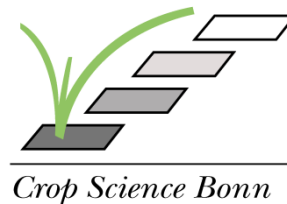


Pflanzliche Erzeugung im Klimawandel: Auswirkungen und Anpassungen aus Sicht der Ertragsentwicklung

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<http://www.lap.uni-bonn.de>



Klimafaktoren und Ertrag

Veränderungen (Klima und Ertrag)

Transiente Veränderungen und extreme Ereignisse

Historische Veränderungen und zukünftige Projektionen

Anpassungsoptionen

Schlussfolgerungen

Klimafaktoren und Ertrag

- Temperatur
 - Phänologische Entwicklung
 - Assimilation und Atmung
 - Organdifferenzierung
 - Seneszenz
- Niederschlag
 - Wasserhaushalt
 - Transpiration (Hitzetoleranz)
 - Nährstoffaufnahme
 - Seneszenz
- CO₂
 - Assimilation
 - Transpiration
- ...



Klimafaktoren und Ertrag

Temperatur

- Assimilation und Atmung
- Phänologische Entwicklung

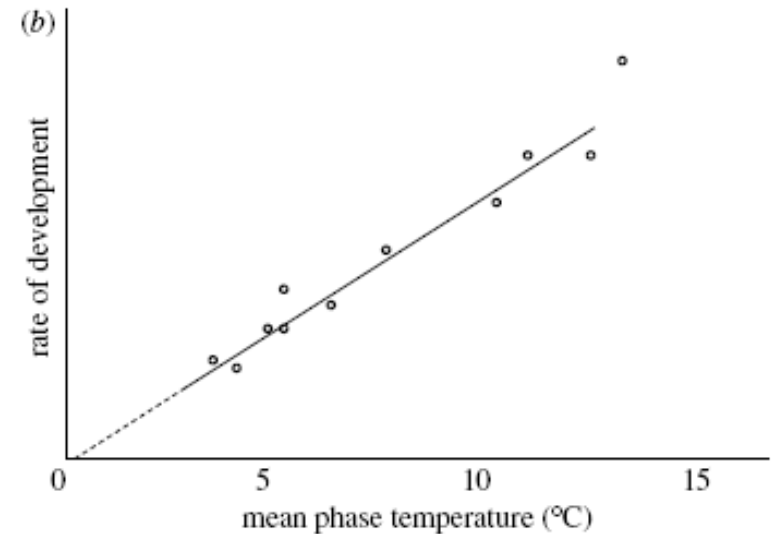
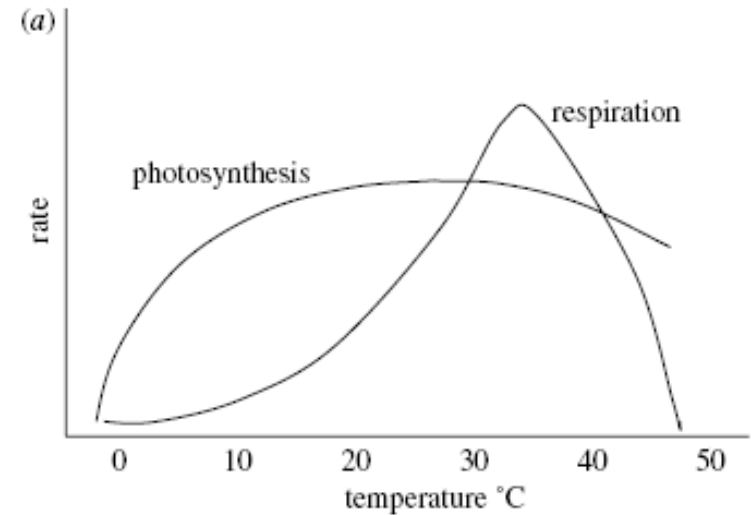
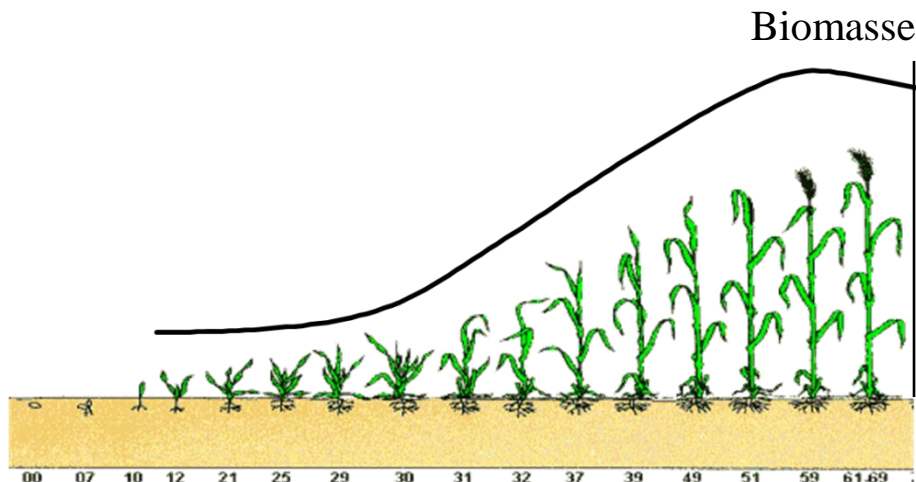


Figure 2. Changes in the rate of (a) C_3 photosynthesis and respiration and (b) rate of crop development as a function of temperature.

Klimafaktoren und Ertrag

Temperatur

- Organanlage und -differenzierung

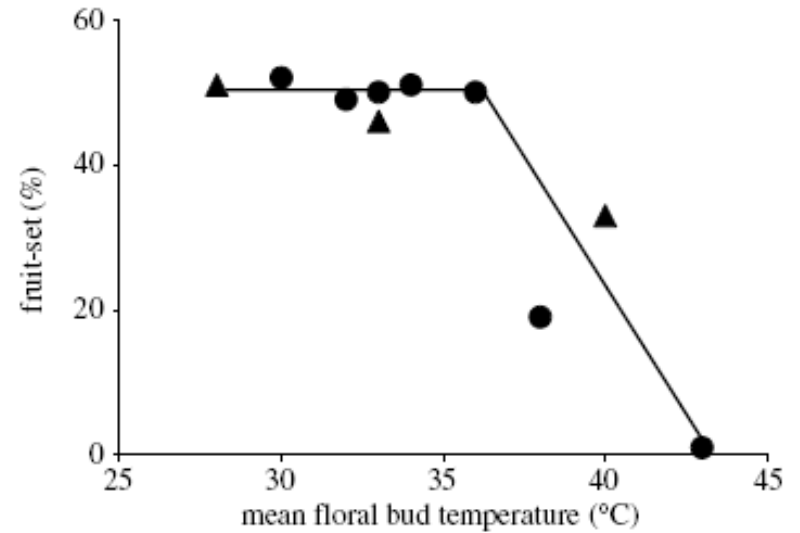


Figure 5. Relationship between percentage fruit set (angular transformed data) and mean floral temperature, from 08:00 to 14:00 h, 9 days after flowering in groundnut (Vara Prasad *et al.* 2000).



Sowing

Emergence

Sensitive period

Harvest

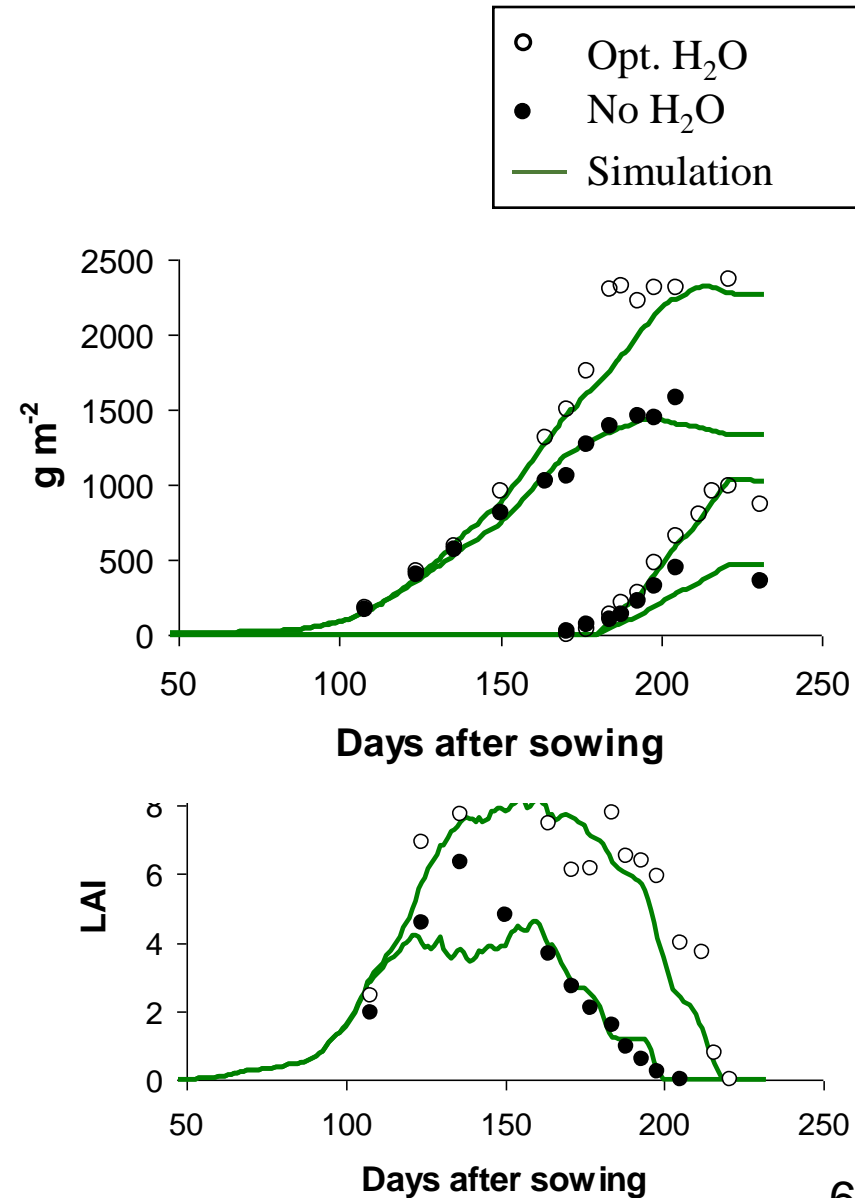
Klimafaktoren und Ertrag

Niederschlag

- Transpiration, assimilation
- Verteilung von Assimilaten
- Seneszenz



Jamieson and Ewert, 1999



Veränderungen (Klima)

Temperatur

- Zunahme Temperaturmittel
- Zunahme Extremereignisse

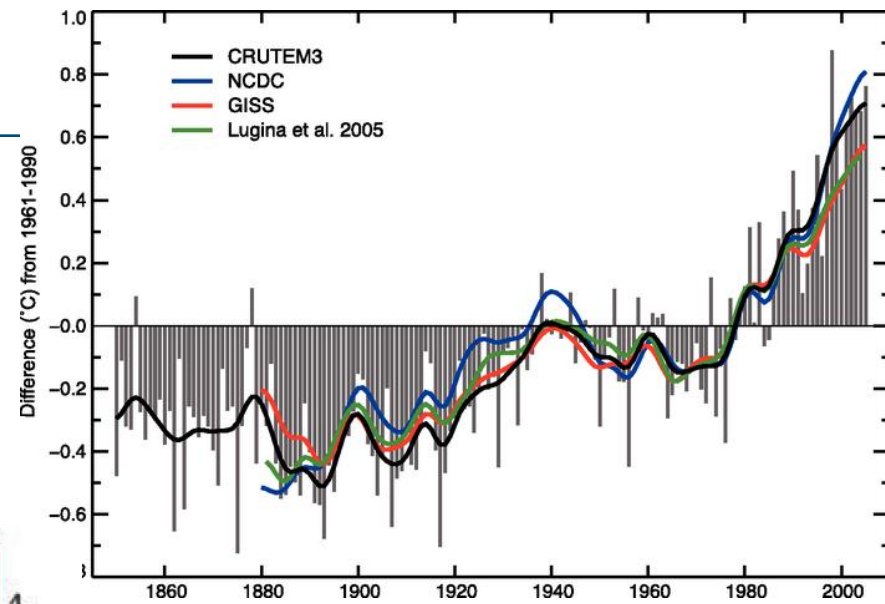


Figure. Annual anomalies of global land-surface air temperature ($^{\circ}\text{C}$), 1850 to 2005, relative to the 1961 to 1990 mean, updated from Brohan et al. (2006) in IPCC, 2007.

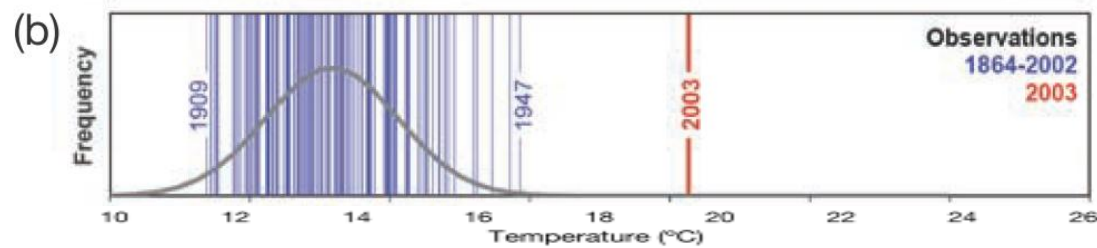
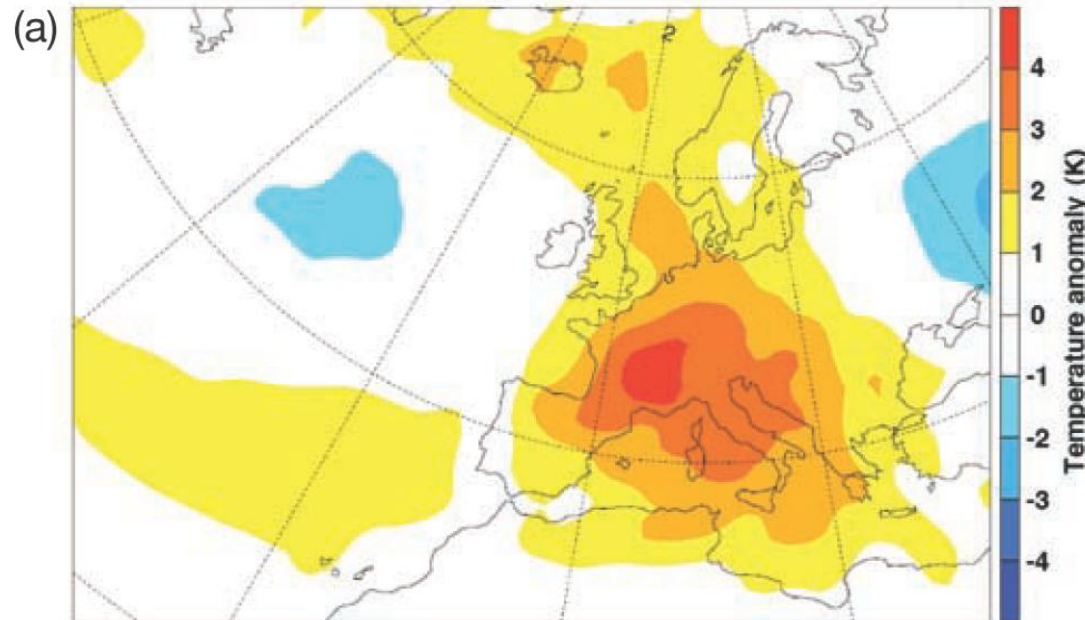


Figure. Characteristics of the summer 2003 heatwave. a) JJA temperature anomaly with respect to the 1961–90 mean; b) JJA temperatures for Switzerland observed during 1864 to 2003. IPCC, 2007, adapted from Schär et al., 2004

Veränderungen (Klima)

Temperatur

- Ertragsvariabilitäten

Beispiel Weizen (Europa)

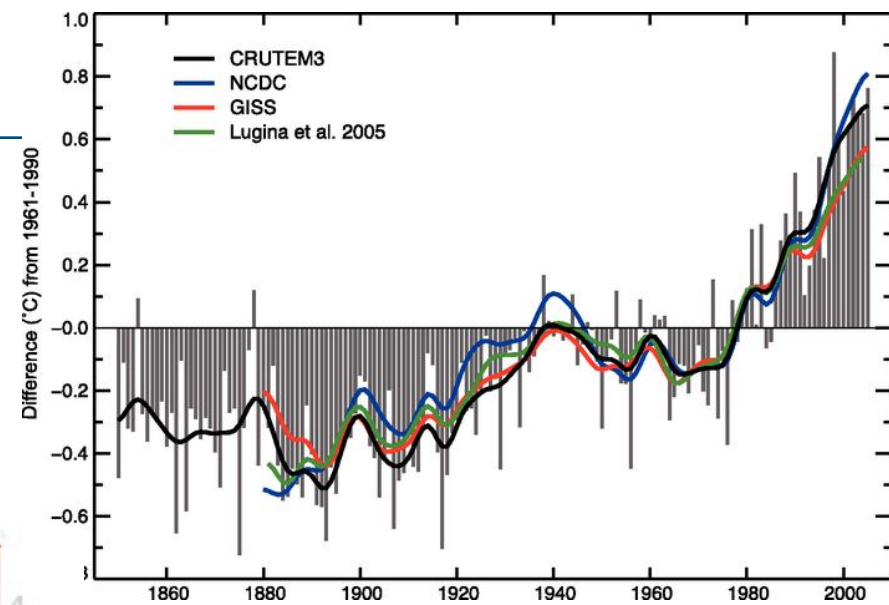
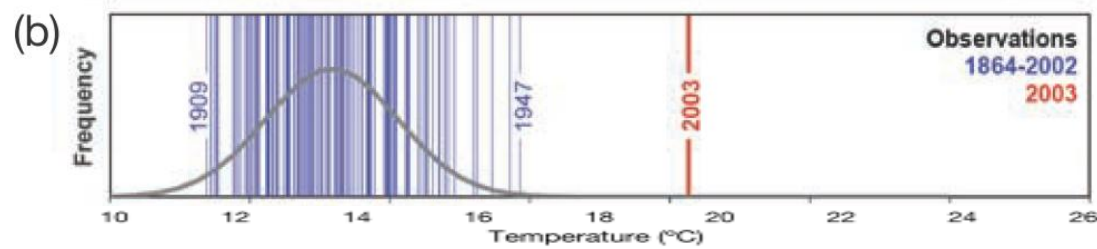
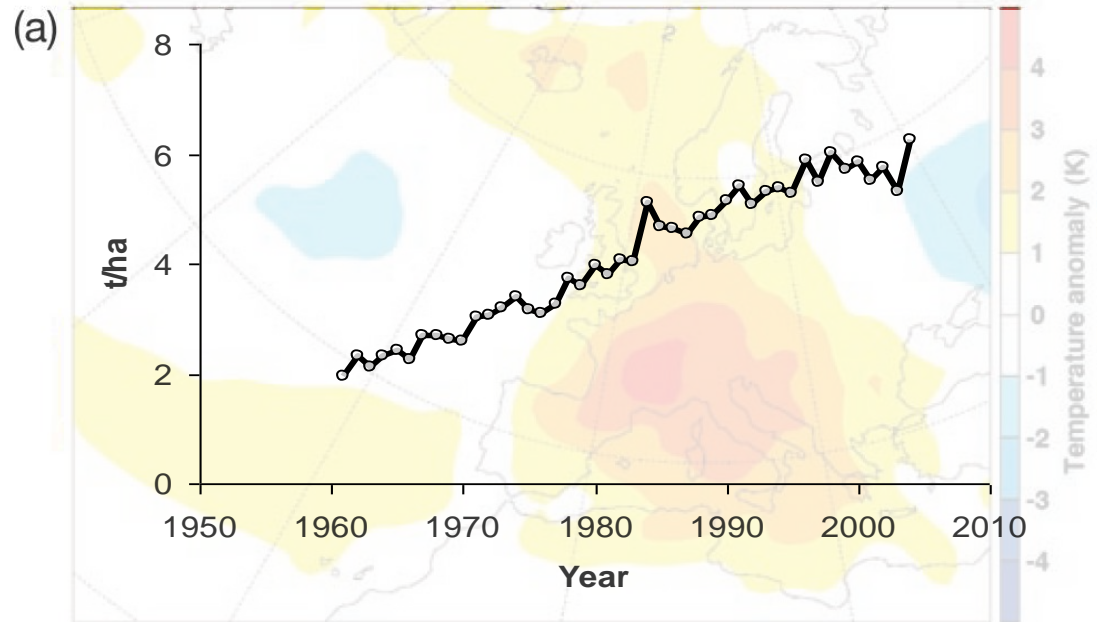


Figure. Annual anomalies of global land-surface air temperature (°C), 1850 to 2005, relative to the 1961 to 1990 mean, updated from Brohan et al. (2006) in IPCC, 2007.

Figure. Yields of wheat in Europe between 1961-2004. Source: FAO.

Figure. Characteristics of the summer 2003 heatwave. a) JJA temperature anomaly with respect to the 1961–90 mean; b) JJA temperatures for Switzerland observed during 1864 to 2003. IPCC, 2007, adapted from Schär et al., 2004

Veränderungen (Klima)

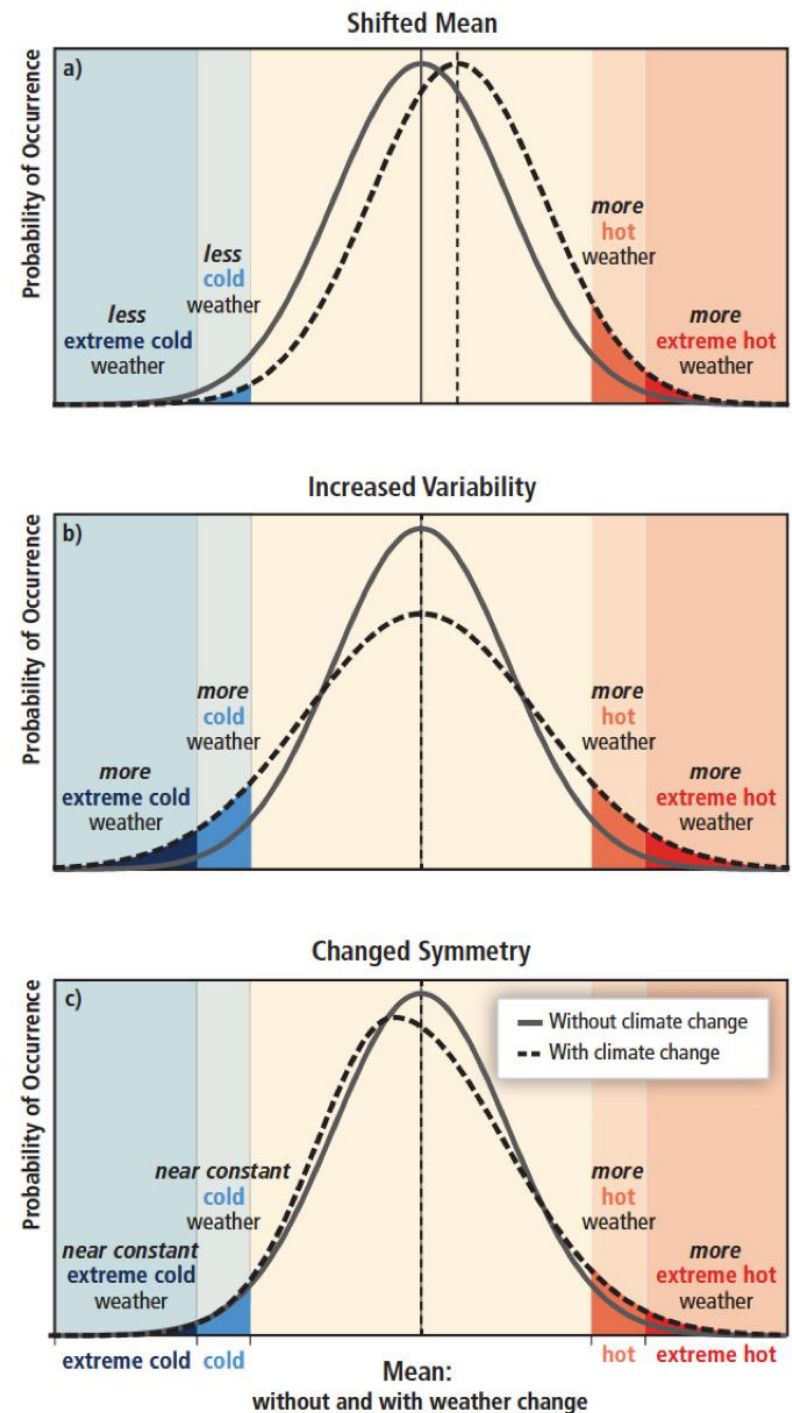
Temperatur

- Mögliche Veränderungen in Mittelwerten und Extremereignissen

Figure. Different changes in temperature distributions between present and future climate and their effects on extreme values of the distributions:

- (a) effects of a simple shift of the entire distribution toward a warmer climate;
- (b) effects of an increase in temperature variability with no shift in the mean;
- (c) effects of an altered shape of the distribution, in this example a change in asymmetry toward the hotter part of the distribution.

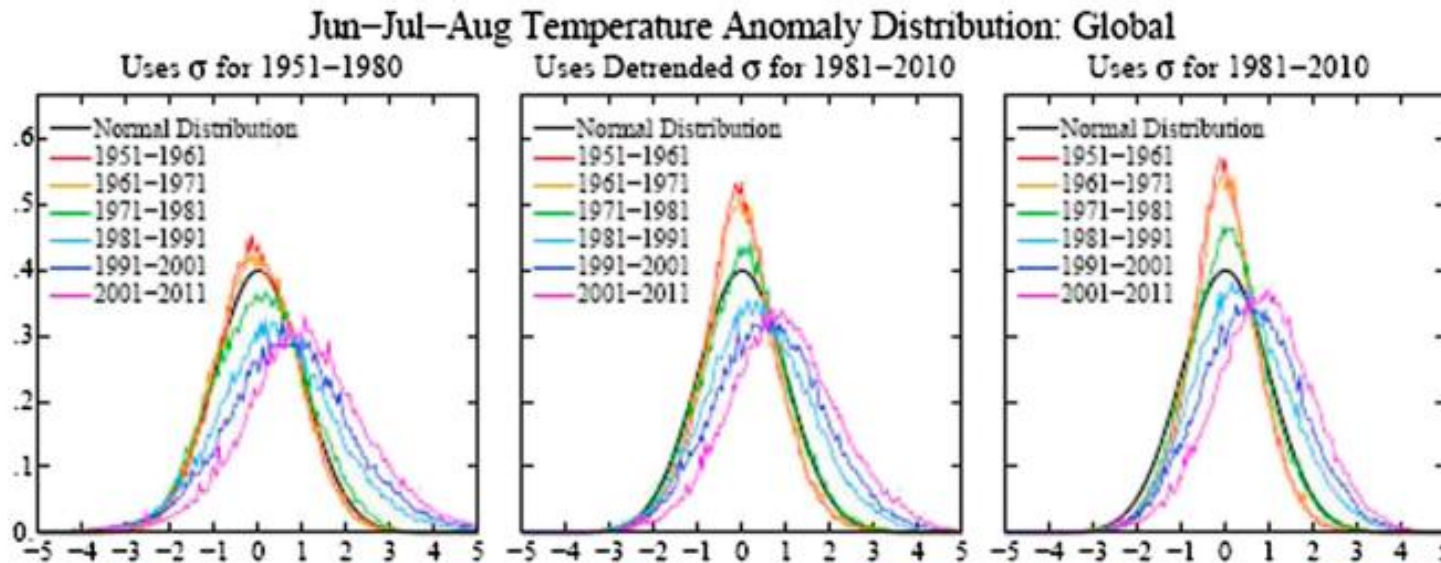
(Reproduced from Special Report of the IPCC 2007).



Veränderungen (Klima)

Temperatur

- Beobachtete Veränderungen in Mittelwerten und Extremereignissen



Hansen et al., 2012

Figure. Frequency of occurrence (y axis) of local temperature anomalies (relative to 1951–1980 mean) divided by local sd (x axis) obtained by counting gridboxes with anomalies in each 0.05 interval. Area under each curve is unity.

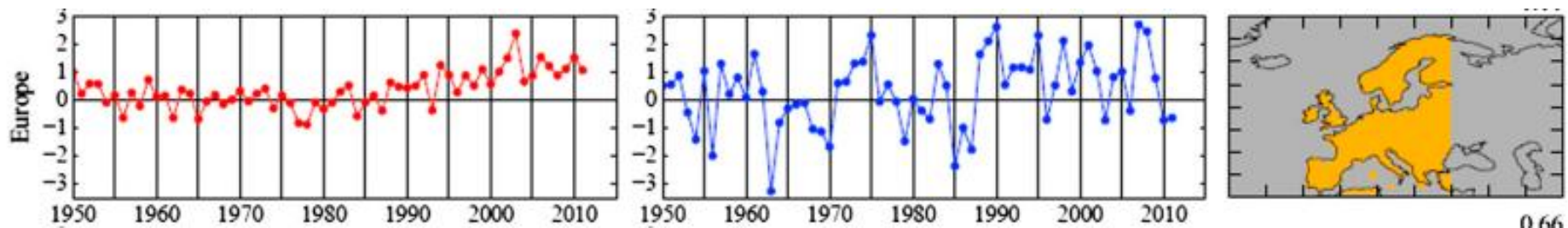


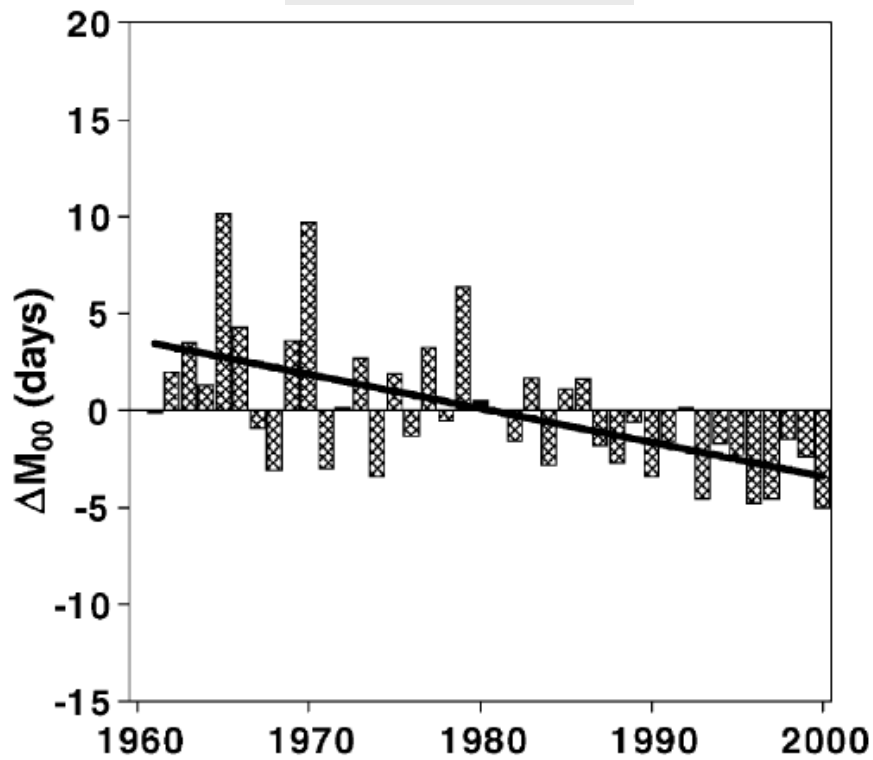
Figure. June–July–August and December–January–February temperature anomalies (°C) relative to 1951–1980 base period for areas shown on the right. Number above each map is the colored region's percent of global area..

Veränderungen (Pflanzenproduktion)

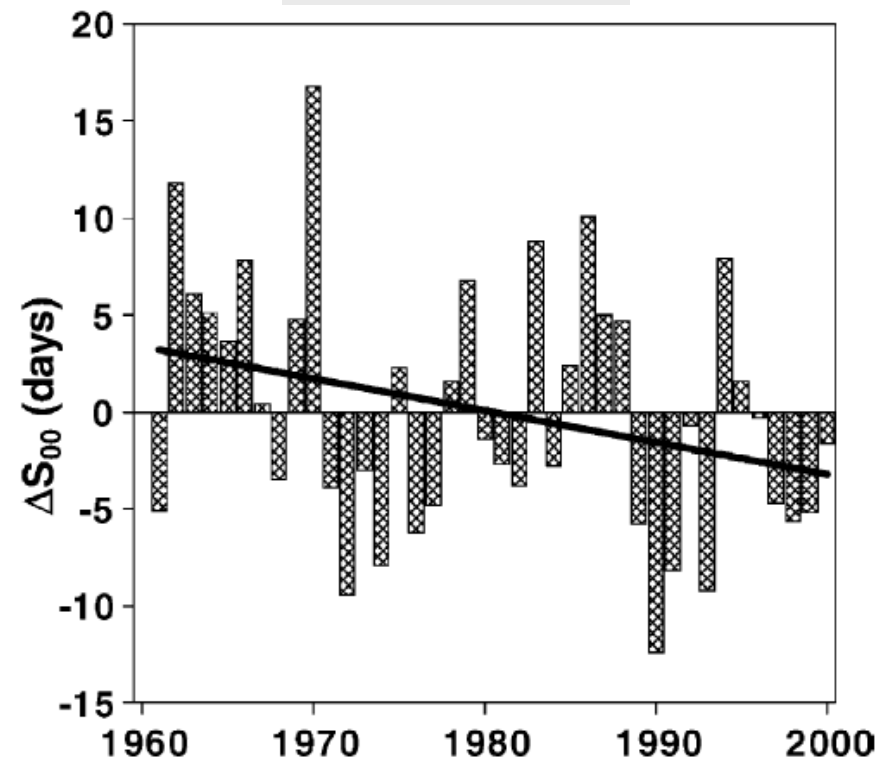
Saattermin

Deutschland

Mais



Zuckerrübe



Changes in the seeding dates of maize (left) and sugar beet (right) in the main cropping areas of Germany, 1961–2000 with calculated trends. Anomalies are shown.

Veränderungen (Pflanzenproduktion)

Deutschland (>6000 stations)

Pänologie (Hafer)

Temperaturänderung

- <15 years
- 15-29 years
- < 29 years

+1.5 °C (1959-2009)

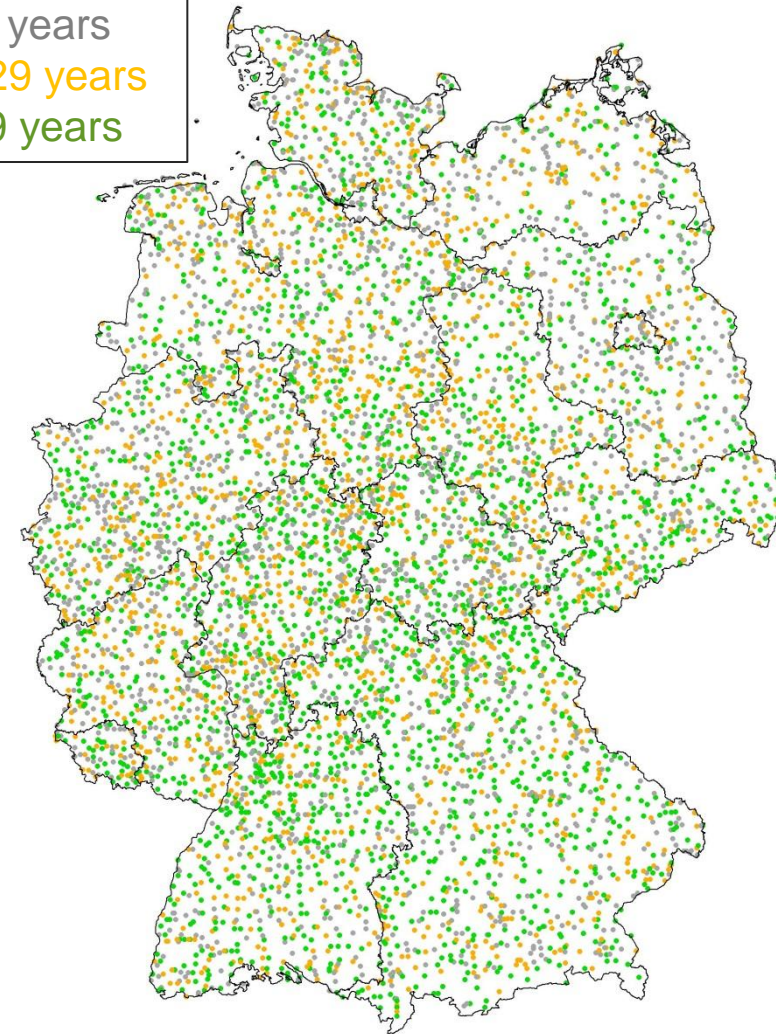
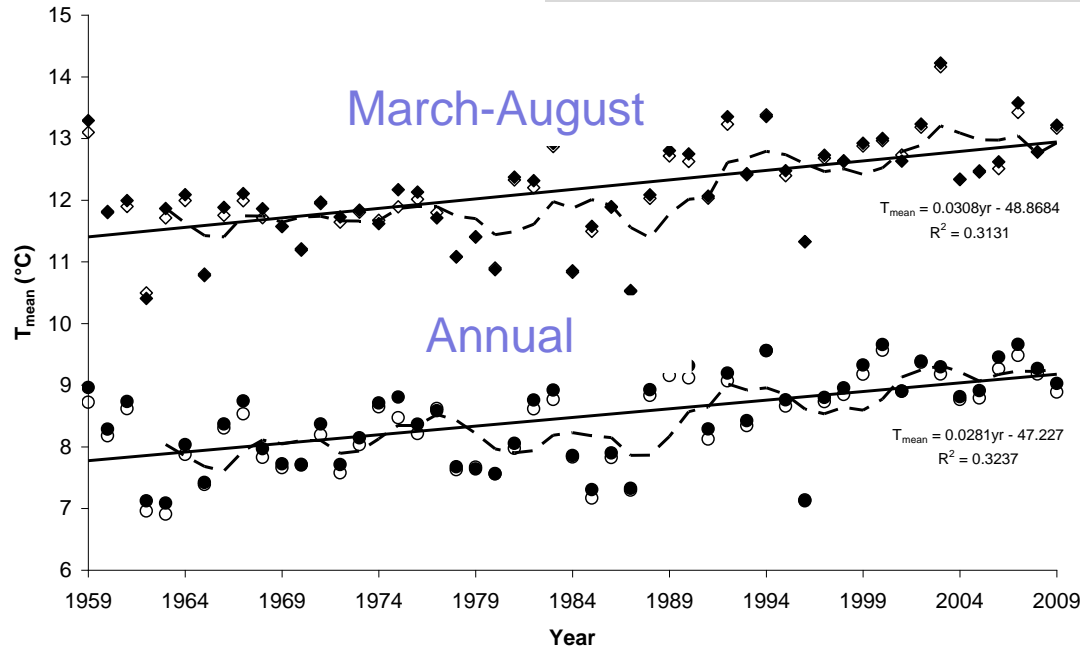


Figure: Change in mean temperature (March to August and annual) between 1959-2009.

Figure: Phenology observation stations, 1959-2009

Veränderungen (Pflanzenproduktion)

Germany

Phänologie (Hafer)

Temperaturänderung

-14 Tage (Aussaat-Gelbreife)

-17 Tage (Eintritt Gelbreife)

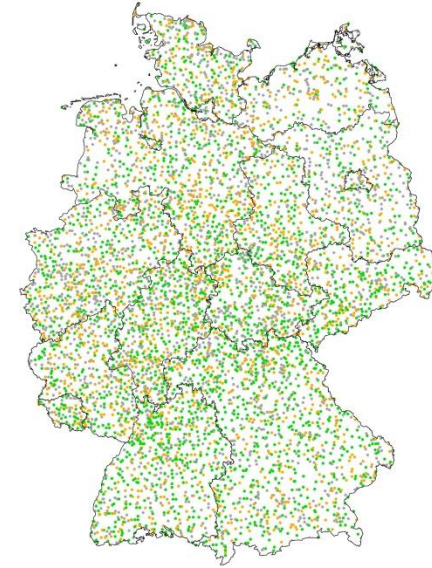
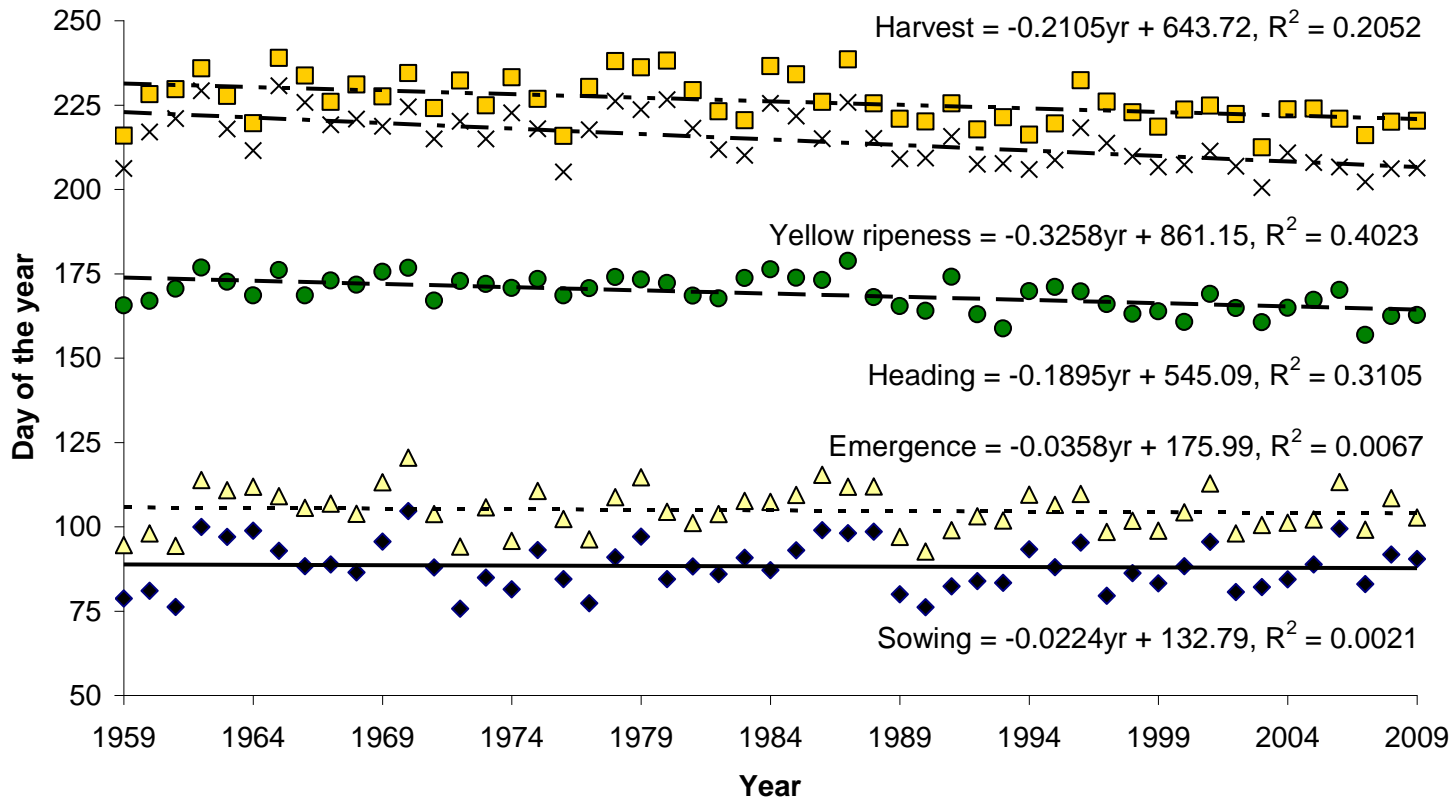


Figure: Change in observed phenological stages of oat in Germany between 1959-2009.

Veränderungen (Pflanzenproduktion)

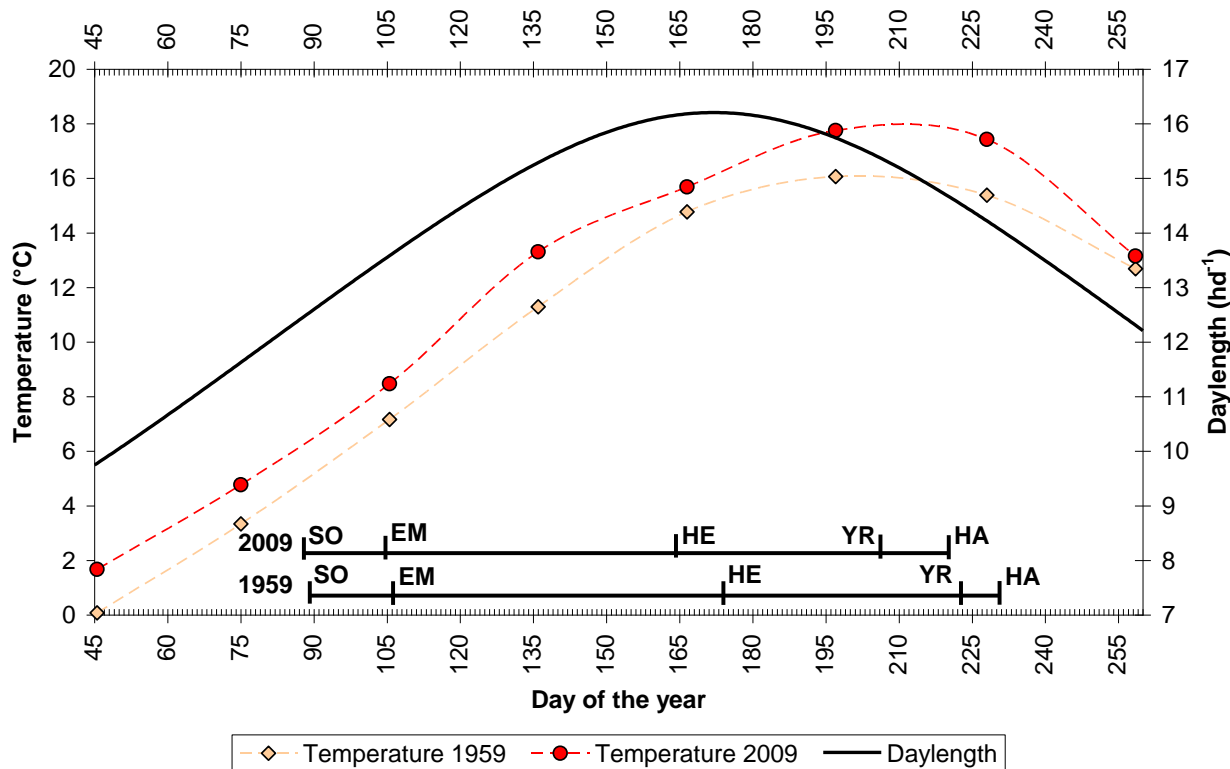
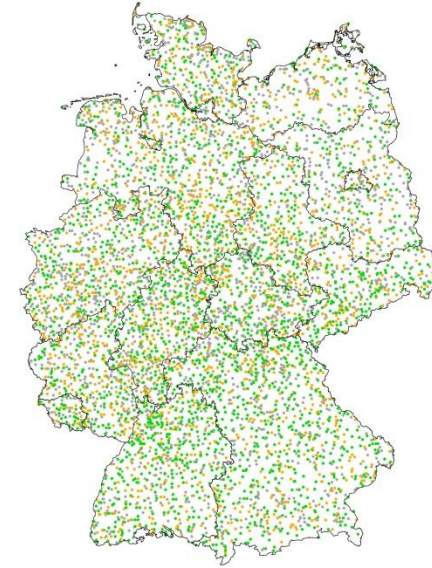
Germany

Phänologie (Hafer)

Temperaturänderung

-14 Tage (Aussaat-Gelbreife)

-17 Tage (Eintritt Gelbreife)



SO = sowing;
EM = emergence;
HE = heading;
YR = yellow ripeness;
HA = harvest

Figure: Temperatures and phenological stages from linear regression equations of oat in Germany between 1959-2009.); day length refers to 50.36° N (average latitude of sowing observations)

Veränderungen (Pflanzenproduktion)

Germany

Phänologie (Hafer)

Adaptation ?

- Anbau von früheren Sorten (keine Anpassung an Temperaturerhöhung)

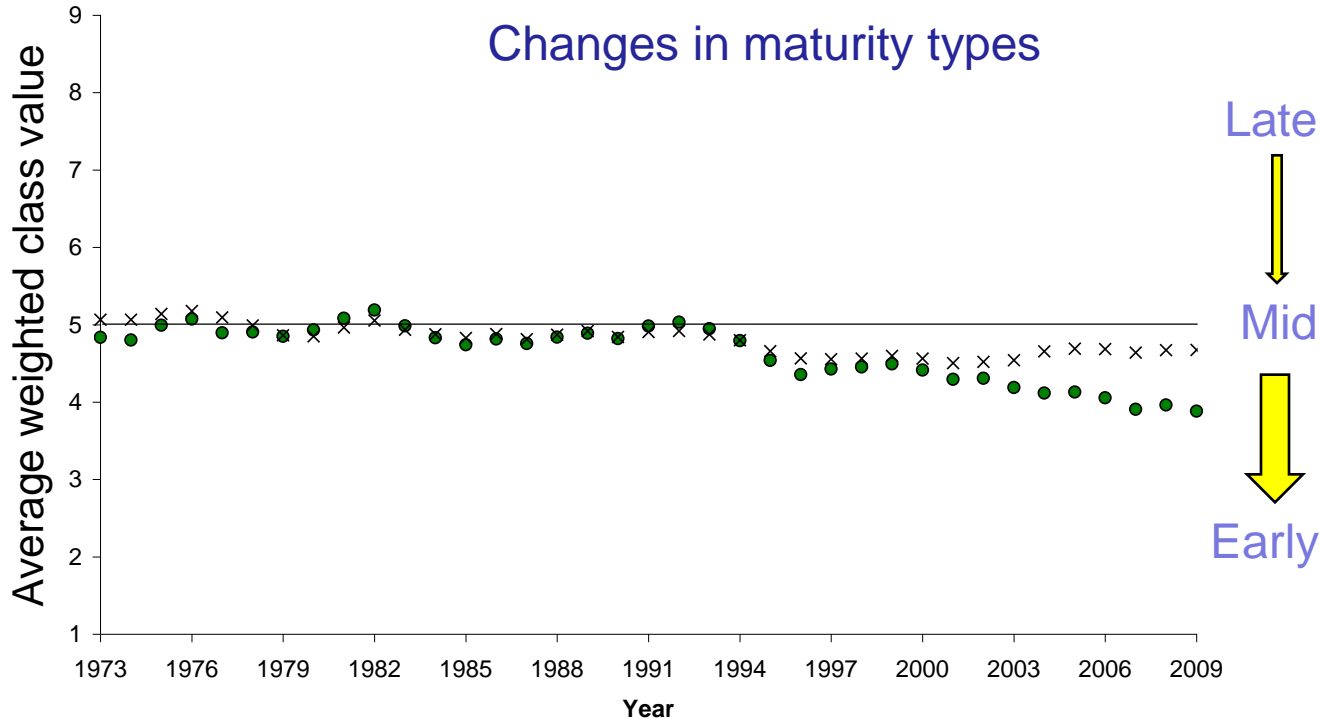
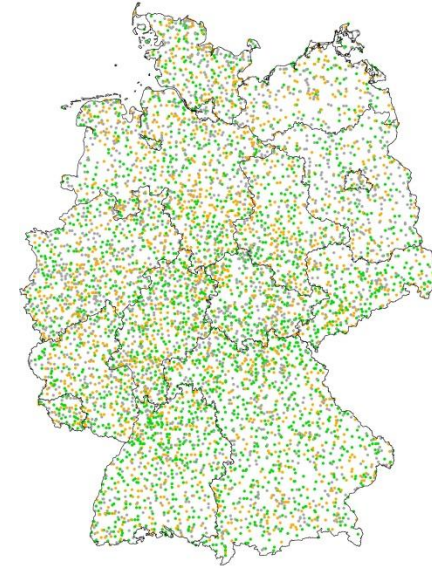
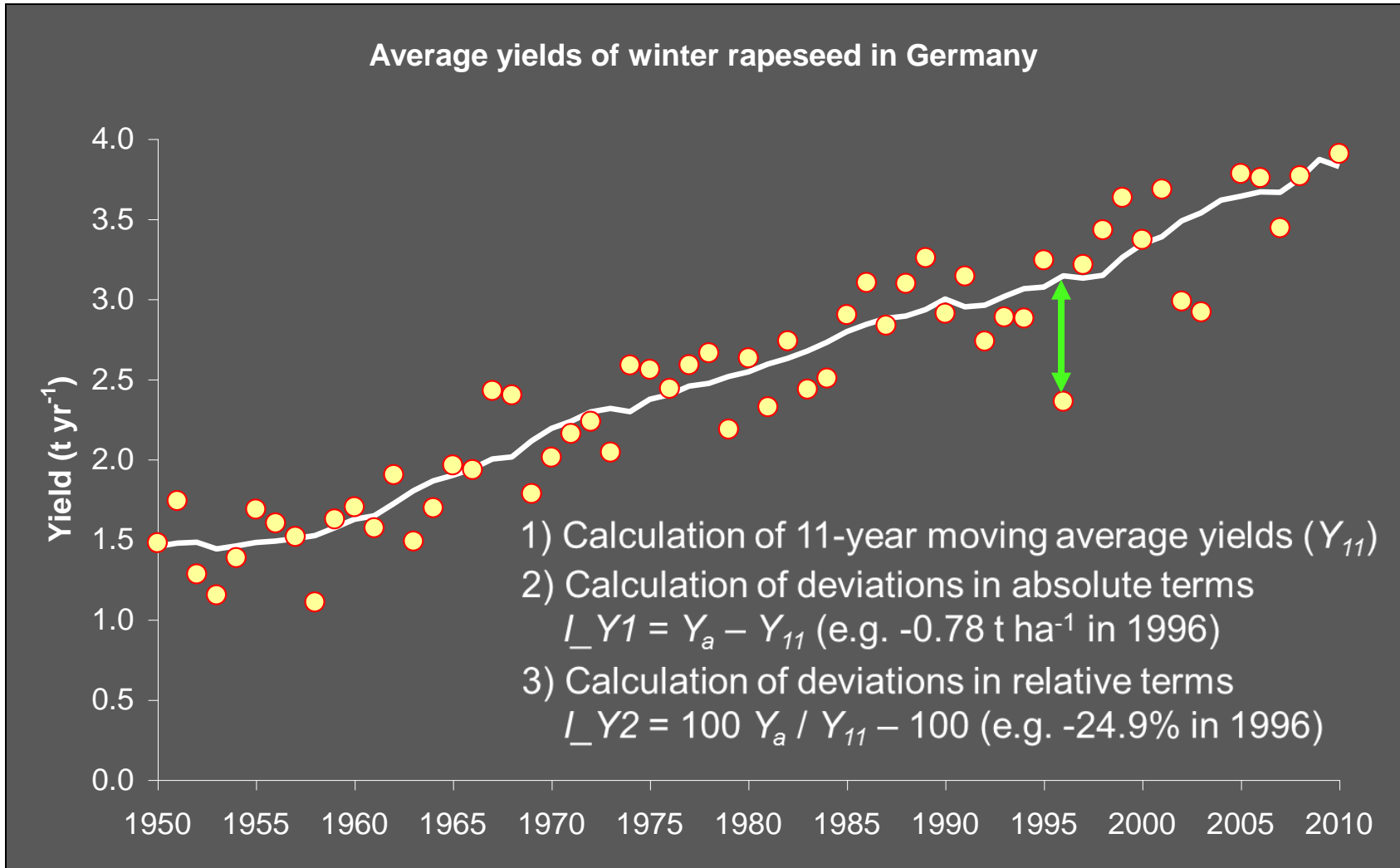


Figure: Average weighted (by growing area) maturity class computed for the occurrence of heading (green circles) and ripeness (crosses) for oat cultivars grown in Germany in the period 1973 to 2009.

Veränderungen (Pflanzenproduktion)

Ertragsanomalien

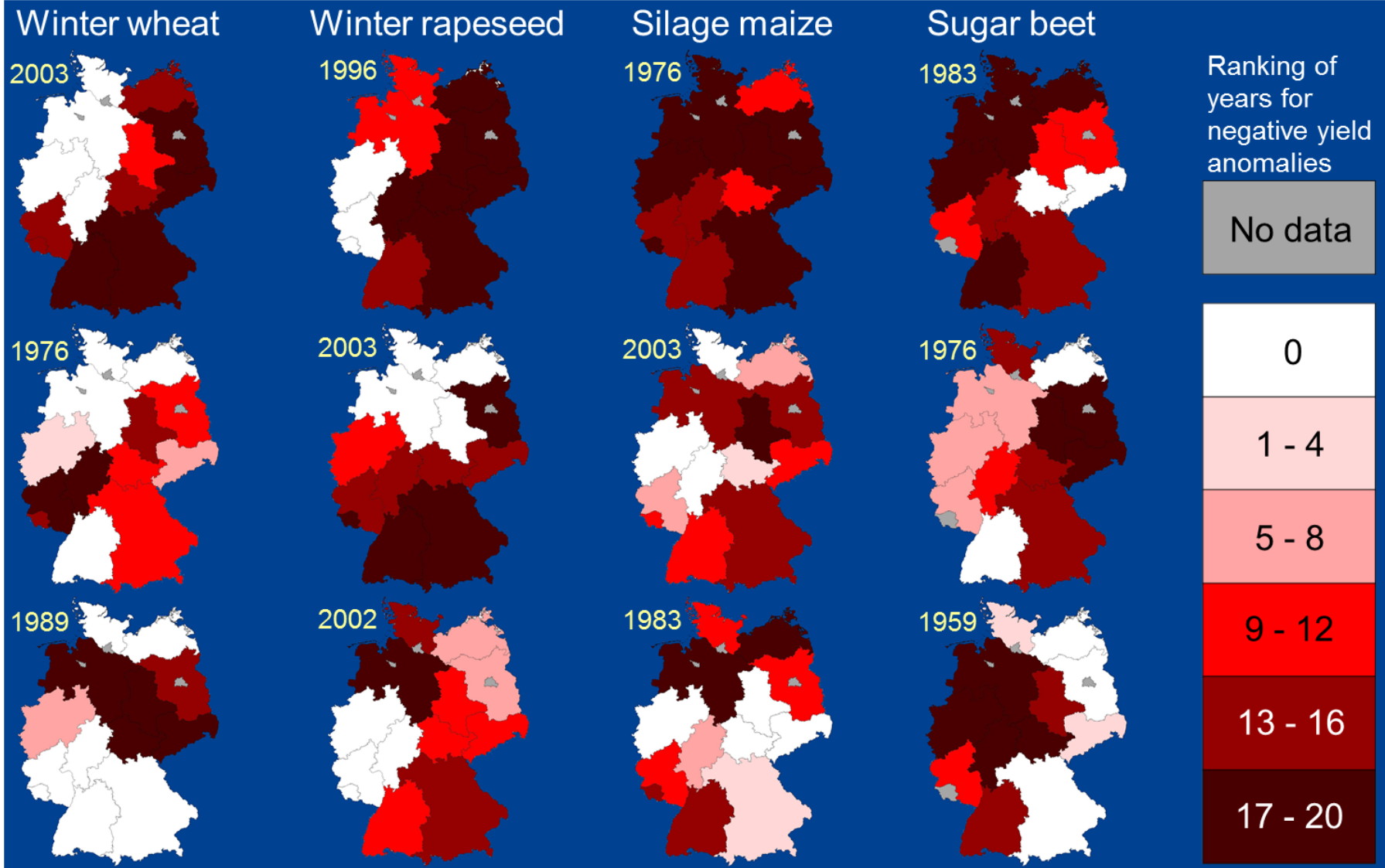
Können Ertragsanomalien und der Einfluss von Stressoren verallgemeinert werden (Fruchtarten, Regionen, Zeiträume) ?



Veränderungen (Pflanzenproduktion)

Siebert and Ewert, 2012, 2013

- ⇒ Years with largest negative yield anomalies differed among crops
- ⇒ Strong regional differences in the magnitude of negative yield anomalies

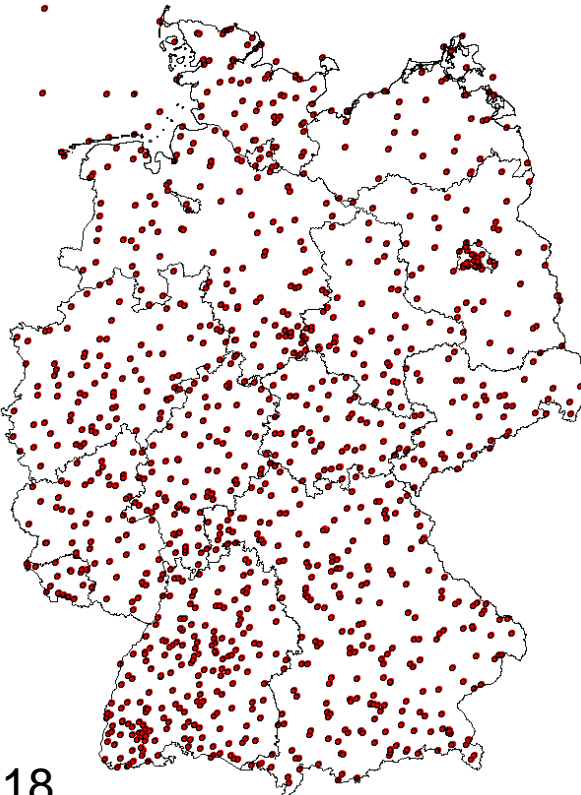


Veränderungen (Pflanzen...)

Ertragsanomalien

Einfluss von Stressoren

Data (DWD): > 1000
weather stations



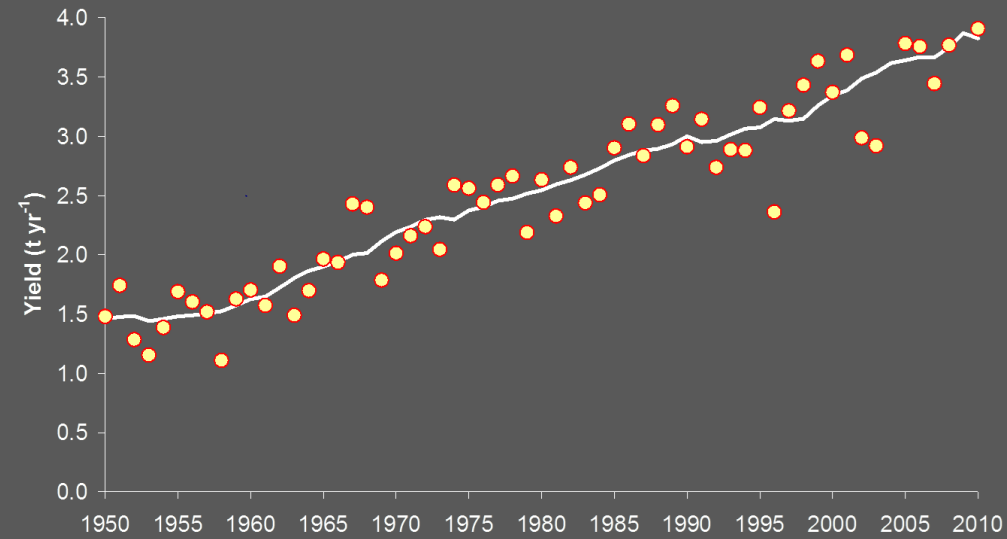
➤ Drought stress indicators:

- precipitation sum in current year – long-term mean precipitation sum 1961-1990
- accumulated relative monthly precipitation deficit
- accumulated relative monthly precipitation surplus

➤ Heat stress indicator: sum of daily max. temperatures above 30°C

- Winter wheat
- Sugar beet
- Winter rapeseed
- Maize (silage)

Average yields of winter rapeseed in Germany



Siebert and Ewert, 2012

Veränderungen (Pflanzenproduktion)

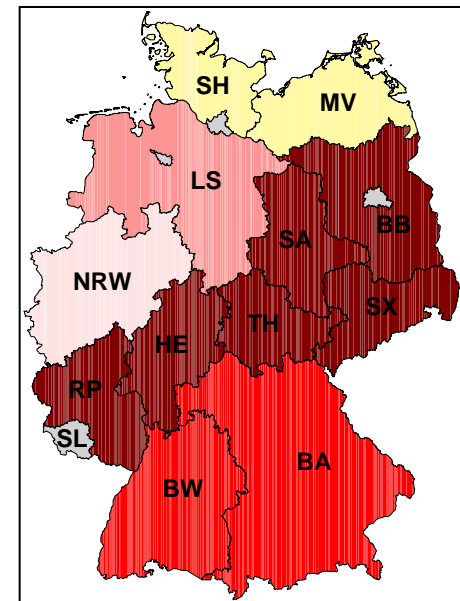
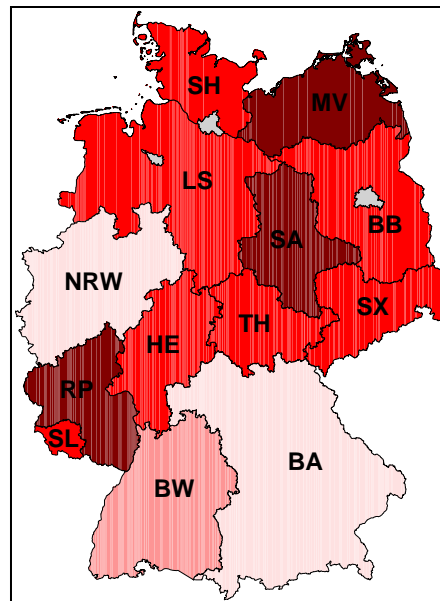
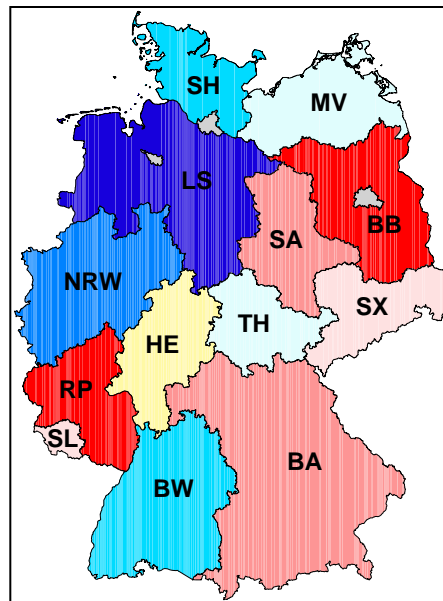
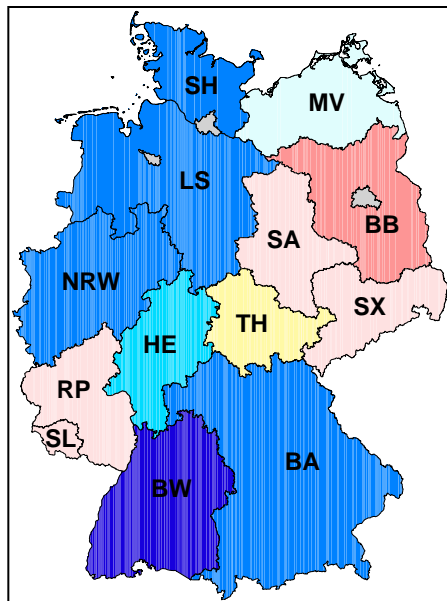
- ⇒ Strong regional differences in the impact of precipitation anomalies
- ⇒ Winter crops: long-term mean climate to wet in the western but to dry in eastern Germany
- ⇒ Summer crops: long-term mean climate to dry

Winter wheat

Winter rapeseed

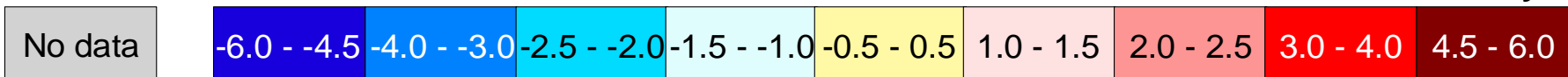
Silage maize

Sugar beet



to wet

to dry



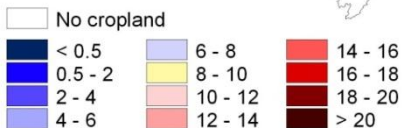
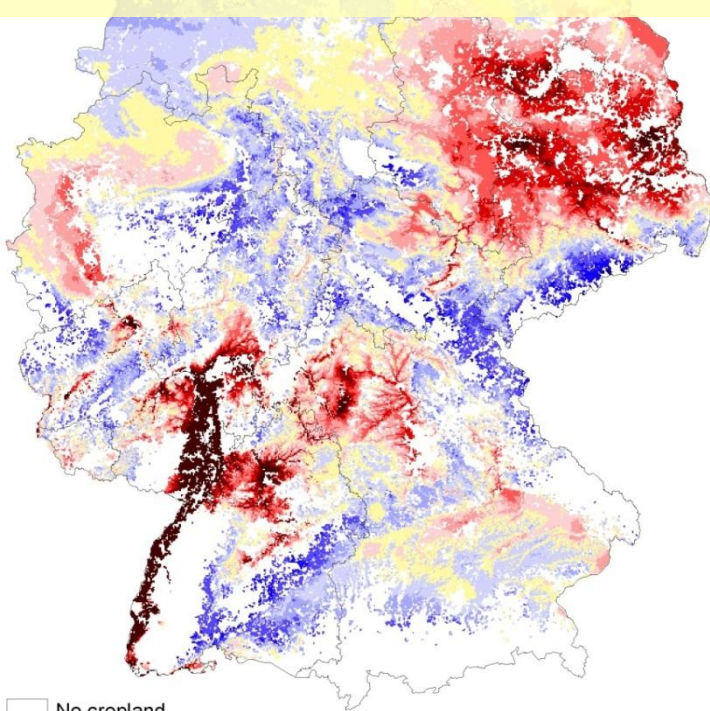
Siebert and Ewert, in prep.

Figure: Impact of precipitation anomalies on yield anomalies for different crops in federal states of Germany for the period 1950-2010. Negative values indicate that long-term mean climate during the main growing season is to wet and positive values that long-term mean climate is to dry.

Veränderungen (Pflanzenproduktion)

Mean annual (1950-2010) temperature sum of daily maximum temperatures above 30°C (I_H)

⇒ Hitzestress erklärt Ertragsanomalien nur in den Regionen, die kaum oder nicht durch Dürre beeinflusst sind



Long-term mean monthly values of heat stress indicator I_H for federal states and whole Germany for the period 1950-2010 (only cropland considered)

State	$I_{H_{APR}}$	$I_{H_{MAY}}$	$I_{H_{JUN}}$	$I_{H_{JUL}}$	$I_{H_{AUG}}$	$I_{H_{SEP}}$	$I_{H_{OCT}}$
BA	0.00	0.09	1.03	4.75	3.15	0.06	0.00
BB	0.03	0.26	2.10	6.53	3.88	0.14	0.00
BW	0.00	0.17	1.33	5.45	3.96	0.13	0.00
HE	0.00	0.11	0.96	4.80	3.21	0.09	0.00
LS	0.00	0.06	0.90	3.62	2.42	0.04	0.00
MV	0.00	0.05	0.76	2.26	1.54	0.02	0.00
NRW	0.01	0.11	1.15	4.67	3.00	0.09	0.00
RP	0.00	0.14	1.30	5.55	3.71	0.14	0.00
SA	0.02	0.16	1.72	6.29	4.08	0.21	0.00
SH	0.00	0.04	0.44	1.42	0.95	0.00	0.00
SL	0.00	0.06	0.90	4.52	3.24	0.08	0.00
SX	0.01	0.10	1.38	5.26	3.36	0.13	0.00
TH	0.00	0.09	0.77	4.03	2.77	0.10	0.00
GERMANY	0.01	0.11	1.15	4.57	3.01	0.09	0.00

Months in which the correlation coefficient (r) between yield anomaly and I_H was below -0.25

State	Winter wheat	Winter rapeseed	Maize	Sugar beet
BA	JUN	JUN, AUG	JUL, AUG	MAY, JUL, AUG
BB	JUN, AUG	JUN	JUL, AUG	JUL, AUG
BW		JUN, AUG	JUL, AUG	JUL, AUG
HE	JUN	JUN	JUL	JUL, AUG
LS		JUN	JUL	JUL
MV			JUL, AUG	JUL, AUG
NRW			JUL	JUL
RP	MAY, JUN	JUN, AUG	JUN, JUL	JUL, AUG
SA	AUG	JUN	JUL, AUG	JUL, AUG
SH			JUL	
SL	AUG	AUG	JUN, JUL	n.a.
SX	JUN, AUG		JUL, AUG	JUL
TH	AUG			
GERMANY	JUN, AUG	JUN	JUL, AUG	JUL

Projektionen

Klimavariabilität

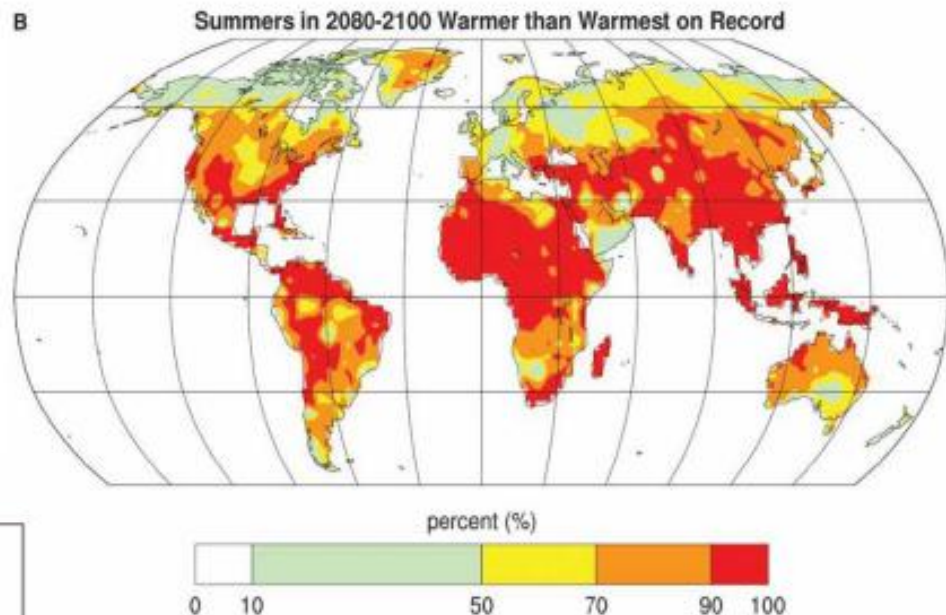
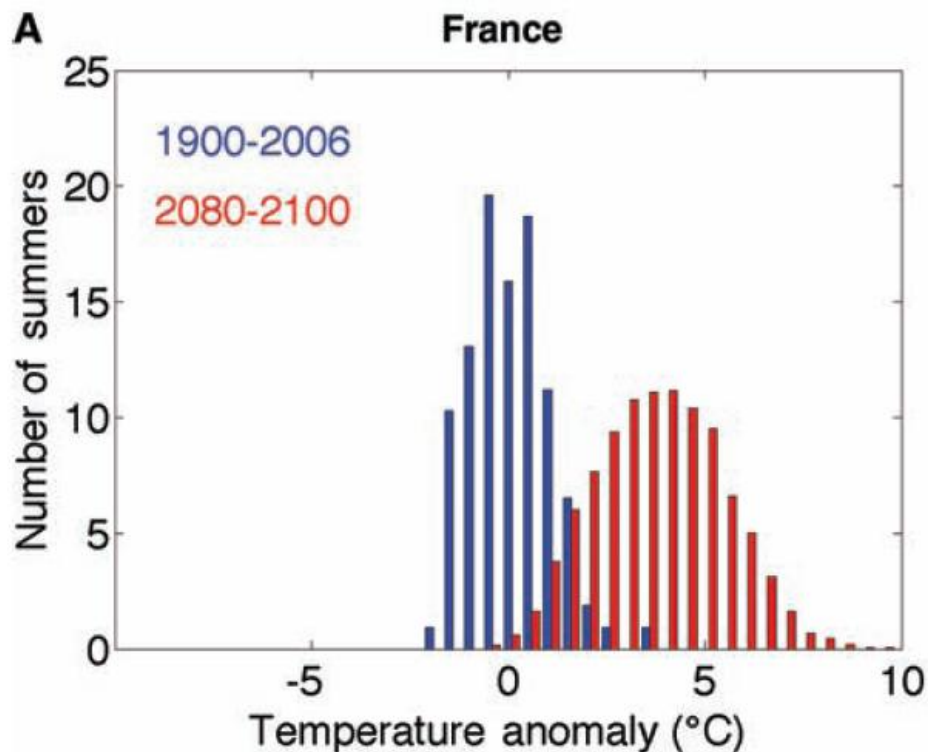


Figure. Likelihood (in percent) that future summer average temperatures will exceed the highest summer temperature observed on record for 2090.

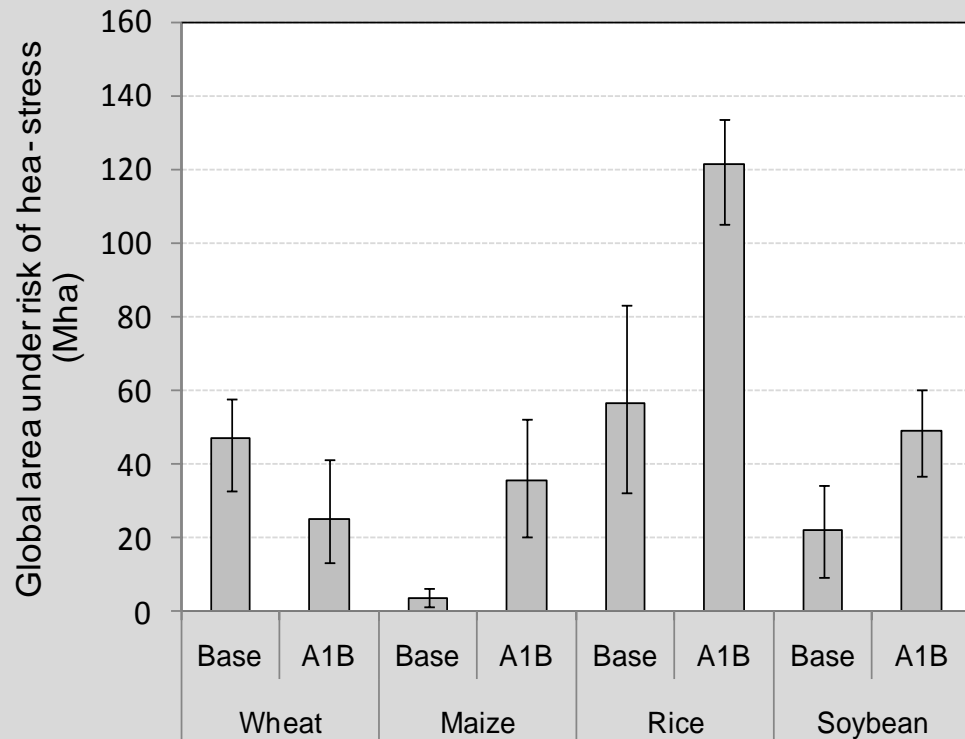
Battisti and Naylor (2009)

Figure. Histogram of summer (June, July, and August) averaged temperatures (blue) observed from 1900 to 2006 and (red) projected for 2090 for France.

Projektionen

Szenario-Simulationen (Klimavariabilität)

Global impacts of heat stress on 4 major crops

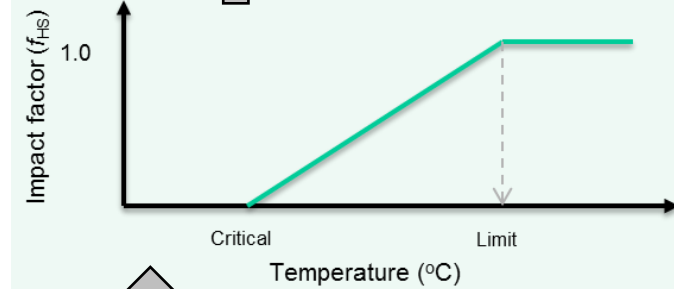


Base line (1971-2000) and A1B (2071-2100)

Teixeira et al. (2012)

FAO/IIASA

GAEZ model



Anthesis



Sowing

Emergence

Sensitive period

Harvest

Projektionen

Global impacts of heat stress

Base line (1971-2000) and A1B (2071-2100)

FAO/IIASA
GAEZ model

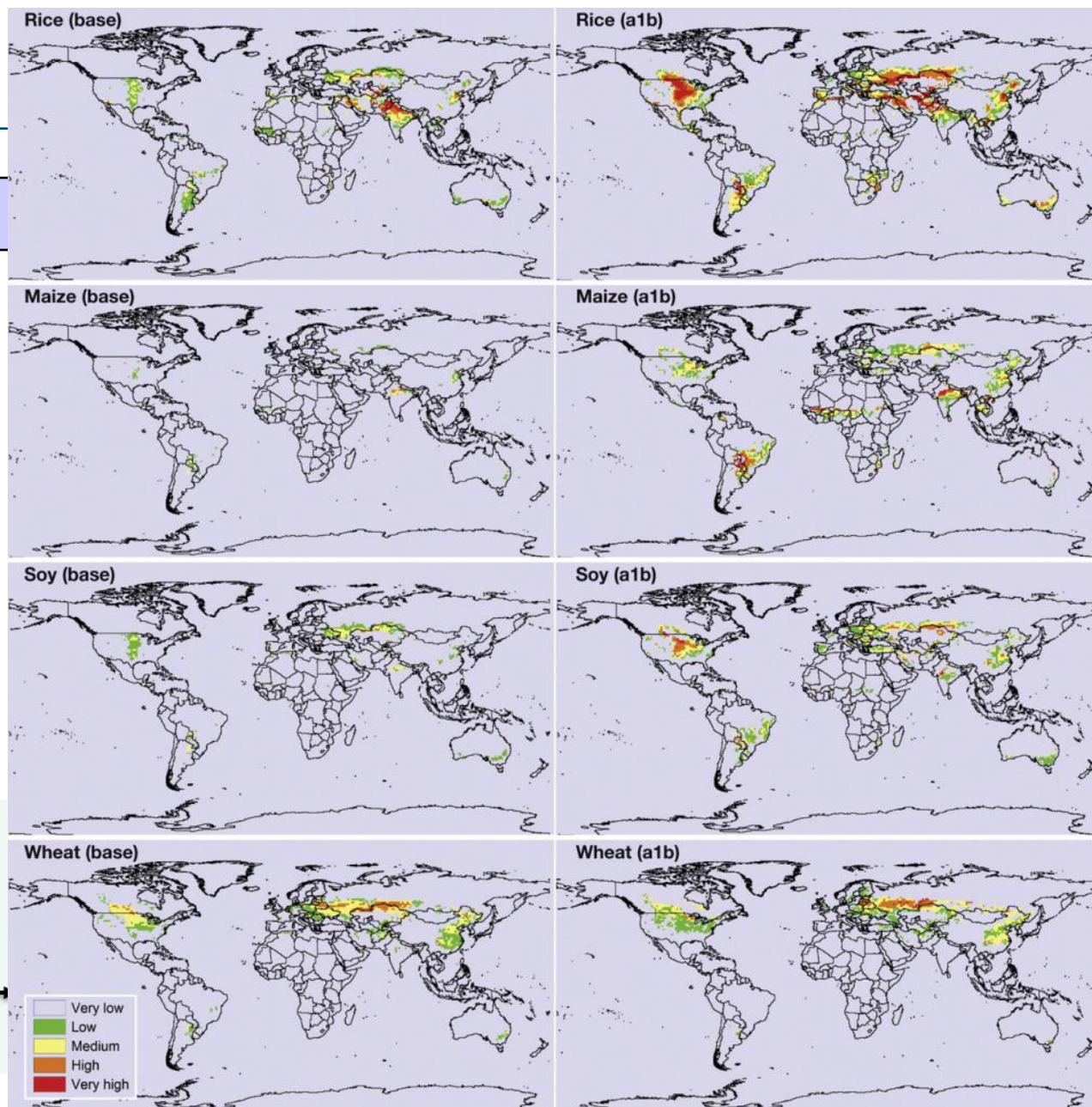
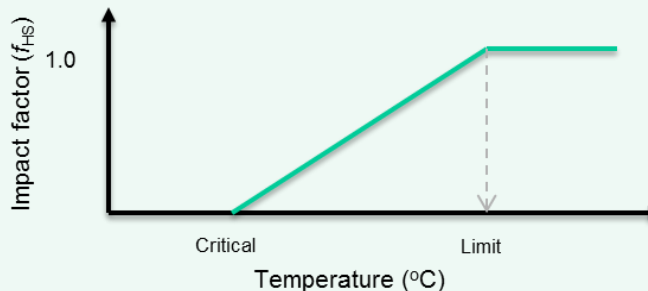


Figure. The maximum heat stress intensity within a 30-year simulation in areas suitable for production. For the baseline climate (Base, 1971–2000) and the A1B climate change scenario (2071–2100).



Projektionen

Szenario-Simulationen

Erträge

Europa

Winter wheat
(1983-2006),
Eurostat

- Winter wheat
- Winter barley
- Sugar beet
- Potatoes
- Maize (silage)

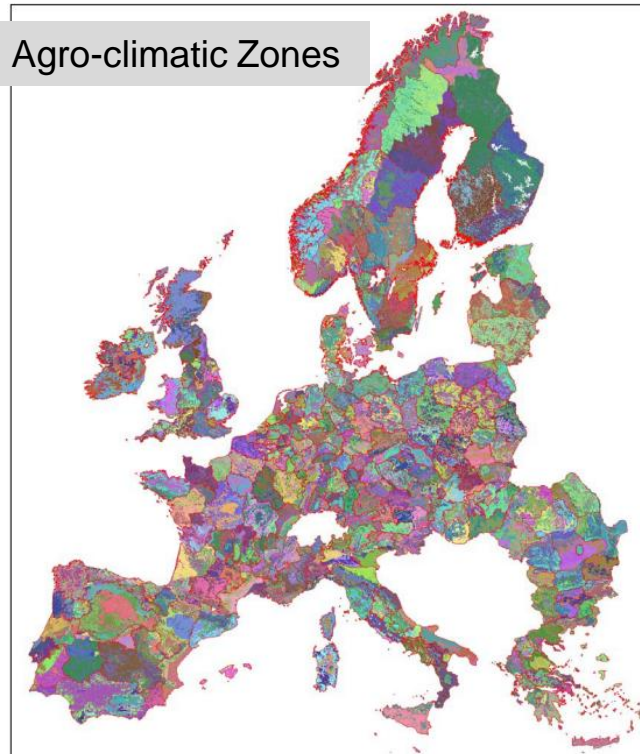
Winter wheat yield
(Mgha⁻¹)



Lintul 2 (FAST, APES)

- 7 GCMs
- 4 IPCC Szenarien
- 5 Fruchtarten

Agro-climatic Zones



Projektionen

Szenario-Simulationen

Winter wheat,
centered at 2040

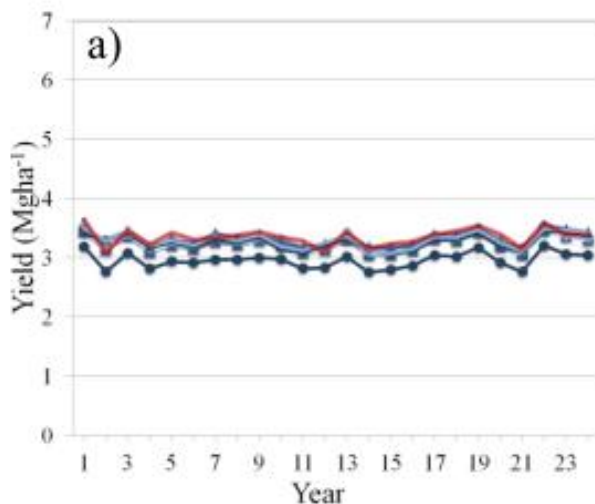
Lintul 2 (FAST, APES)

- 7 GCMs
- 4 IPCC Szenarien
- 5 Fruchtarten

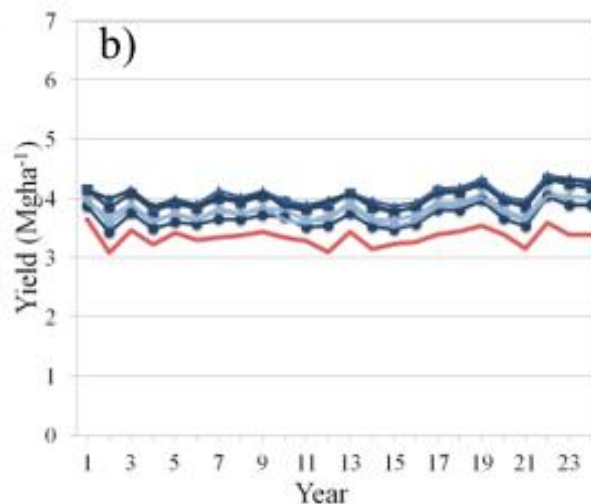


- ⇒ Bedeutung technologischer Entwicklung
- ⇒ Regional starker Einfluss des Klimawandels (nicht gezeigt)

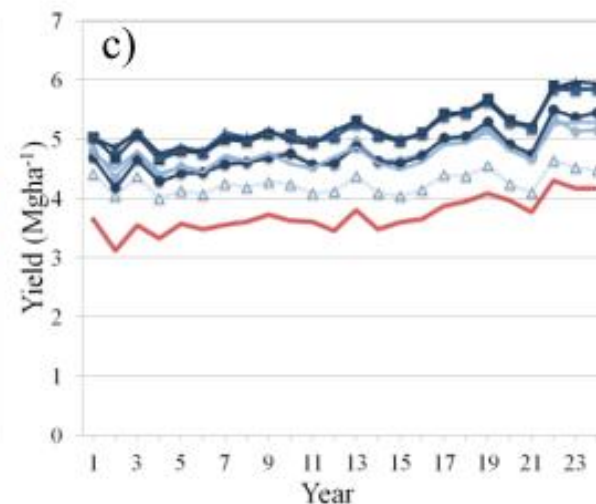
Climate



Climate and CO₂



Climate, CO₂ and technology

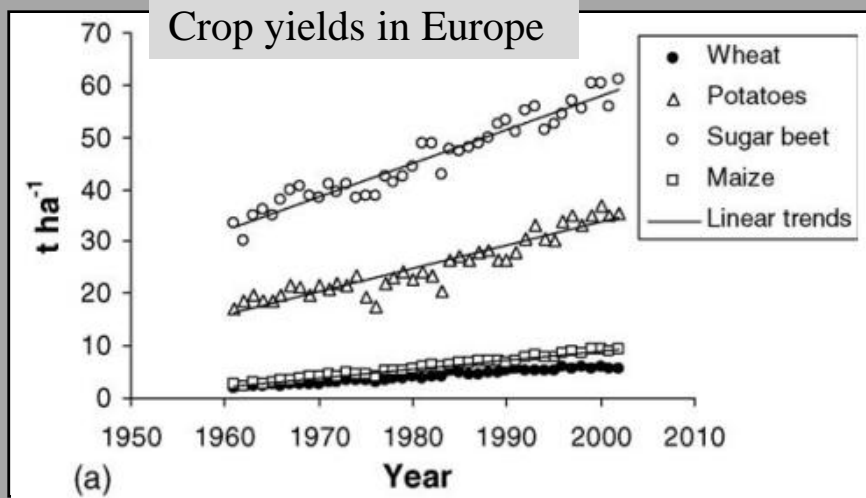
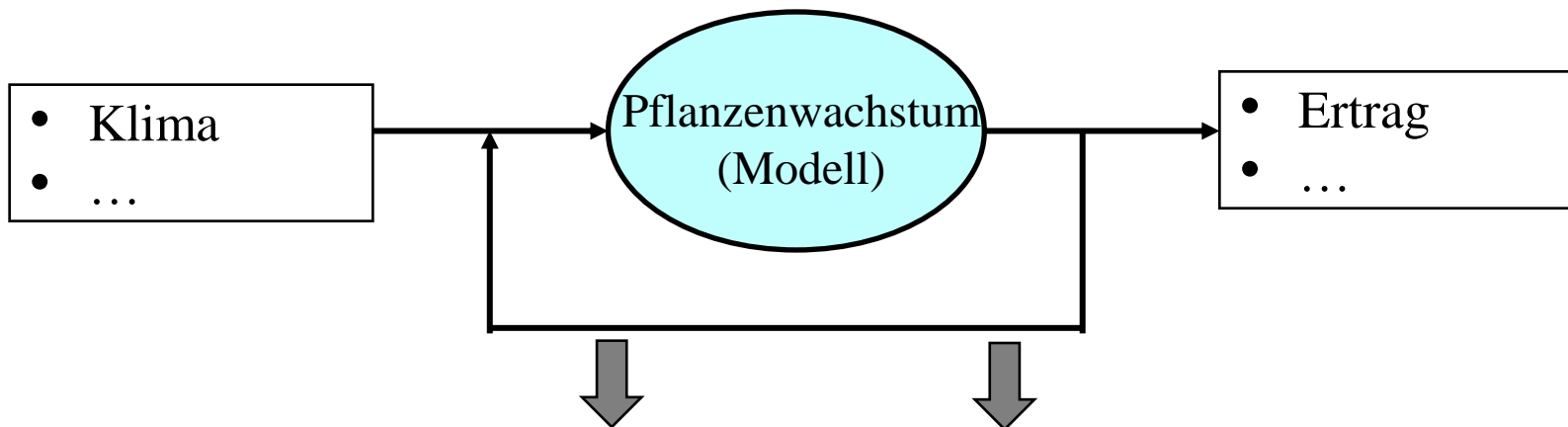


- 15GCM A1B
- ▲ 15GCM B2
- ◆ BCCR B1
- ◆ CGCM A2
- ◆ GISS A1B
- ◆ MIROC A1B
- ◆ MIROC B1
- Baseline

Adaptation

Technologische Entwicklung

- ⇒ Relative Bedeutung der technologischen Entwicklung
- ⇒ Anpassung an viele Faktoren



Intensivierung

- Düngung
 - Pflanzenschutz
 - Wachstumsregulatoren
 - Mechanisierung
 - Bewässerung
- Züchtung (Ertragspotential, ...)
- ...

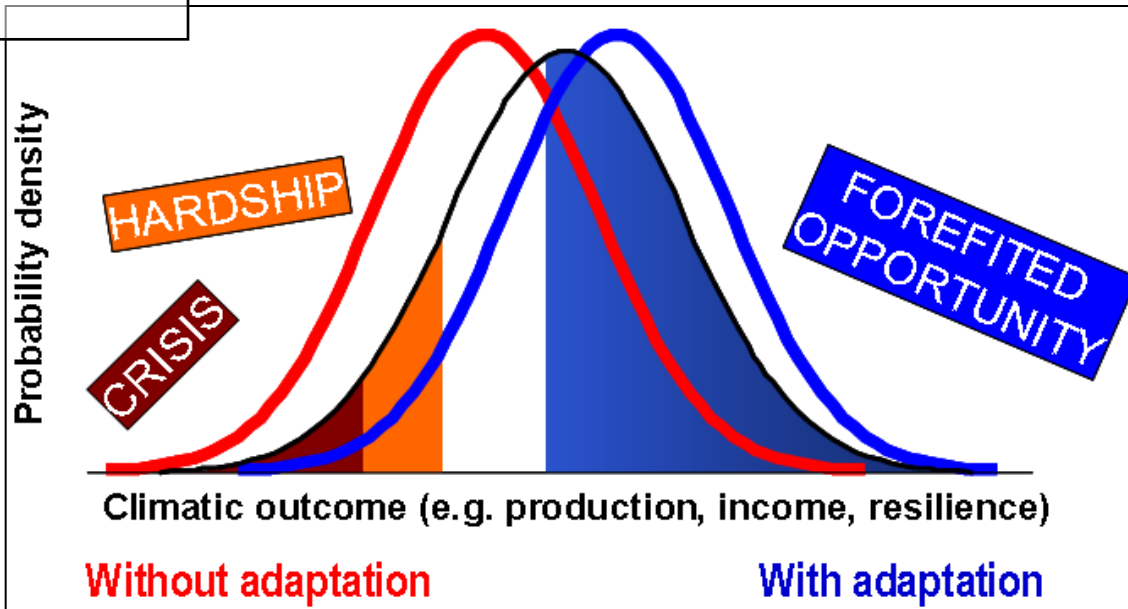
Adaptation

Pflanzenbau

- Saatzeitverschiebung
- Sortenwahl (Vegetationsperiode)
- Artenwahl (angepasste Arten)
- **Fruchtartenvielfalt** (Risikostreuung)
- Bewässerung
- Bodenbearbeitung (Wasserbilanz)
- Düngung (z.B. Blattdüngung)



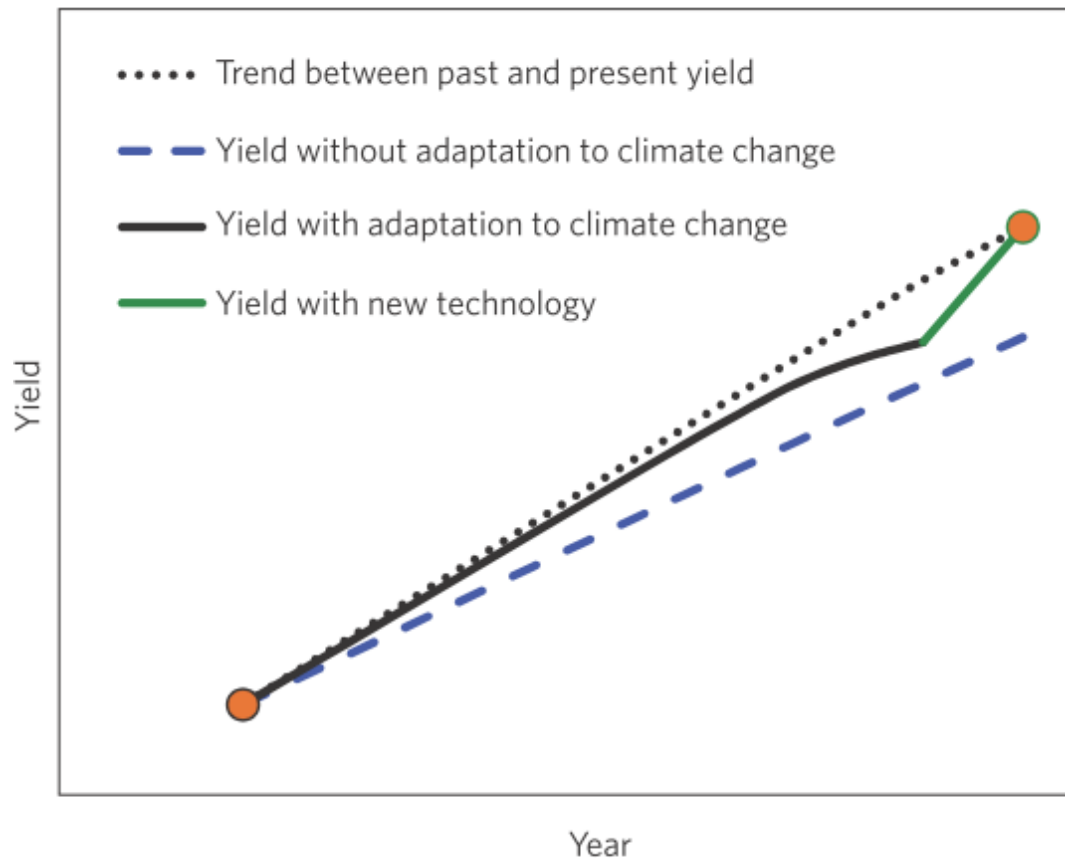
Meinke et al., 2009



Adaptation

Beispiel North China Plain

‘double-delay’ technology



IRTG field trial at Quzhou research station



New technology anticipating the effect of climate change

Yield increase through improved crop management and technology

Ewert, 2012

Figure. Simplified representation of the main factors determining yield change and the implication of climate change-anticipating technologies. The graph illustrates the results reported by Wang et al. (2012) for wheat-maize cropping systems in the North China Plain. Different yield trends are shown without and with adaptation to climate change and through introduction of the ‘double-delay’ technology which further increased yield

Schlussfolgerungen

- Klimawirkung auf Pflanzenwachstum unterliegt komplexen physiologische Zusammenhängen
- Veränderungen im Klima der letzten Jahrzehnte mit nachweislichen Einflüssen auf Pflanzenproduktion
- Historische Ertragsanomalien variieren räumlich und zeitlich und in Abhängigkeit von Kulturpflanzen
- Anpassungsmöglichkeiten hängen von verschiedenen Faktoren ab (ökophysiologisch und sozio-ökonomischen)
 - Diversifizierung von Fruchtfolgen, Anbausystemen
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- Klimawandel > Suche nach neuen Möglichkeiten für die Pflanzenproduktion

Pflanzliche Erzeugung im Klimawandel: Auswirkungen und Anpassungen aus Sicht der Ertragsentwicklung

Danke

<http://www.lap.uni-bonn.de>

