Future challenges for (Austrian) plant breeding and opportunities from modern phenotyping approaches

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The challenge:
more demand for food, feed & materials **BUT land is limited**

The second billion (1825–1927)

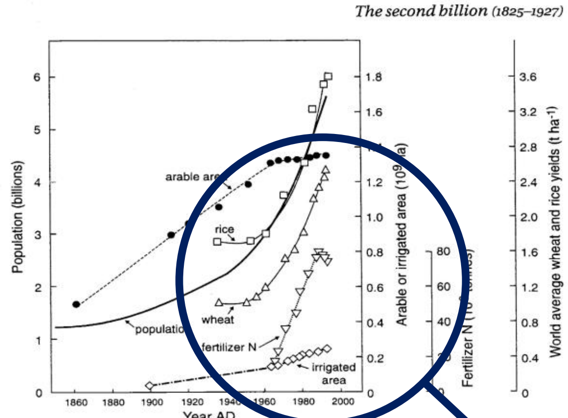

Figure 17 Increases this century in world population, arable area, the average yields of wheat and rice, the amount of N fertilizer used, and the irrigated area of the world[59].

Evans 1998

Source: J.R Porter, University of Copenhagen, DK

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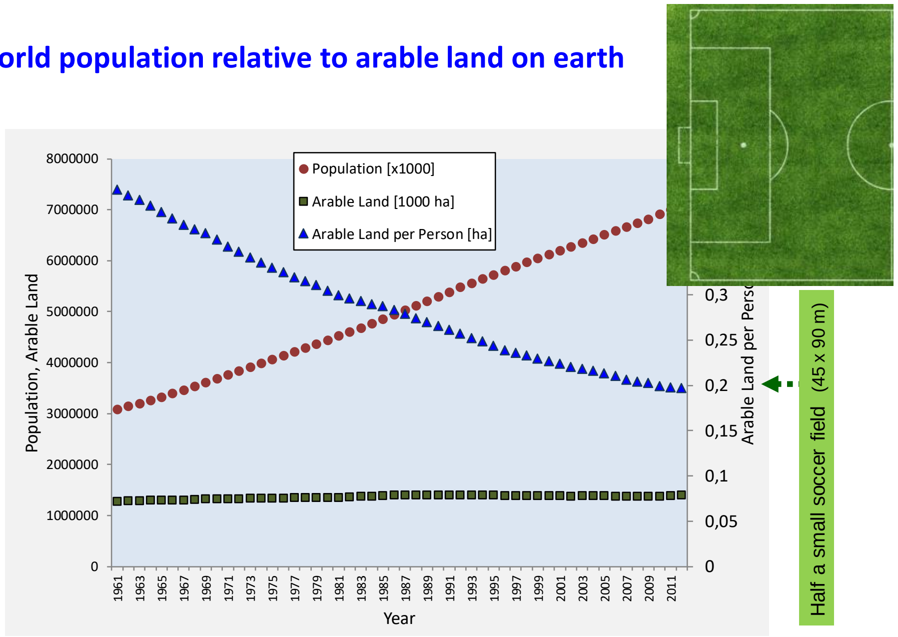
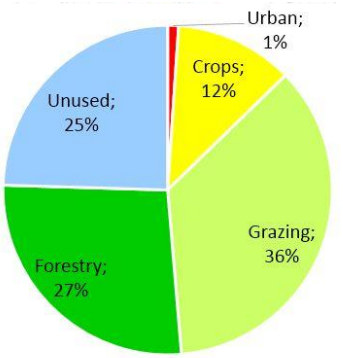
World population relative to arable land on earth



Source: FAO Statistic

Current global land use

- ¾ of the world‘s ice-free land is already used.
- Big differences in land-use intensity
- The remaining unused land is largely infertile (e.g. deserts, alpine or arctic tundra), except for remnants of pristine forests (5-7% of the ice-free land)

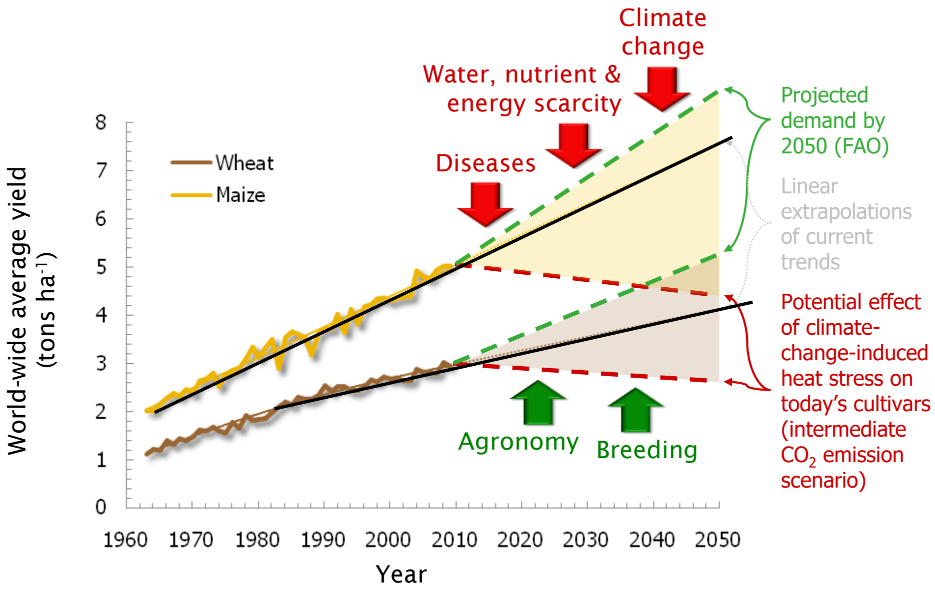


→ Most additional services have to come from land that is already in use (*sustainable* intensification & land-use competition ↑)

Erb *et al.* 2007. *J Land Use Sci.* **2**, 191-224;
Haberl 2015, *Ecol. Econ.*, **119**, 424-431

Courtesy: Prof. Helmut Haberl, lecture at IWGS 2017

Maize and wheat - productivity development



Quelle: H.J. Braun, CIMMYT

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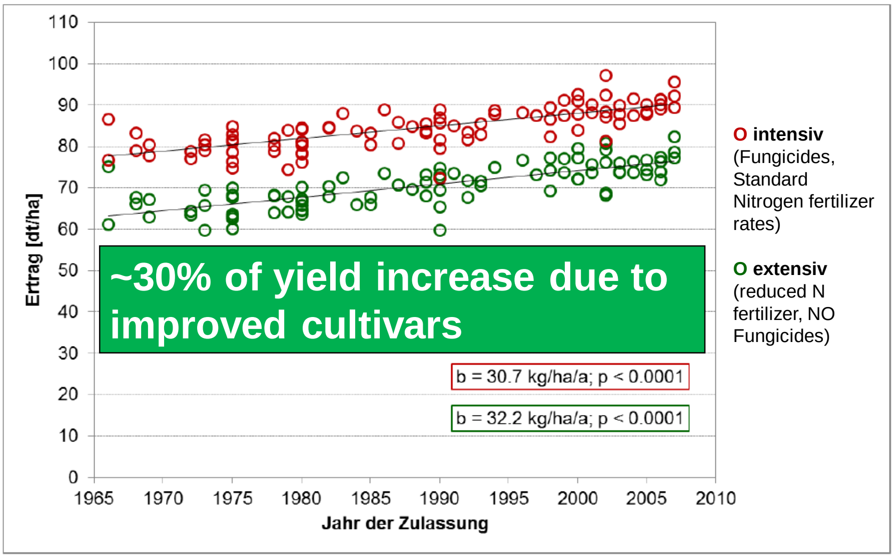
Example Germany, 1965-2010: Genetic improvement of wheat cultivars



Source: Ahlemeyer und Friedt, 2011: Züchtungsfortschritt bei Winterweizen

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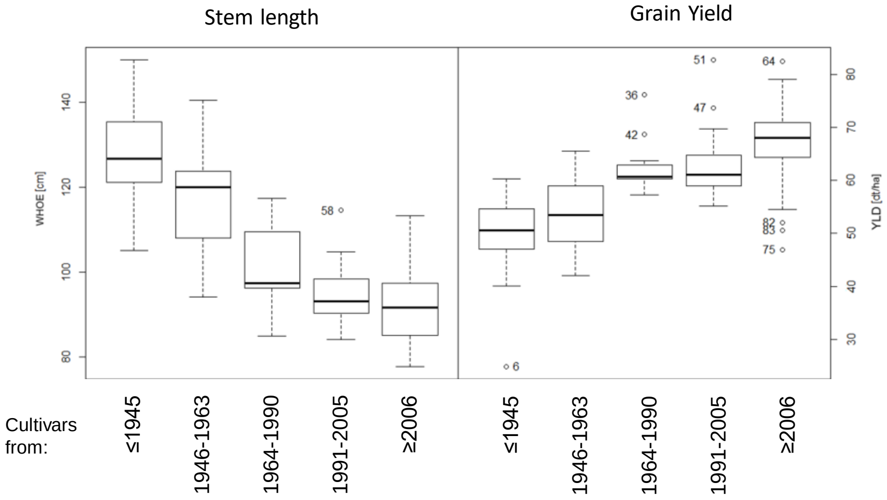
Genetic changes in stem length and yield



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Definitions

Plant breeding)* **is genetic improvement of plants for human benefit**

or a bit more expanded:

Plant breeding)* is the **Science**, **Art**, and **Economic Activity** to **genetically** modify (*improve*) plants according to (*our*) **human needs**

*) syn. ***Plant Improvement***

Rex Bernardo (2010, 2014)
Diepenbrock, Ellmer, Léon (2005)

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An alternative view - bringing innovation into the field

Source: ESA – European Seed Association

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How much time is needed for breeding a new cultivar?

How much investment is needed for a new cultivar?

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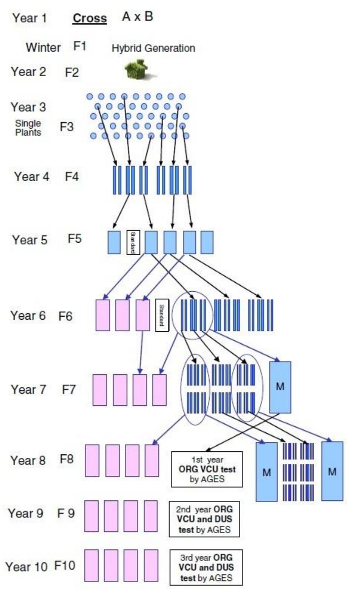

Breeding a new (wheat) cultivar requires typically 10 years

Breeding a new (wheat) cultivar costs typically 1 Mill €

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Success (selection gain) in breeding rests on two basic pre-conditions

- Genetic variation for the traits of interest
- Tools and procedures to identify the desired variants (genotypes), but we often select based on the phenotypes

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Selection through the years…

- Great progress in the genetic improvement of crop plants by breeders

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Cost of one field plot for yield testing? **50 €**

Cost of one genetic fingerprint with 15.000 ‚markers'? **30 €**

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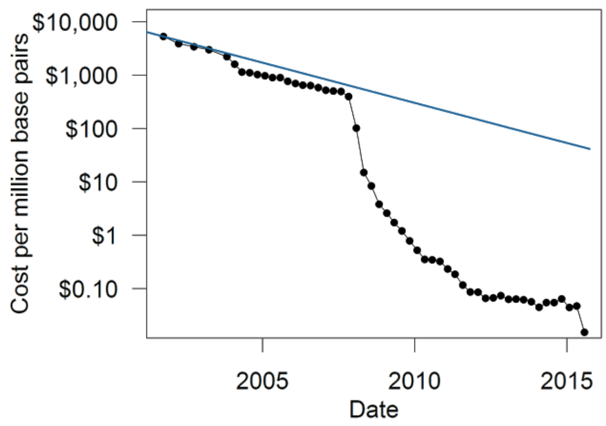
BIG DATA in breeding

Technology Jump
Genotyping is getting cheaper



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- Phenotype = Genotype + Environment

- $P = \sum(m_i) + E$

	Marker_1	Marker_2	Marker_3	Marker_4	Marker_5	Marker_6	Marker_7	Marker_8	Marker_9	Marker_10	Marker_11	Marker_12	Marker_13	Marker_14	Marker_15	Marker_16	Marker_17	Marker_X
Linie_1	1	1	2	1	0	1	2	0	0	0	1	0	0	2	1	0	0	.
Linie_2	1	2	1	2	1	1	1	2	1	0	1	1	2	1	1	2	1	.
Linie_3	2	1	2	1	1	1	1	0	1	0	1	0	2	1	2	2	2	.
Linie_4	0	1	2	1	0	1	0	1	1	0	0	0	0	0	0	2	2	.
Linie_5	1	2	0	1	1	0	2	1	2	0	1	0	0	1	0	0	0	.
Linie_6	1	2	1	1	1	1	1	1	2	1	2	1	0	2	2	1	1	.
Linie_7	2	2	1	0	1	0	0	1	0	0	1	1	1	1	1	2	1	.
Linie_8	1	1	1	1	0	2	0	1	0	1	2	1	2	0	0	0	1	.
Linie_9	1	1	1	1	1	1	0	2	1	1	1	2	2	1	2	1	1	.
Linie_10	0	2	2	2	1	2	0	2	0	1	1	0	0	0	0	1	1	.
Linie_11	1	0	0	1	1	1	1	1	1	1	1	0	1	1	1	0	0	.
Linie_12	0	1	2	1	2	0	1	0	1	0	1	1	1	1	1	0	1	.
Linie_13	2	1	1	1	1	2	2	2	2	1	2	2	1	0	1	0	2	.
Linie_X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

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The challenges:

Genotyping
is getting more and more efficient and cheaper

Phenotyping
is still a bottleneck, resource demanding and expensive

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Phenotyping
is still a bottleneck, resource demanding and expensive

Expectations

- *In situ* measurements during plant development
- Destruction-free measurements
- Measure effects of specific stresses
- Faster measurements, less labor needed
- Cheaper measurements
- Avoid the human factor

Challenges

- Missing the human factor (the breeder‘s eye)
- For which traits?
- How deal with variation that is possibly confounded with the target traits?
- How deal with genotype x environment interaction
- Which type of measurements, devices, … ?
- Data handling and data analysis
- Integration in breeding programs

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