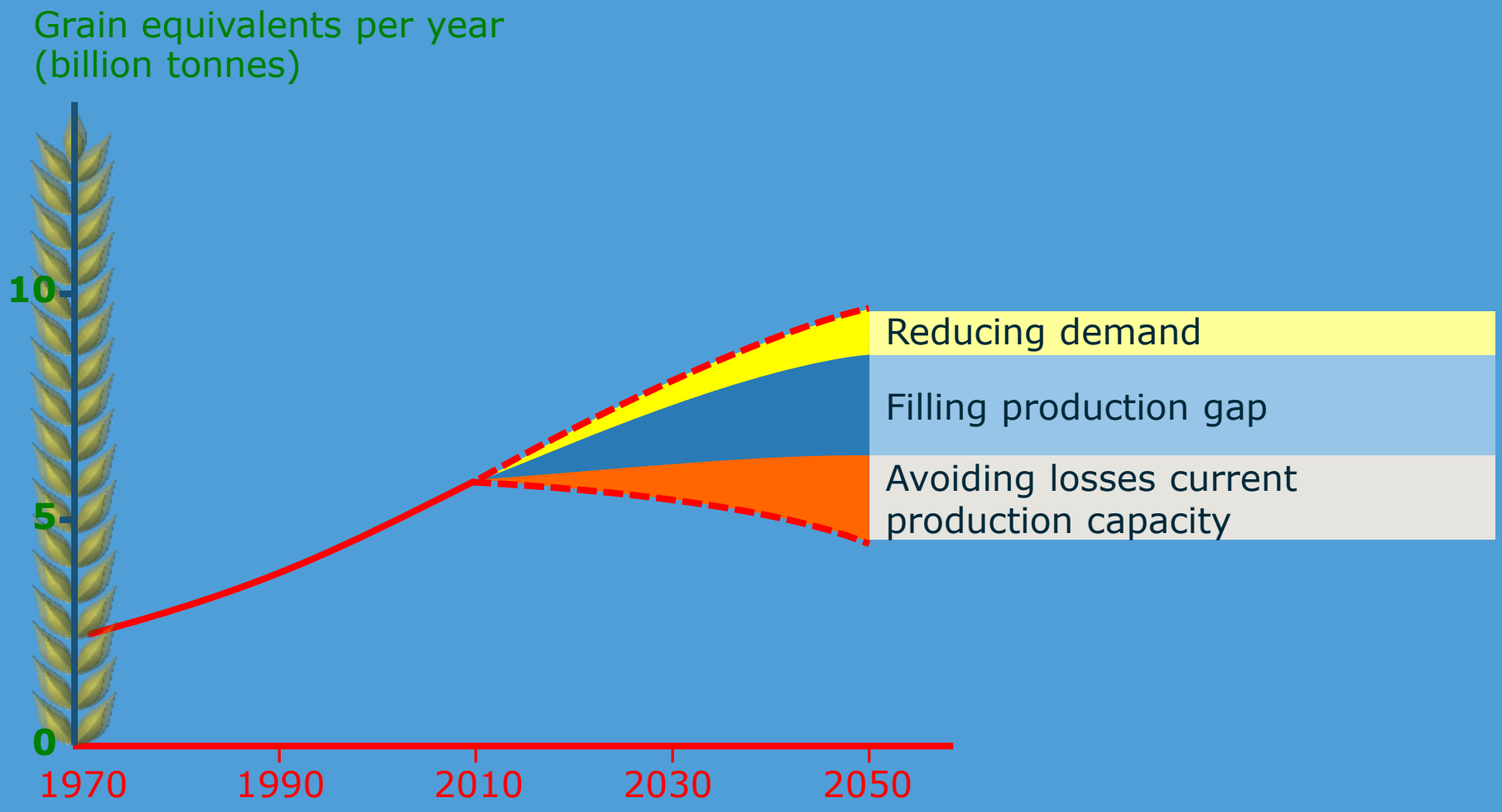
Source: FAOSTAT

Increase in global crop areas



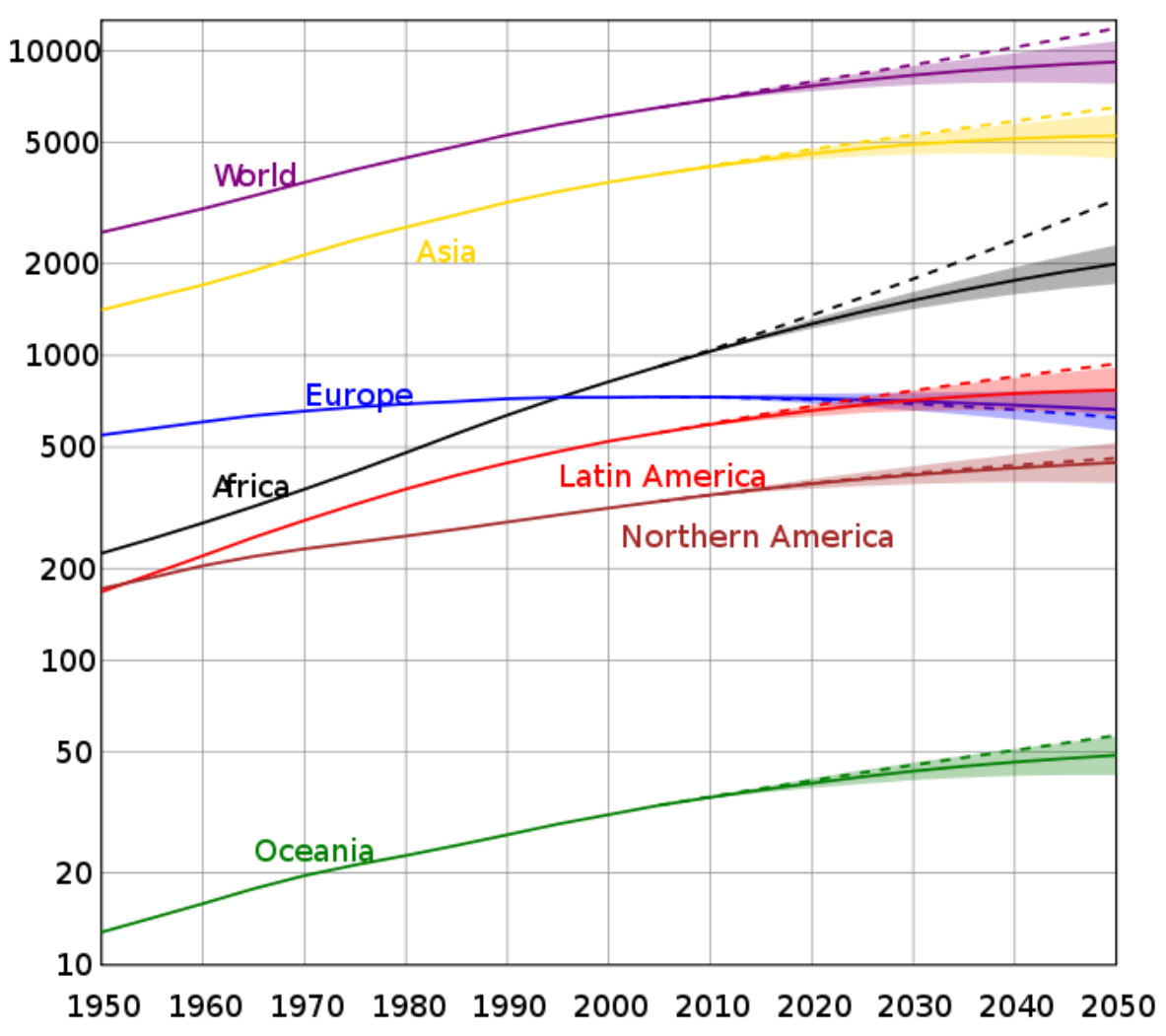
Grassini et al., 2013

Looking ahead: Pathways to increase availability

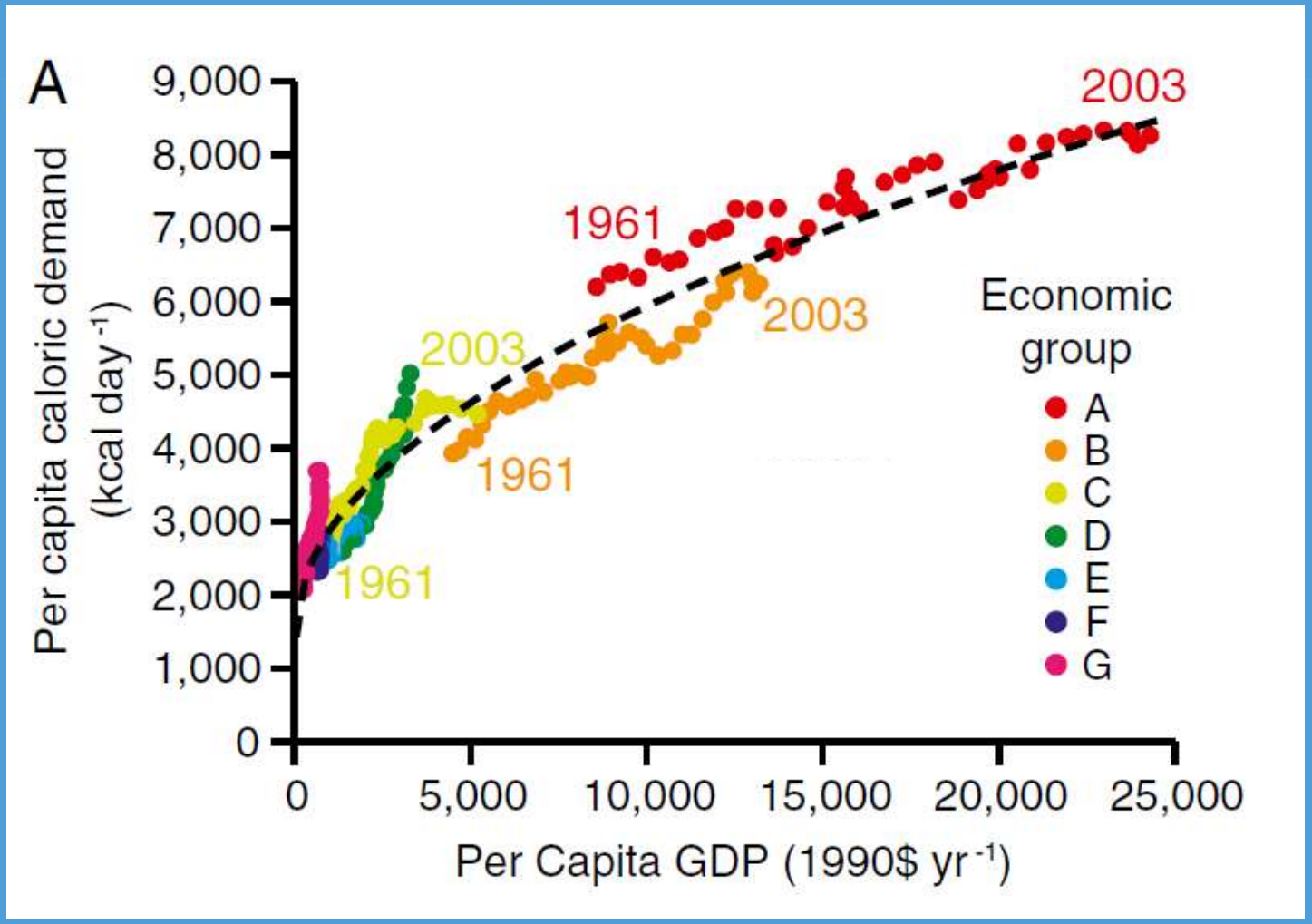


after Keating et al., 2014. Global Food Security

Population growth



Demand versus income (per capita)

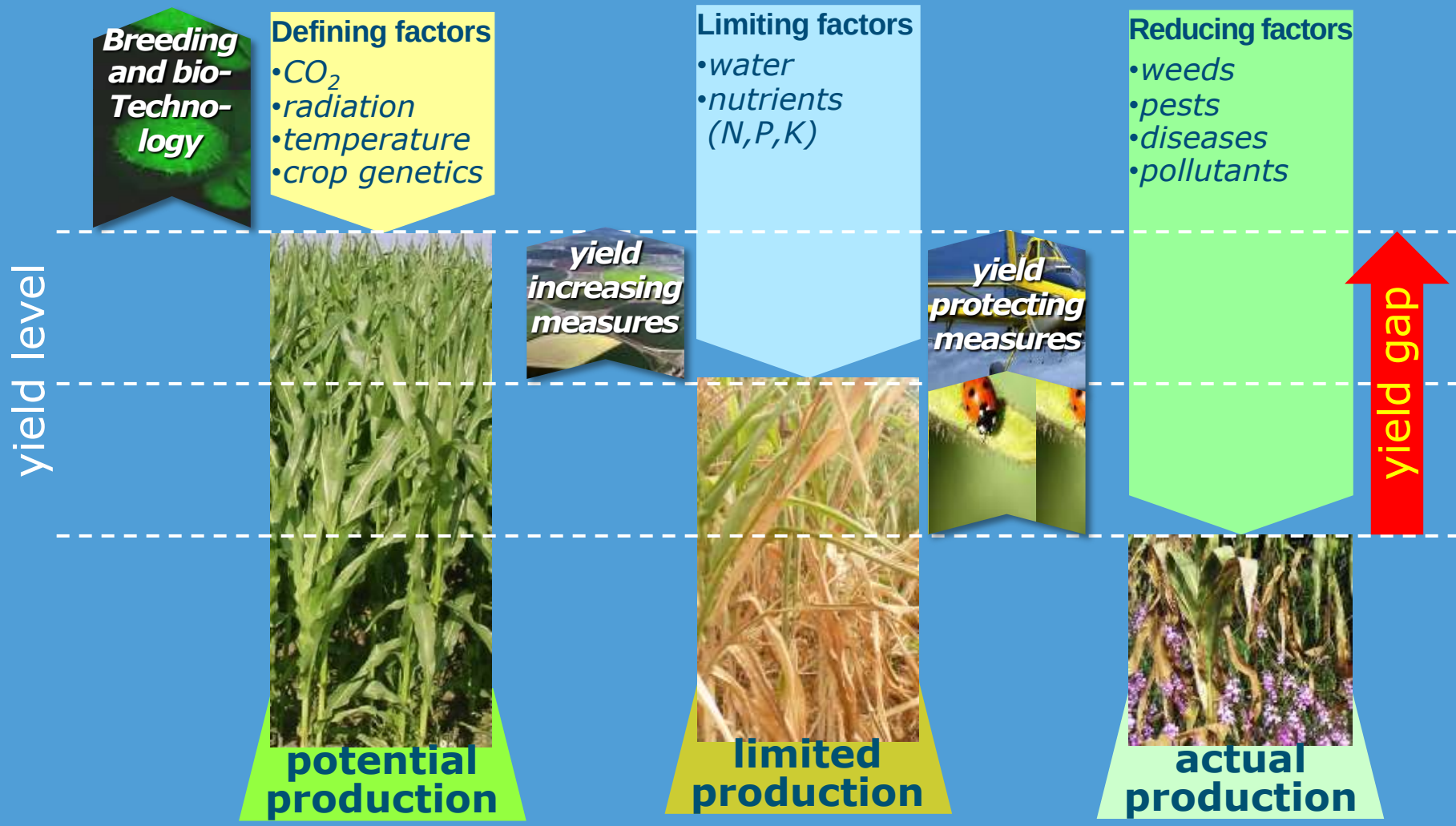


Tilman et al., 2011 (PNAS)

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



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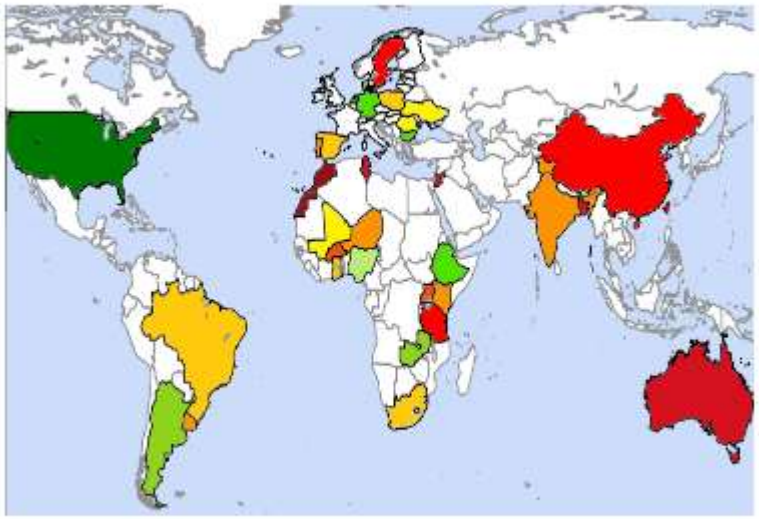
Yield gap analysis

Photo: Ken Giller

Global Yield Gap Atlas

Global Yield Gap Atlas

Go to the Atlas



Go to the Atlas for advanced users

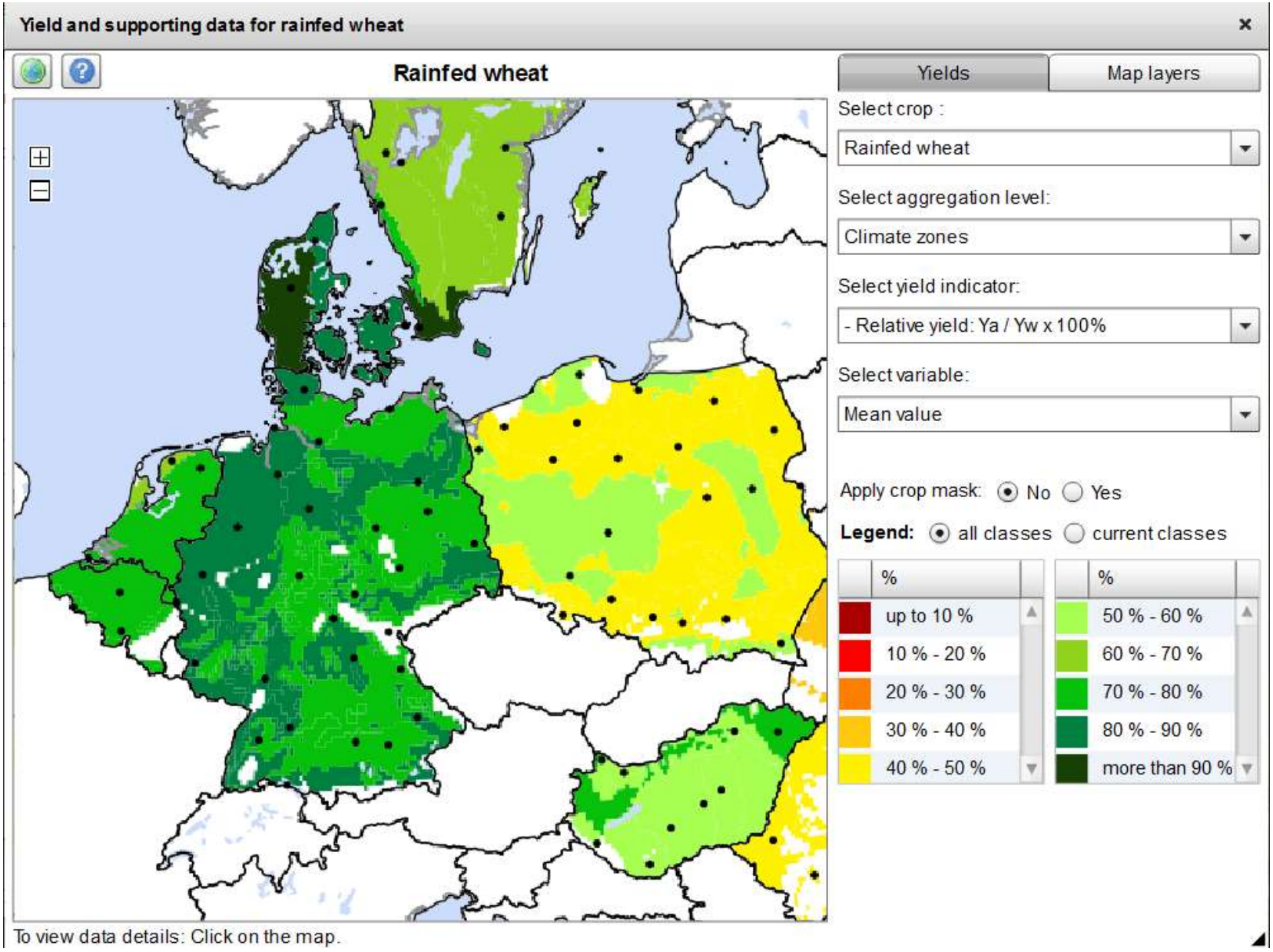
www.yieldgap.org

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

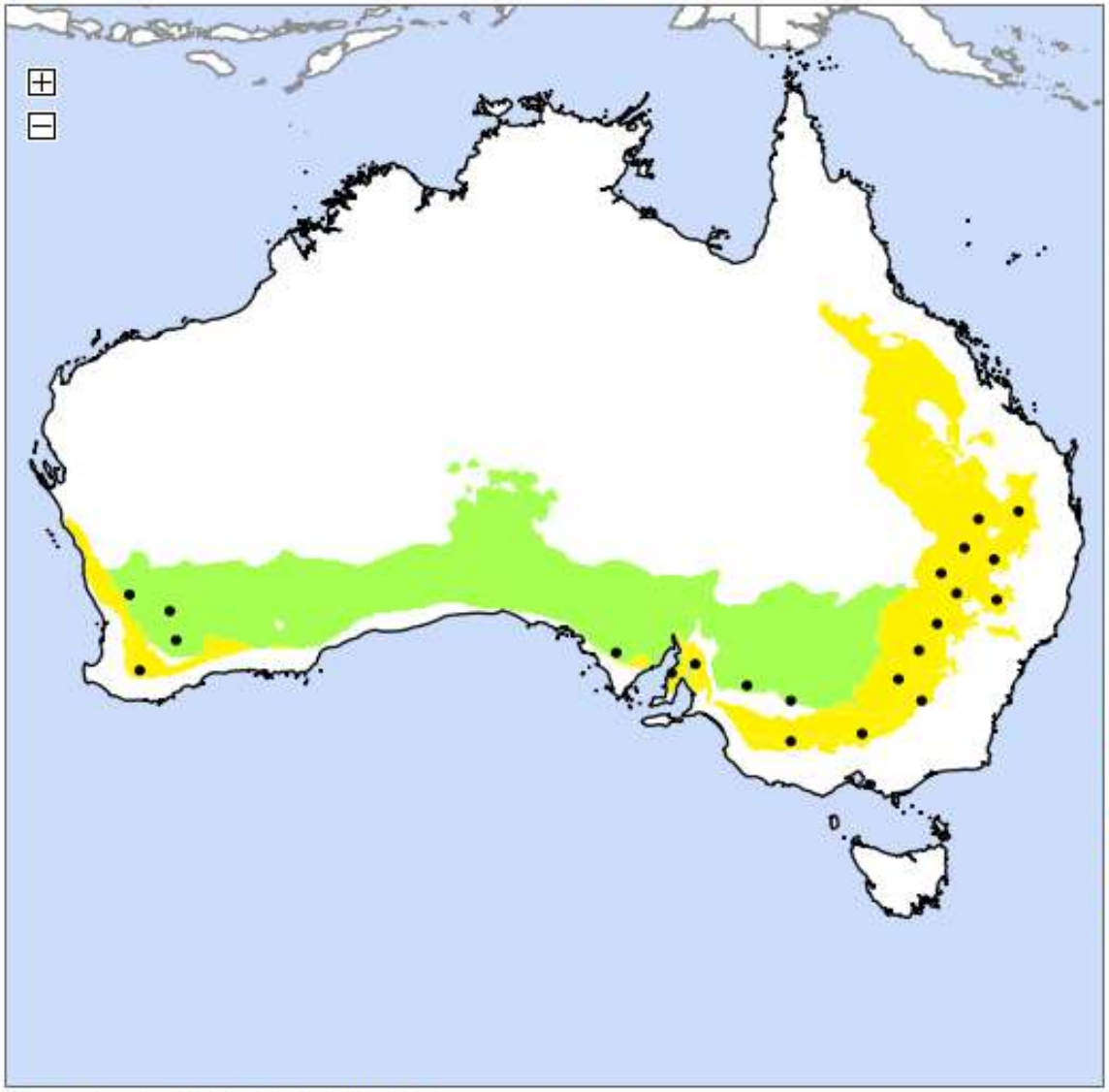
- Major food crops in the world
- Global protocol with local application
- Local data and evaluation
- Strong agronomic foundation

- 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:
- Relative yield: Ya / Yw x 100%
Select variable:
Mean value
Apply crop mask: No Yes
Legend: all classes current classes
%
up to 10 %
10 % - 20 %
20 % - 30 %
30 % - 40 %
40 % - 50 %
%
50 % - 60 %
60 % - 70 %
70 % - 80 %
80 % - 90 %
more than 90 %
To view data details: Click on the map.

Yield and supporting data for rainfed wheat



To view data details: Click on the map.

Yields | Map layers

Select crop :

Rainfed wheat

Select aggregation level:

Climate zones

Select yield indicator:

- Relative yield: Ya / Yw x 100%

Select variable:

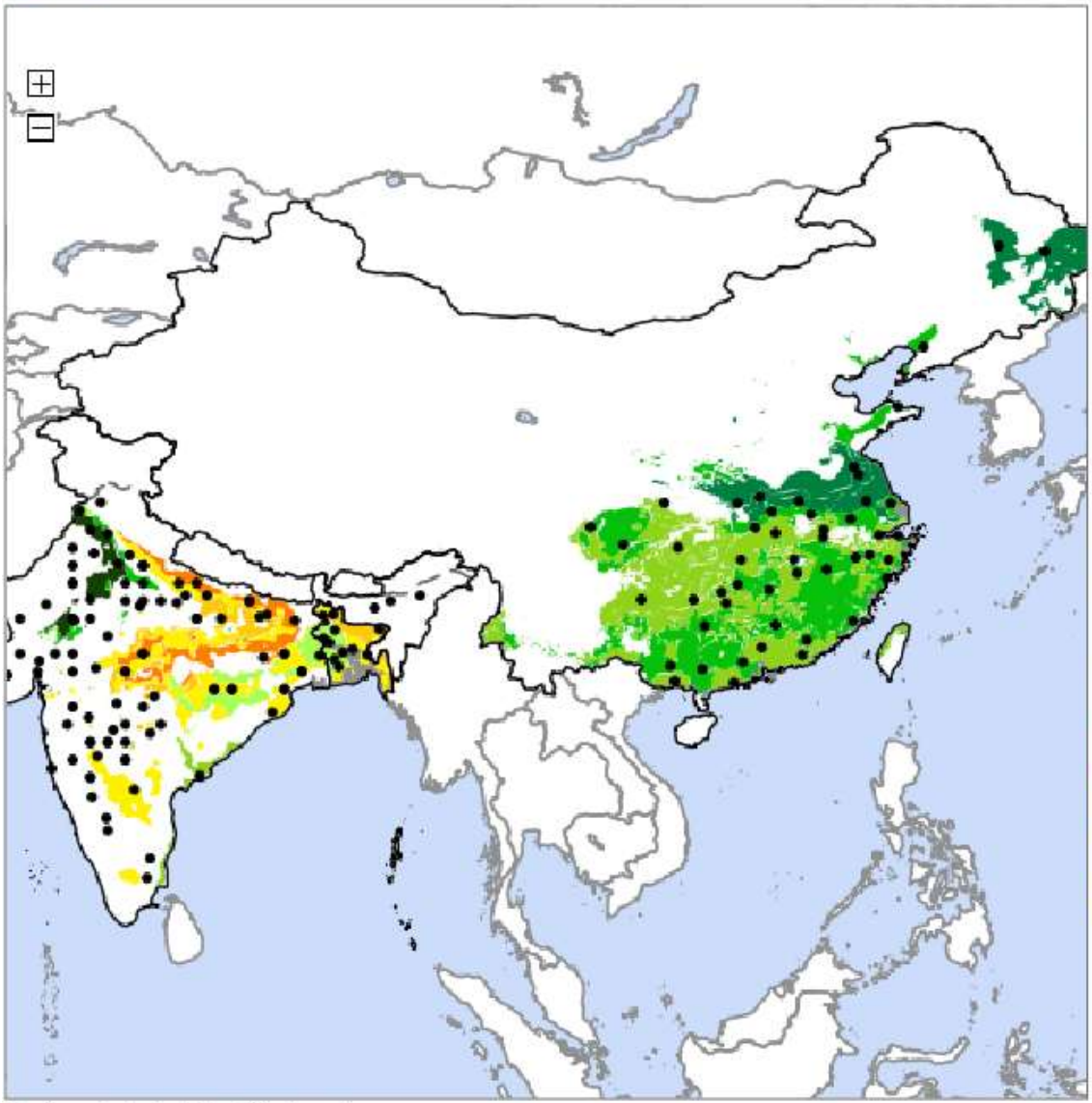
Mean value

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 %

Yield and supporting data for irrigated rice



To view data details: Click on the map.

Yields | Map layers

Select crop :

Irrigated rice

Select aggregation level:

Climate zones

Select yield indicator:

- Relative yield gap: (1 - Ya / Yp) x 100%

Select variable:

Mean value

Apply crop mask: (•) No ( ) Yes

Legend: (•) all classes ( ) current classes

%	%
up to 10 %	50 % - 60 %
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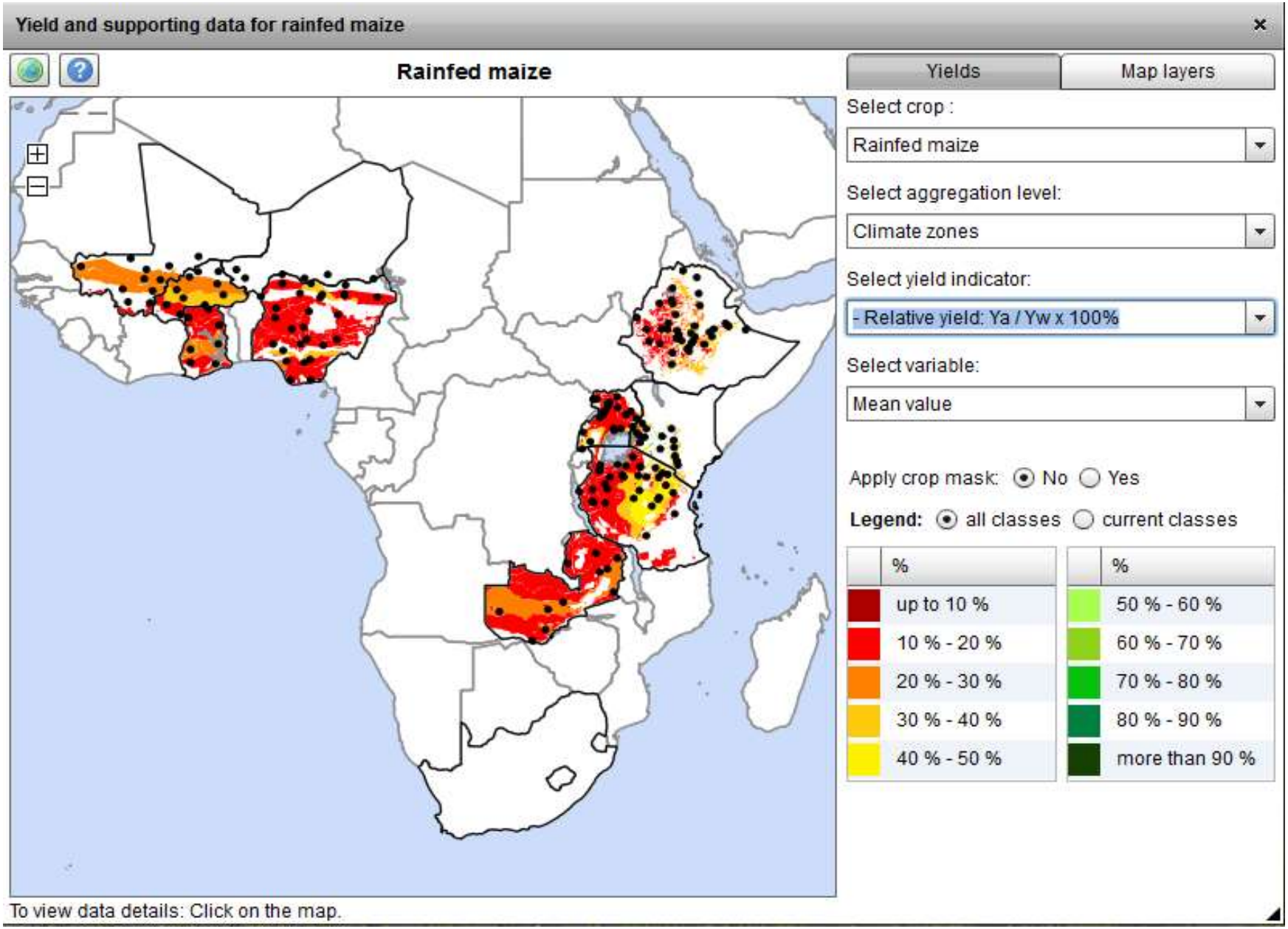
Global Yield Gap Atlas


Yield and supporting data for rainfed maize
Rainfed maize
Yields
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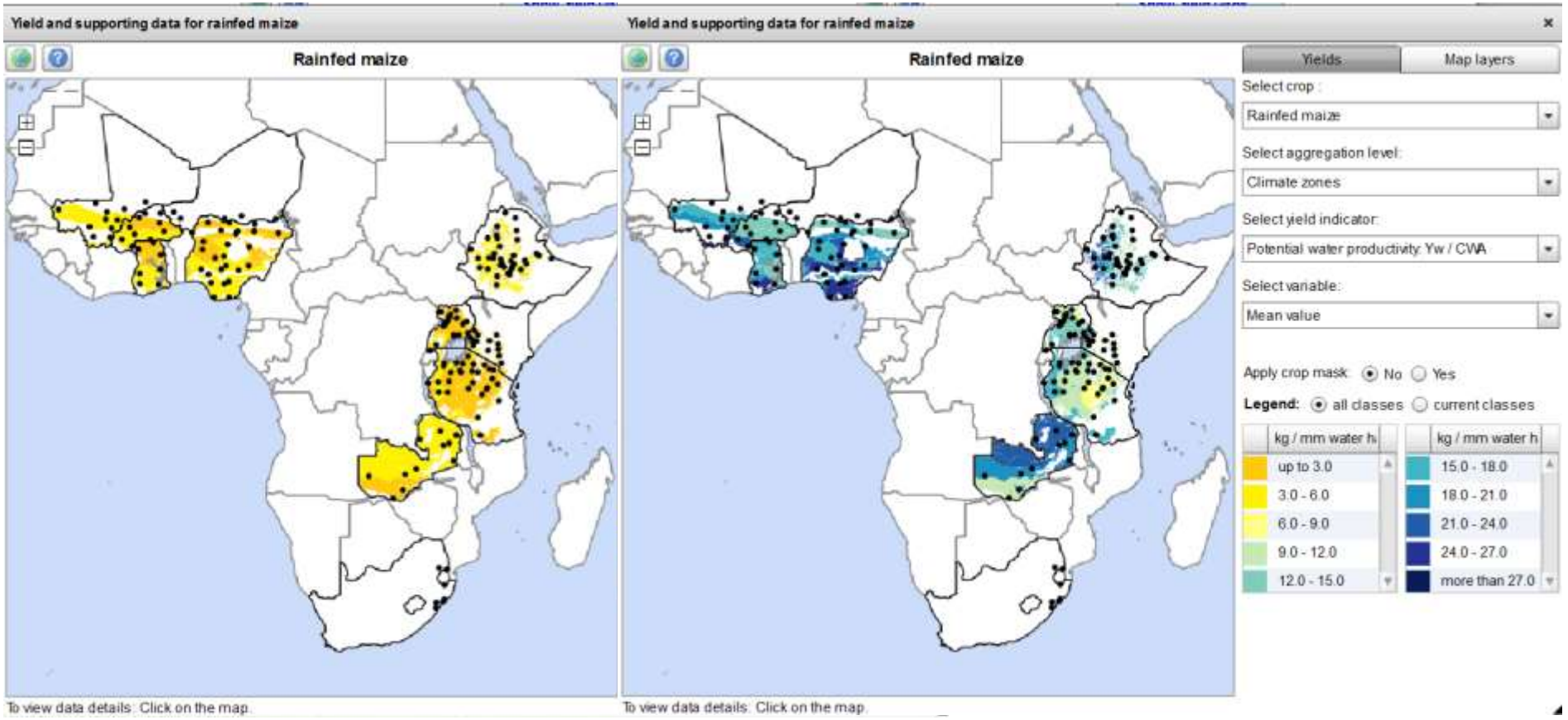
Actual and potential water productivity



www.yieldgap.org

Global Yield Gap Atlas

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

to be published in PNAS

University of Nebraska Lincoln

Wageningen University Wageningen UR

Water for Food Robert B. Daugherty Institute University of Nebraska

ICRISAT Science with a human face

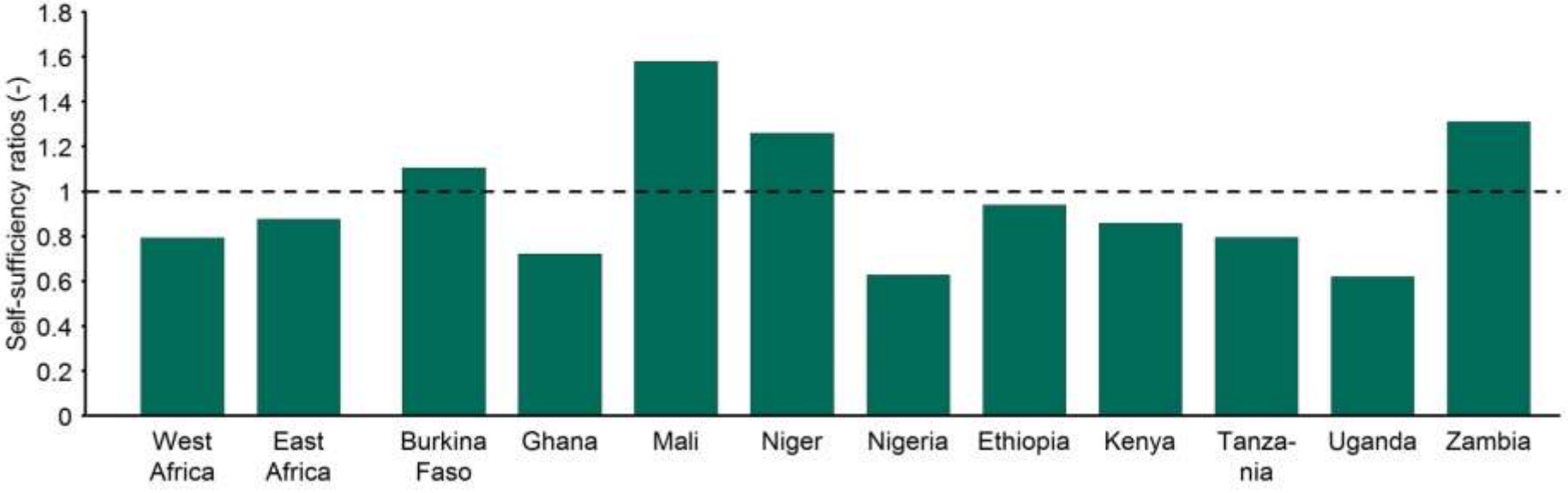
Growth in population and cereal demand - 2050

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)

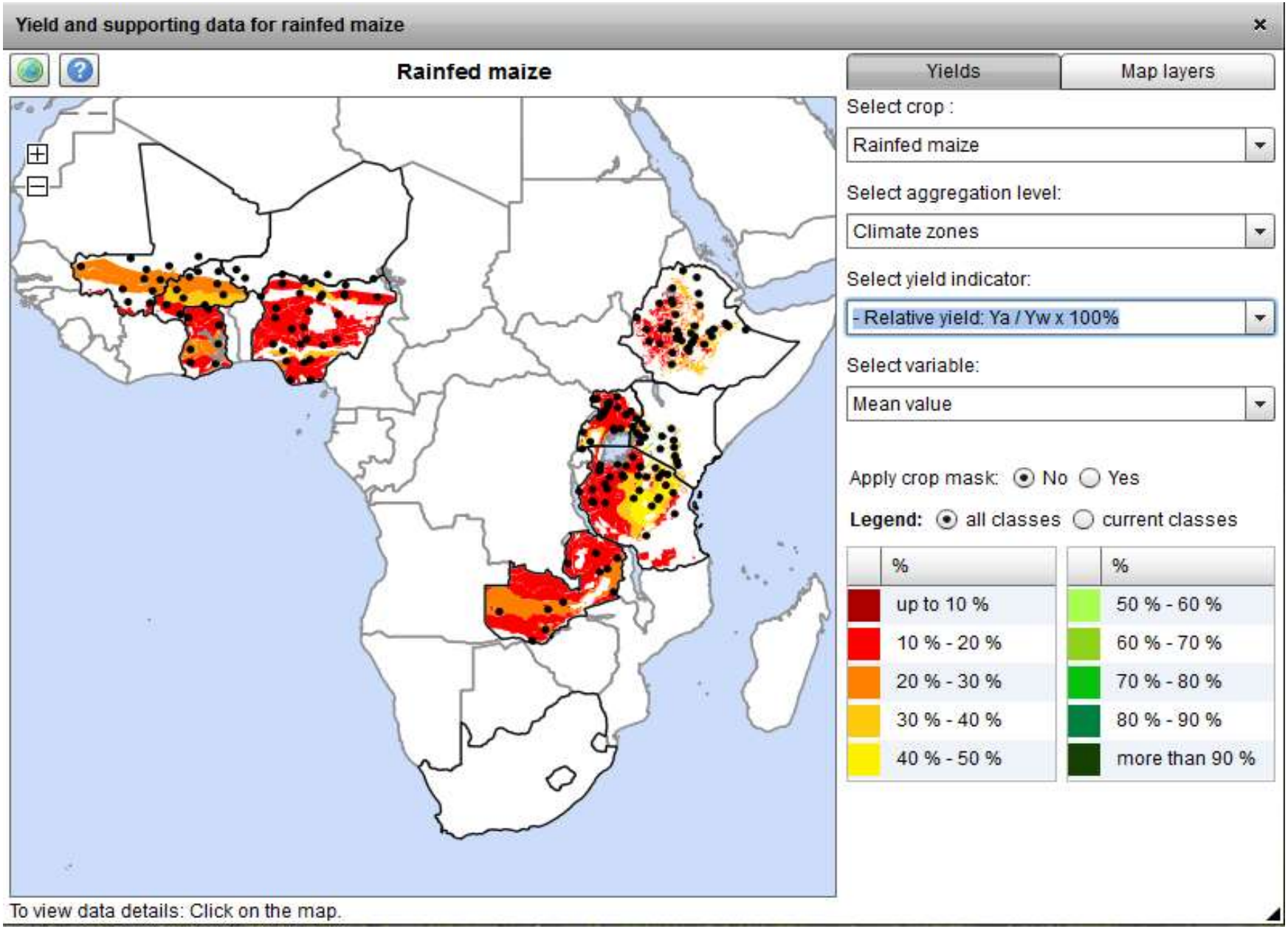
Global Yield Gap Atlas

Current self-sufficiency cereals SSA - 2010



Source: IMPACT model

Global Yield Gap Atlas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more than 90 %
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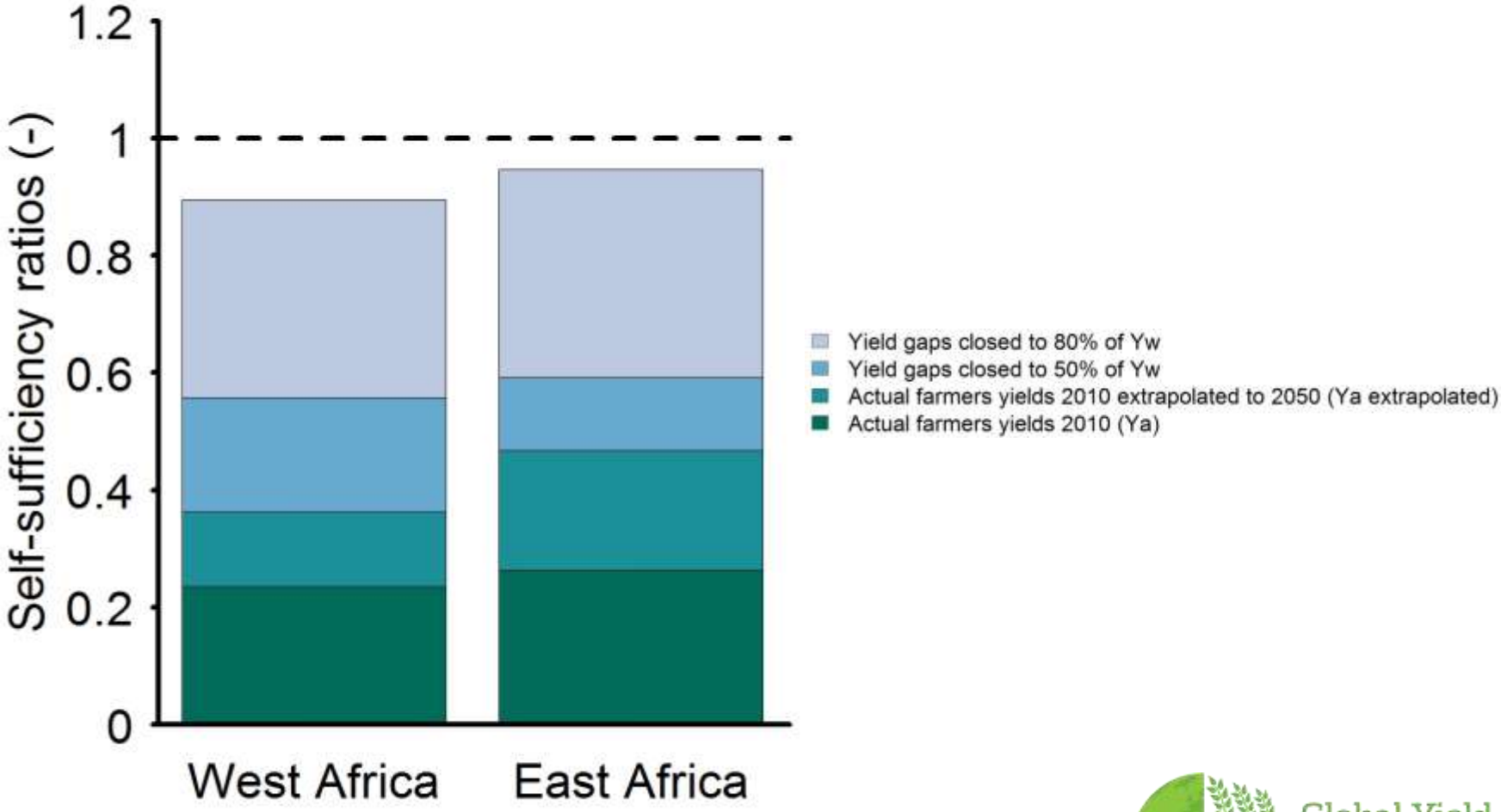
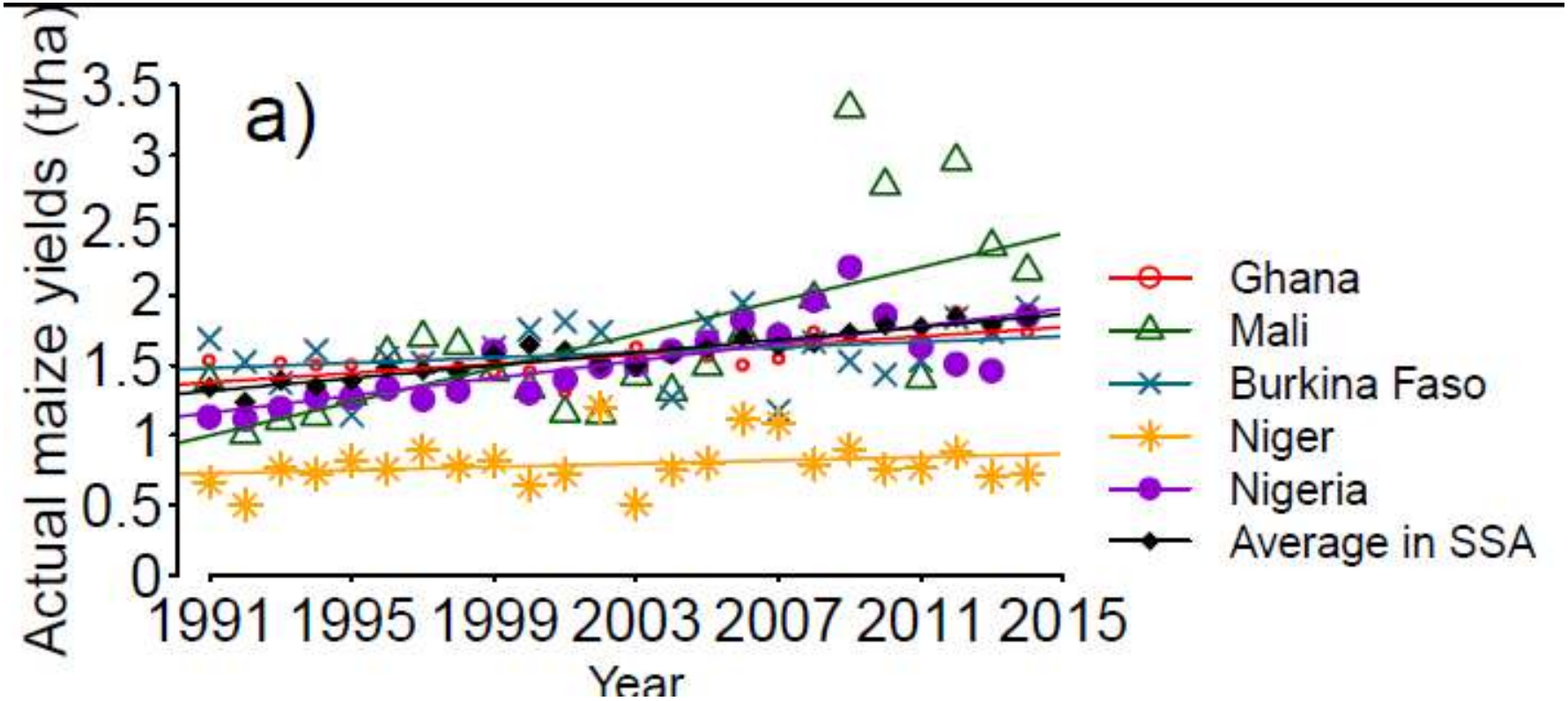
West and East Africa aggregated



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


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

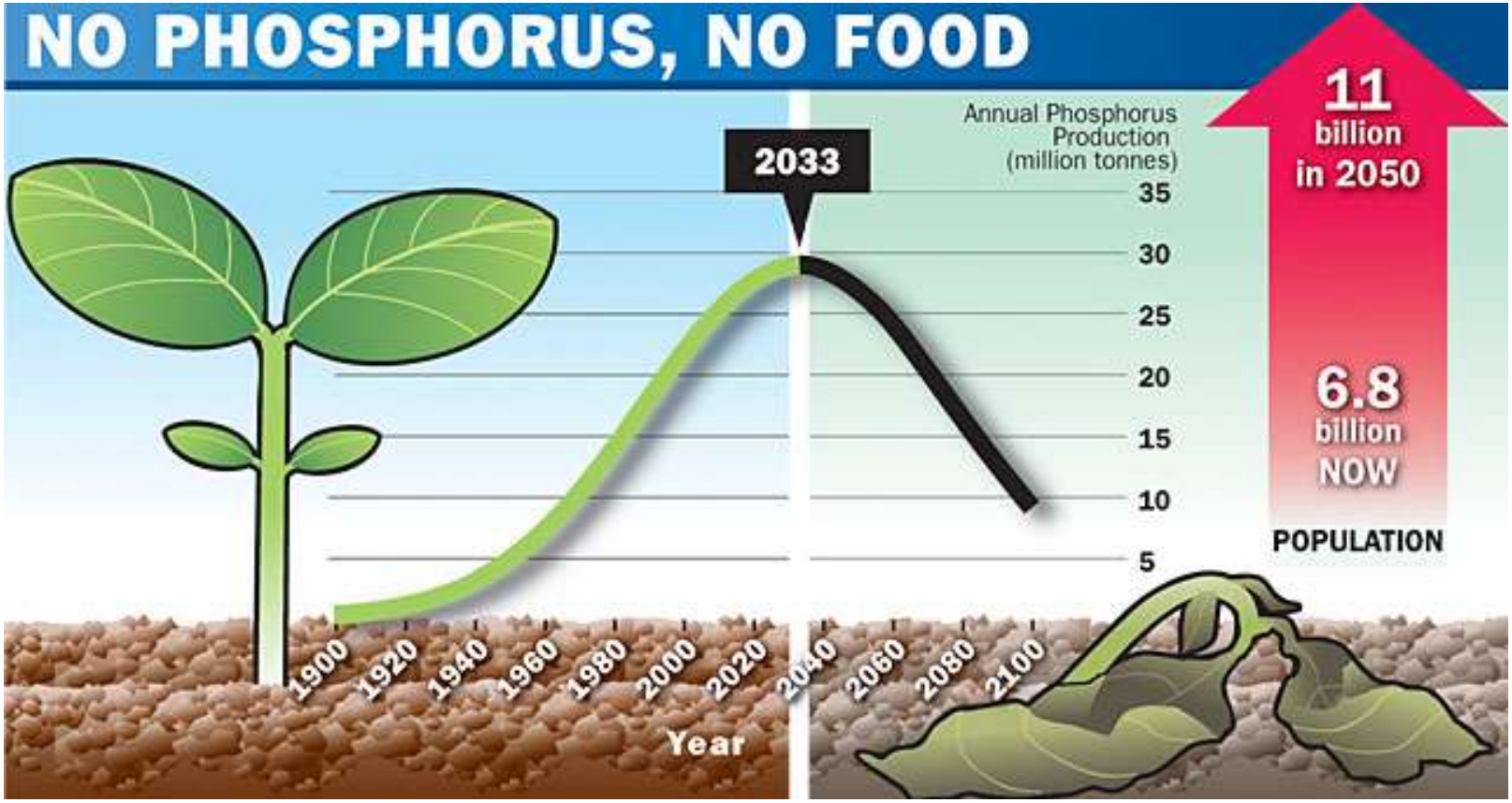
And what about Sustainable intensification?

Global Yield Gap Atlas

Reducing GHG emissions and/or intensity

Global Yield Gap Atlas

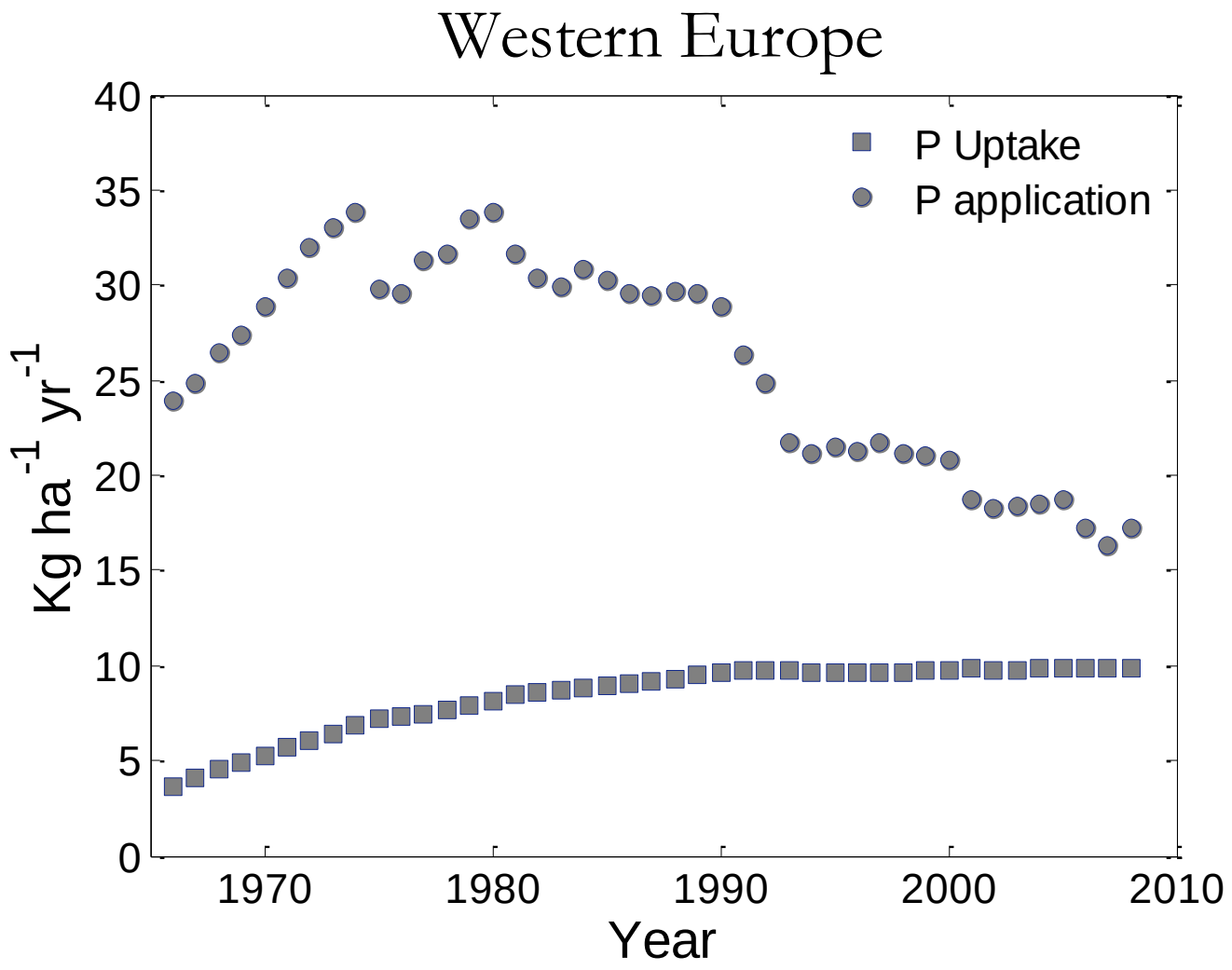
Efficient, or better, circular use of finite resources



Weekly TimesNow,
21 September 2009

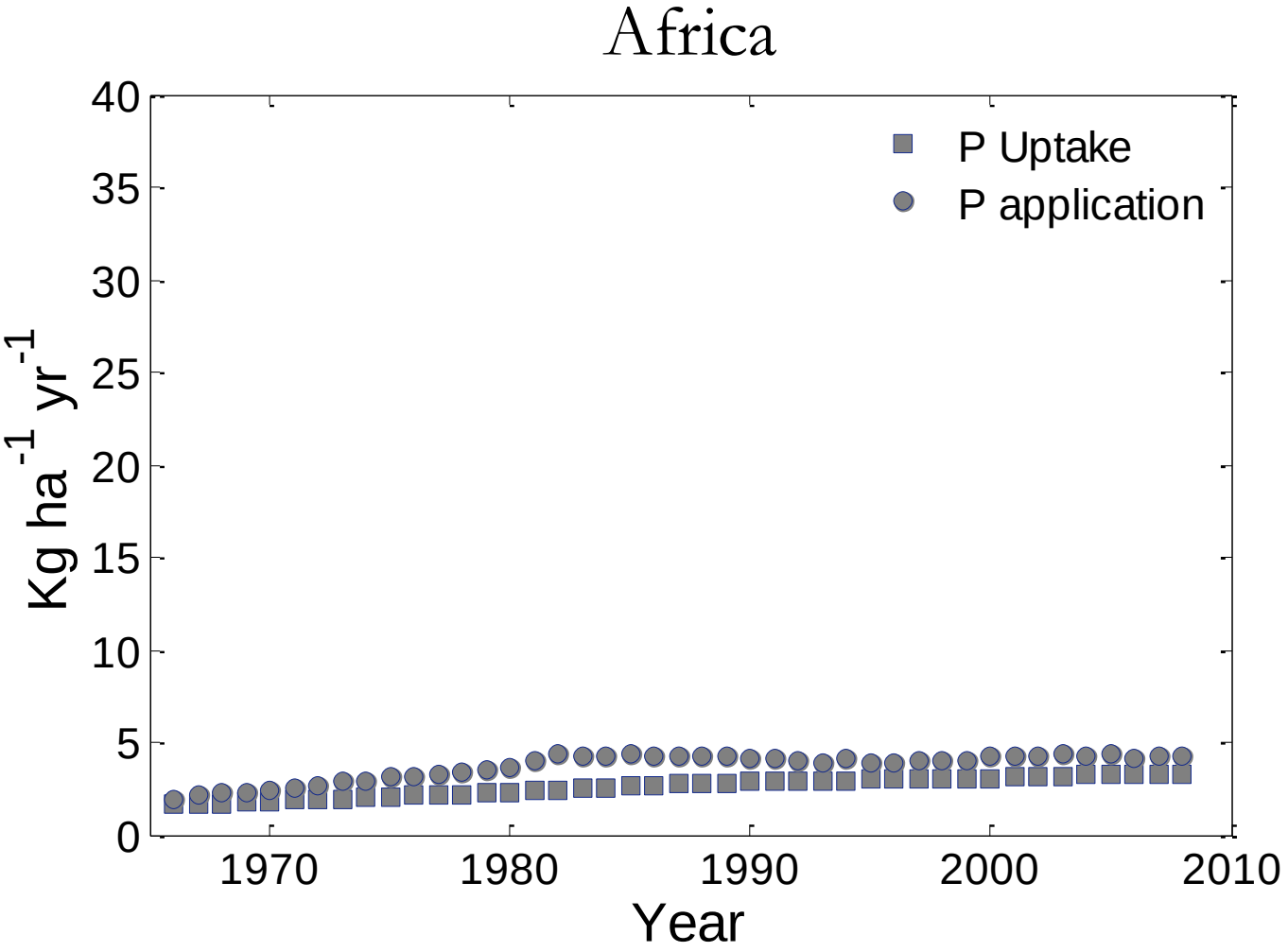
Global Yield Gap Atlas

P application and P uptake



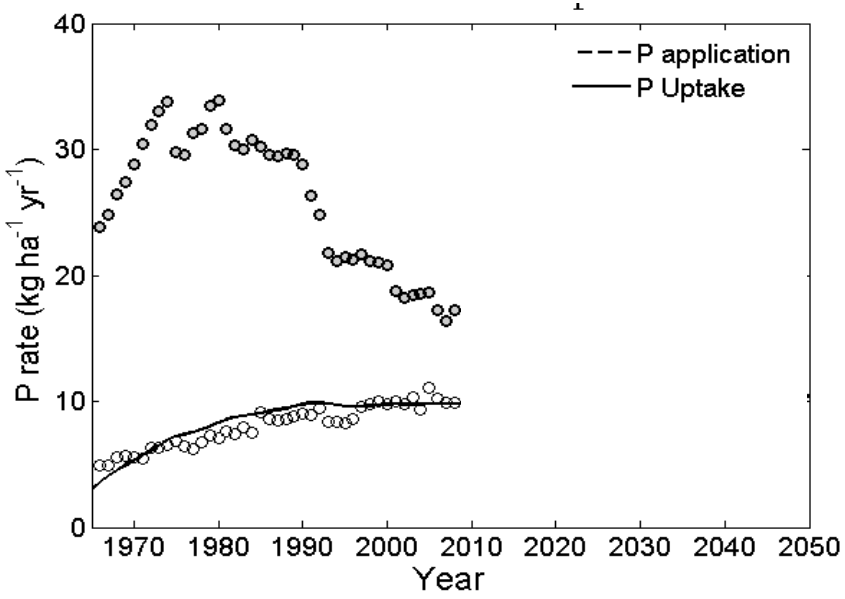
Sattari et al., 2012 - PNAS

P application and P uptake

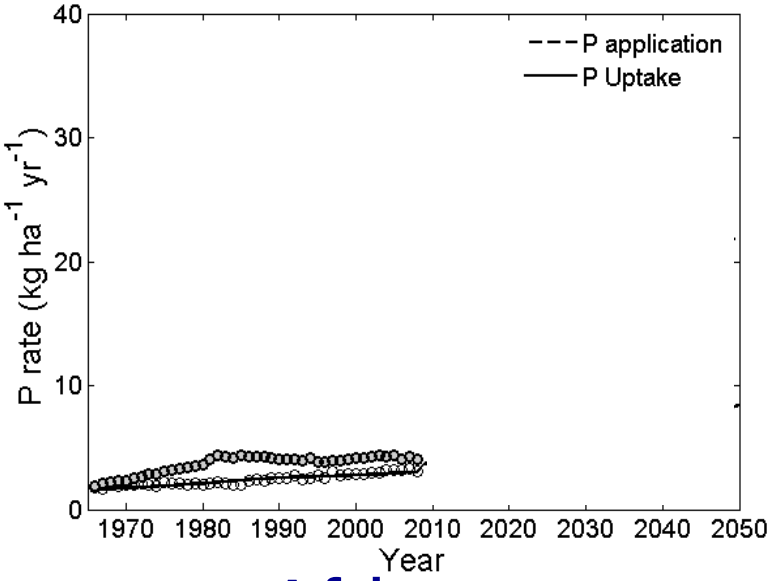


Sattari et al., 2012 - PNAS

Regional differences



Western Europe



Africa

PNAS

Residual soil phosphorus as the missing piece in the global phosphorus crisis puzzle

Iheida Z. Sattari[a,1], Alexander F. Bouwman[b,c], Ken E. Giller[a], and Martin K. van Ittersum[a]

[a]Plant Production Systems Group, Wageningen University, 6700 AK Wageningen, The Netherlands; [b]PBL Environmental Assessment Agency, 3720 AH,

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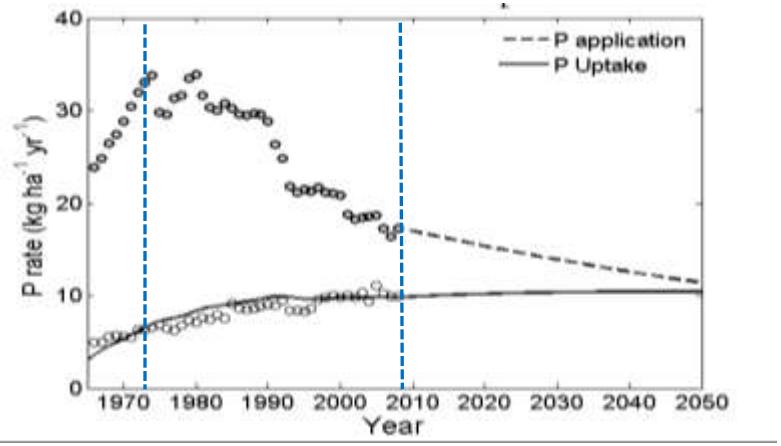
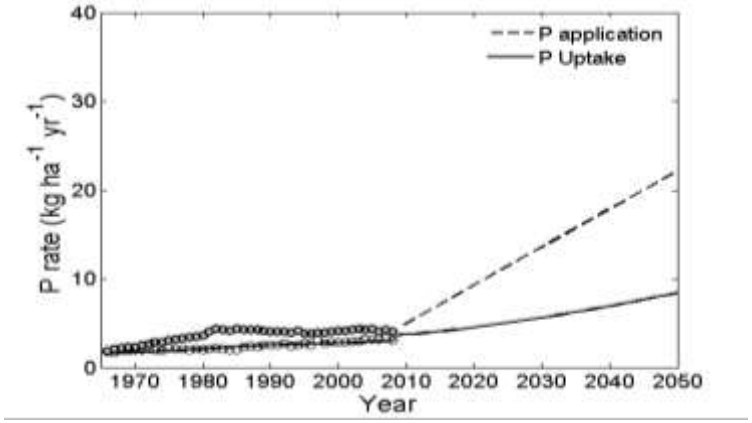
A learning curve!

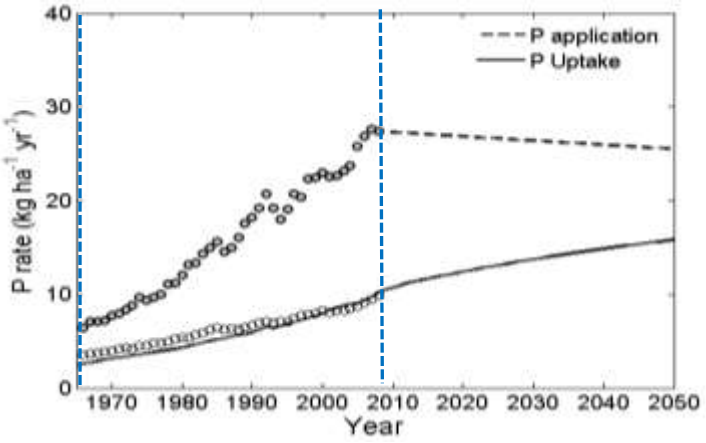
W-Europe



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

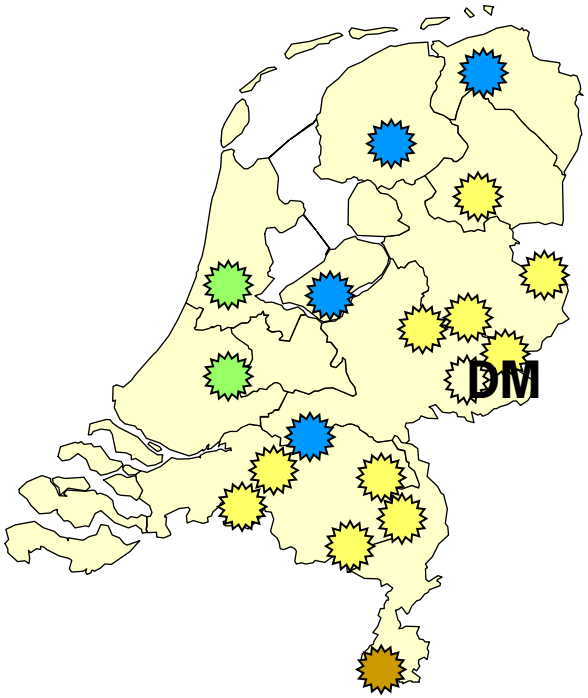
16 pilot farms

clay

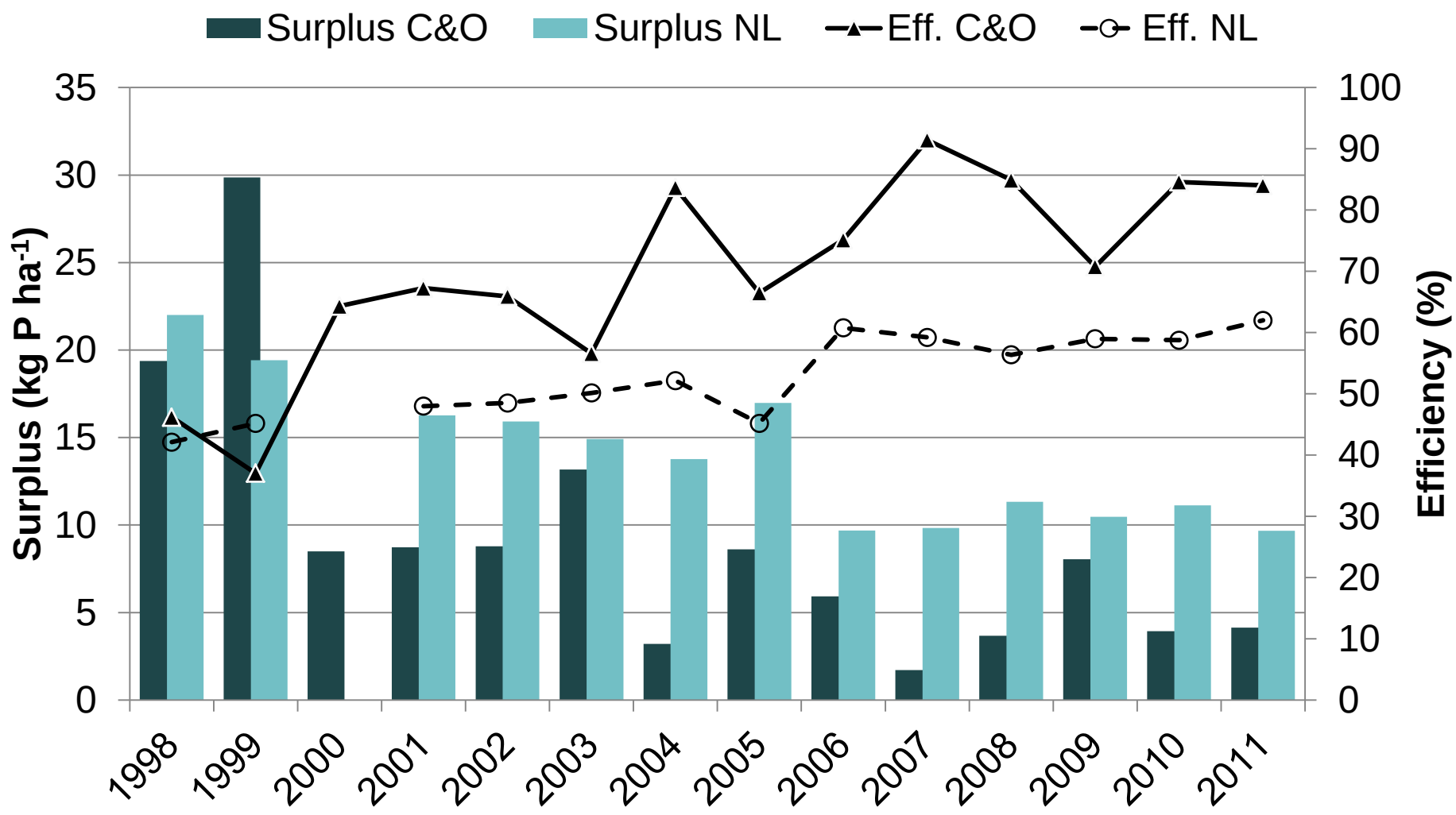
peat

sand

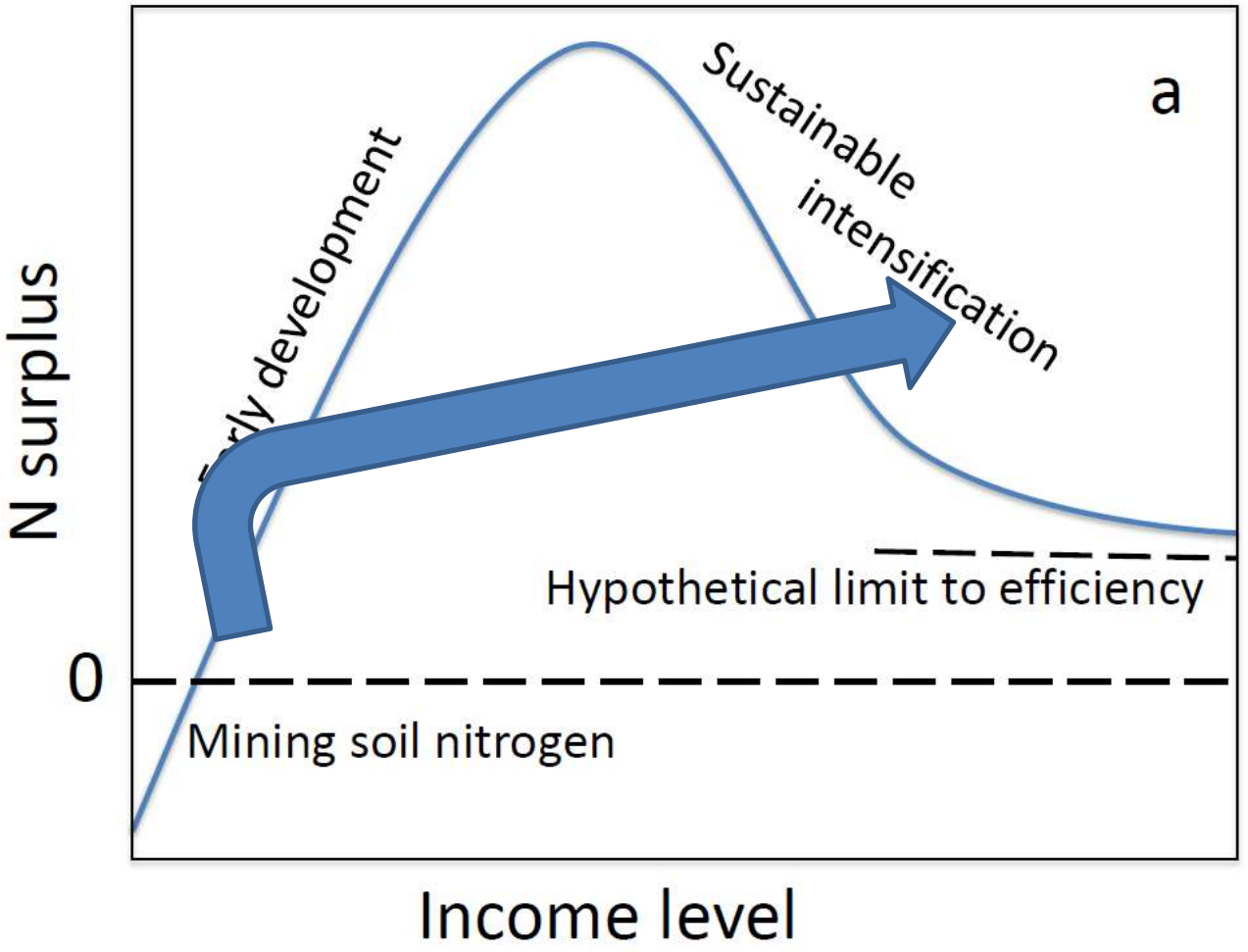
loess



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



The challenge: tunelling through



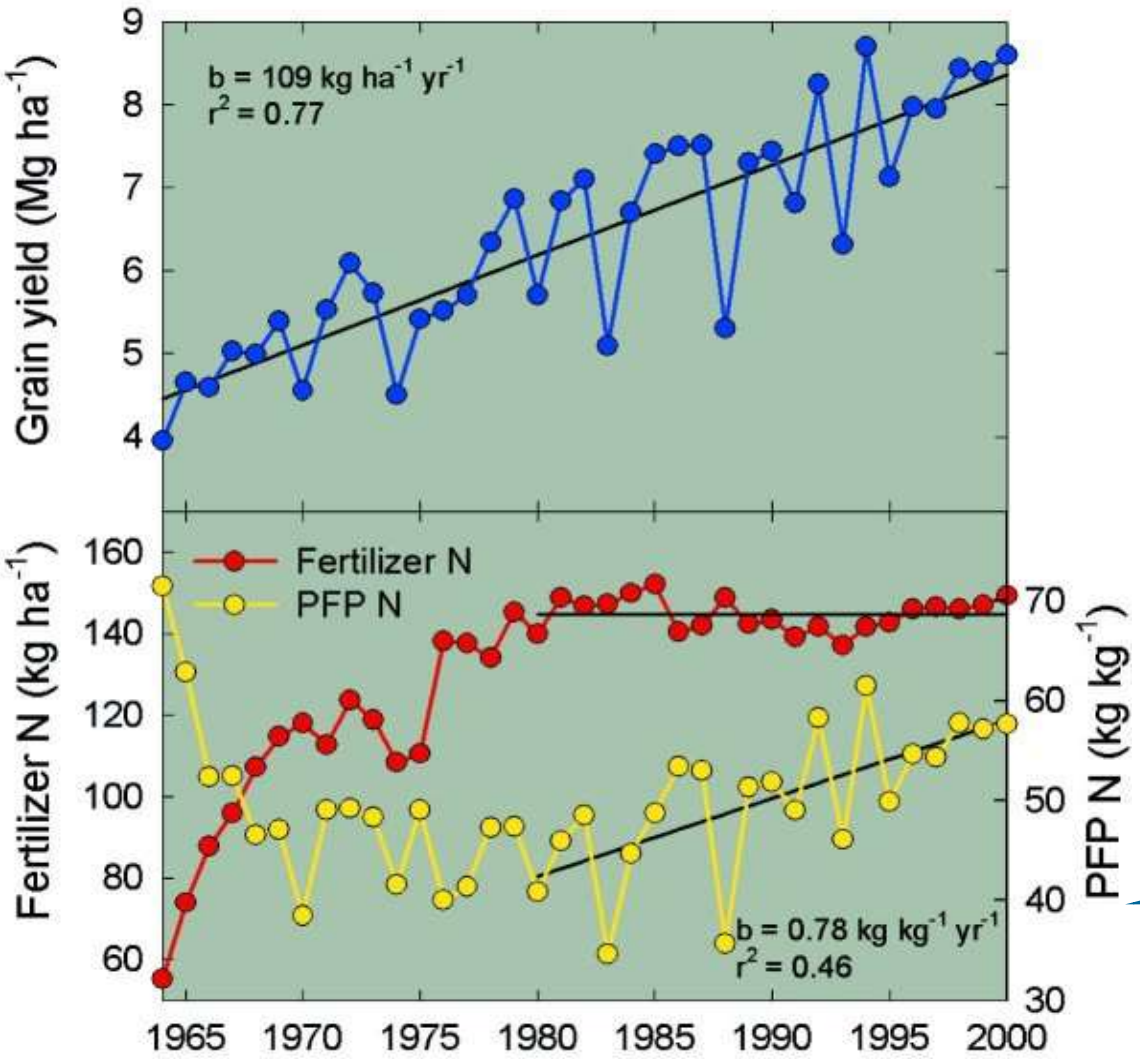
Zhang et al., Nature, 2015

Global Yield Gap Atlas

Intensification versus ‘ecologisation’?

Yield and input use

A success story: USA cereal production

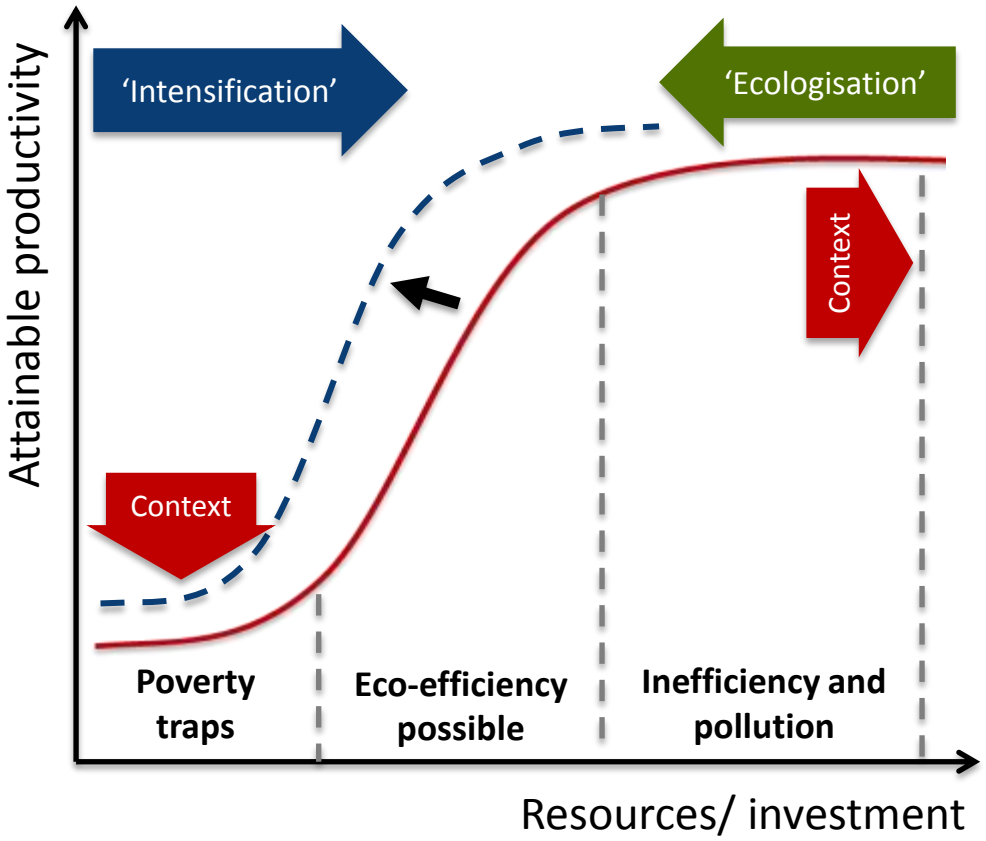


Cassman, 2002

Yield potential
Soil quality
Precision agriculture

Ecological Intensification
(Cassman, 1999)

Intensification or Ecologisation?



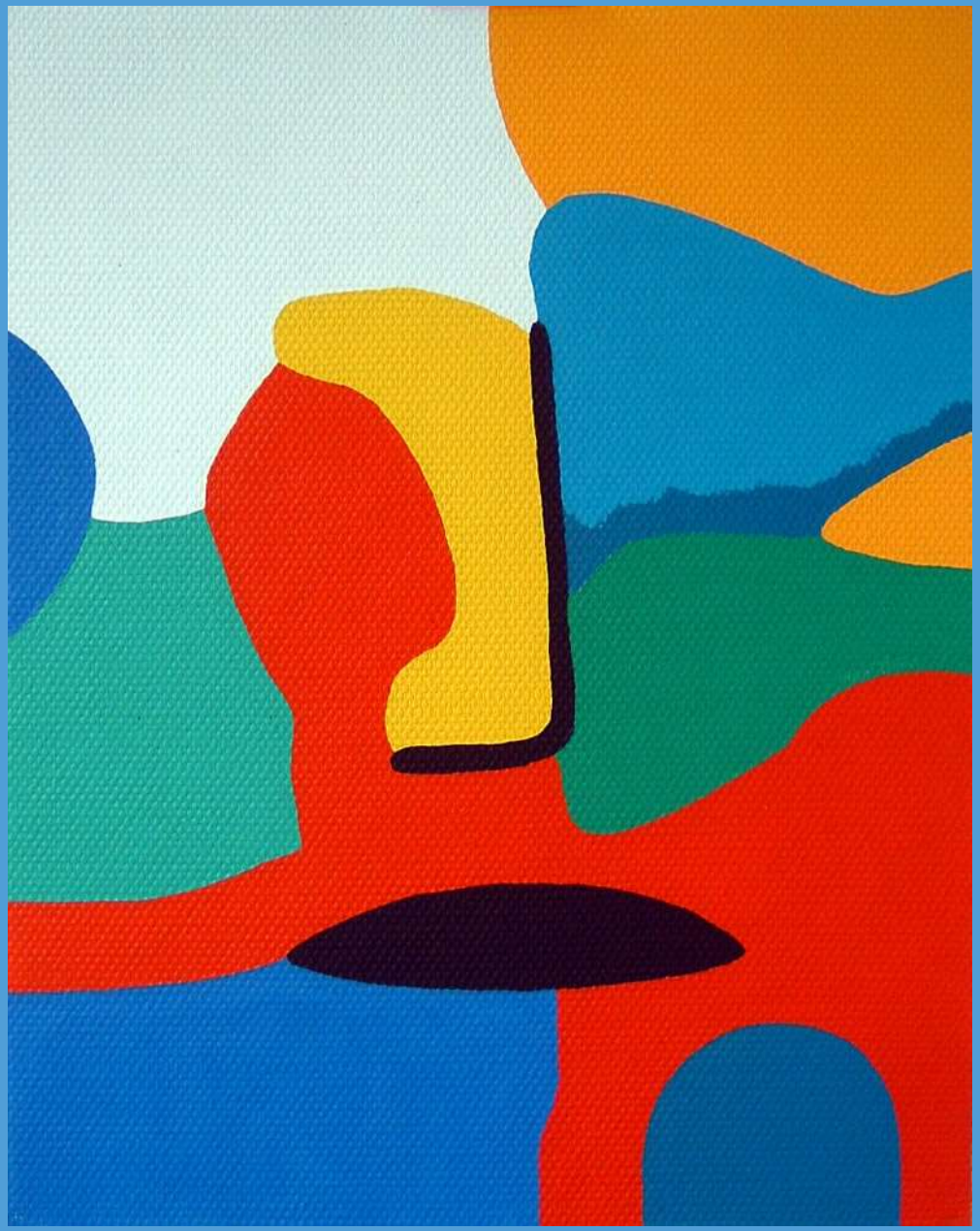
'Ecologisation':
How to maintain productivity while reducing dependence on fossil fuels?

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

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


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

Future harvest



Thank you for your attention!