Climate change and agriculture

Bernard Seguin

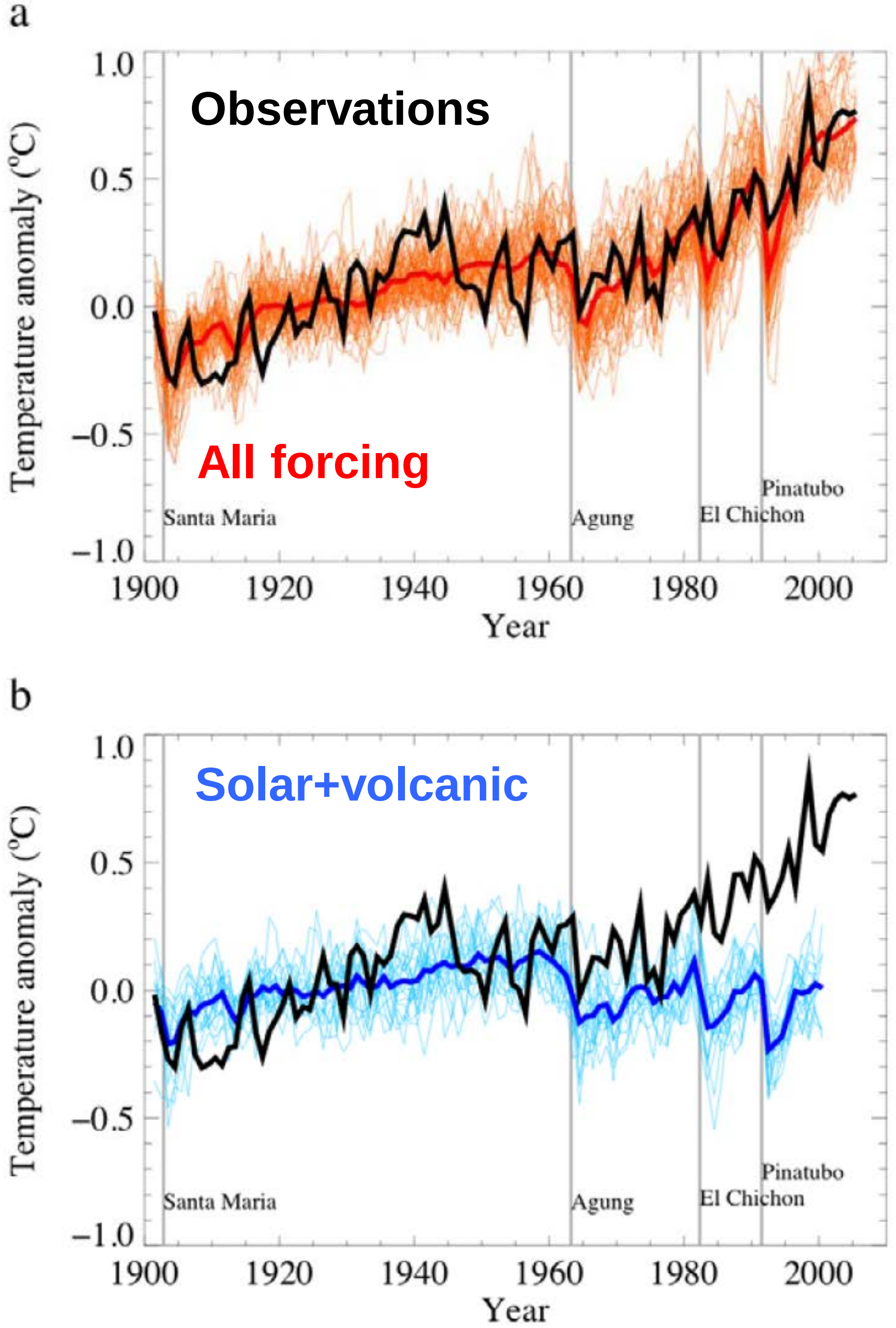
INRA Avignon (France)

Attribution

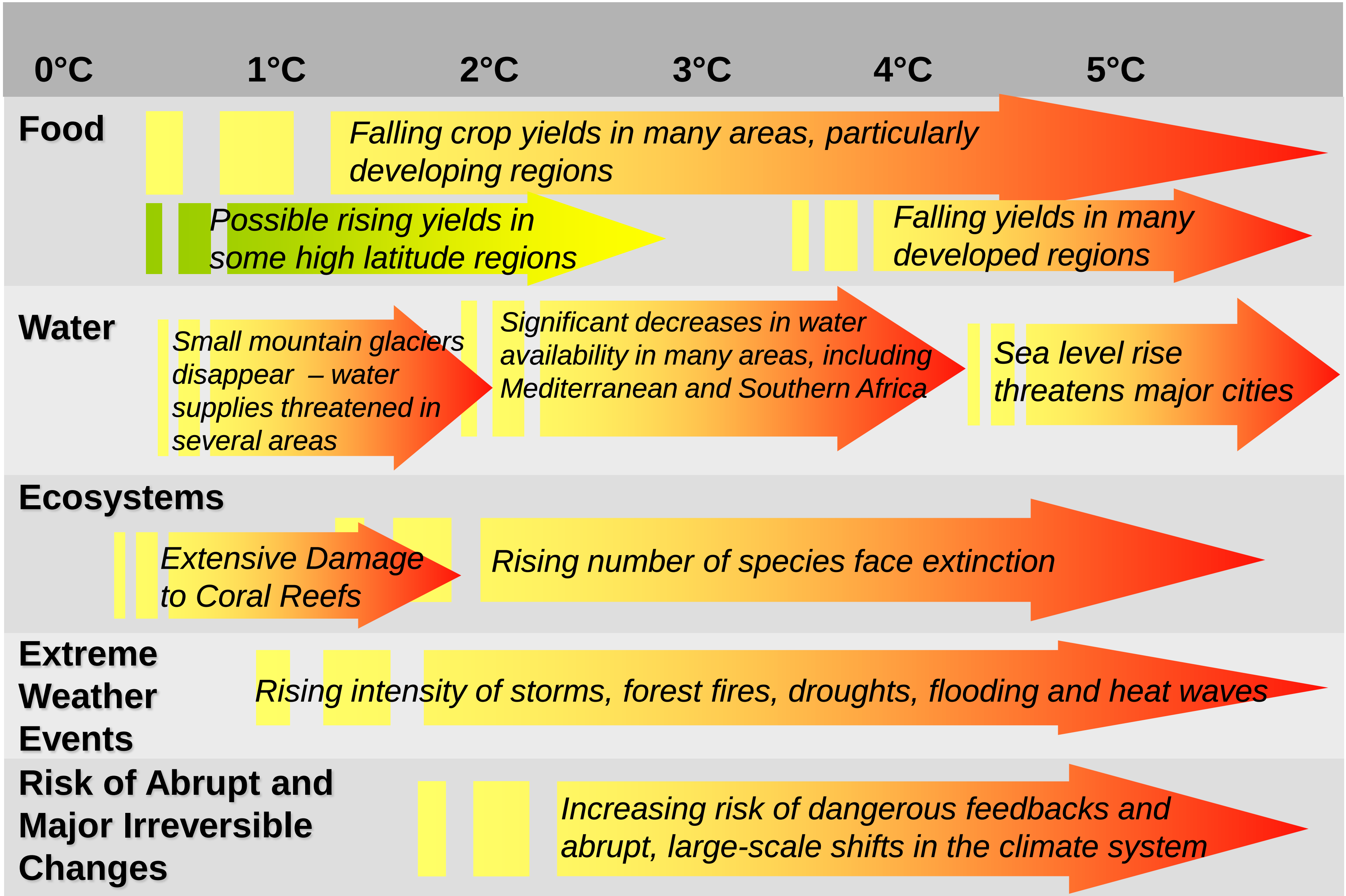
- are observed changes consistent with

☑expected responses to forcings

☒inconsistent with alternative explanations

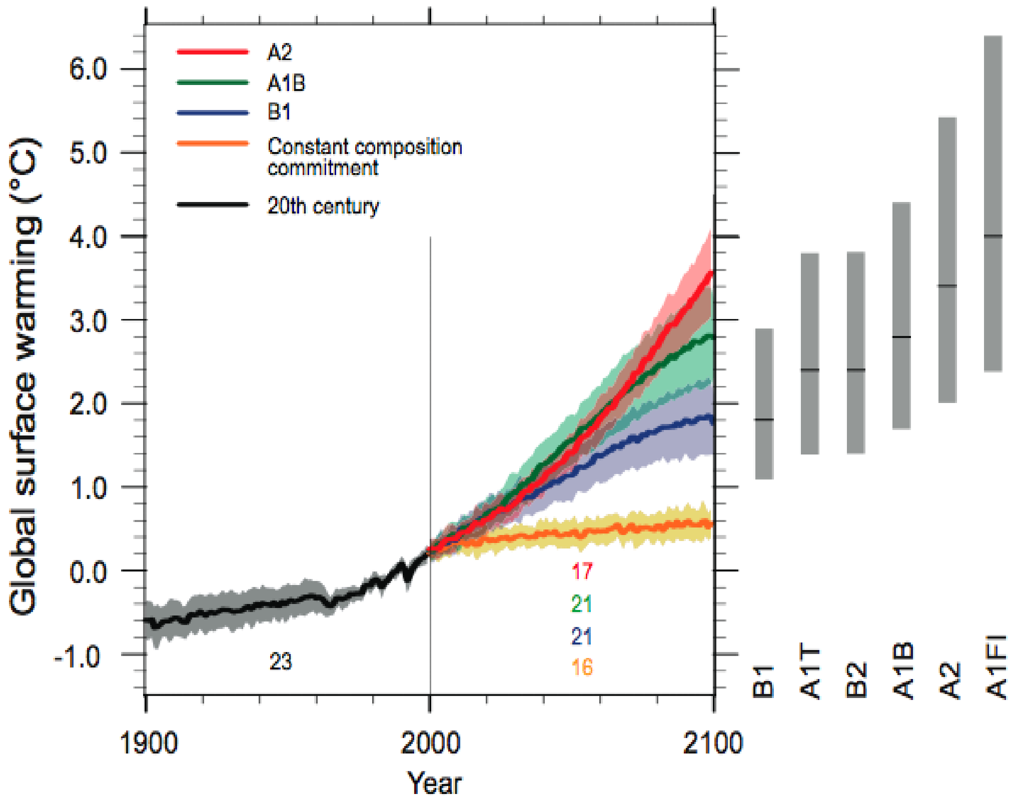


IPCC 2007


0°C
1°C
2°C
3°C
4°C
5°C
Food
Falling crop yields in many areas, particularly developing regions
Possible rising yields in some high latitude regions
Falling yields in many developed regions
Water
Small mountain glaciers disappear – water supplies threatened in several areas
Significant decreases in water availability in many areas, including Mediterranean and Southern Africa
Sea level rise threatens major cities
Ecosystems
Extensive Damage to Coral Reefs
Rising number of species face extinction
Extreme Weather Events
Rising intensity of storms, forest fires, droughts, flooding and heat waves
Risk of Abrupt and Major Irreversible Changes
Increasing risk of dangerous feedbacks and abrupt, large-scale shifts in the climate system

Projections of Future Changes in Climate

Best estimate for low scenario (B1) is 1.8°C (*likely* range is 1.1°C to 2.9°C), and for high scenario (A1FI) is 4.0°C (*likely* range is 2.4°C to 6.4°C).

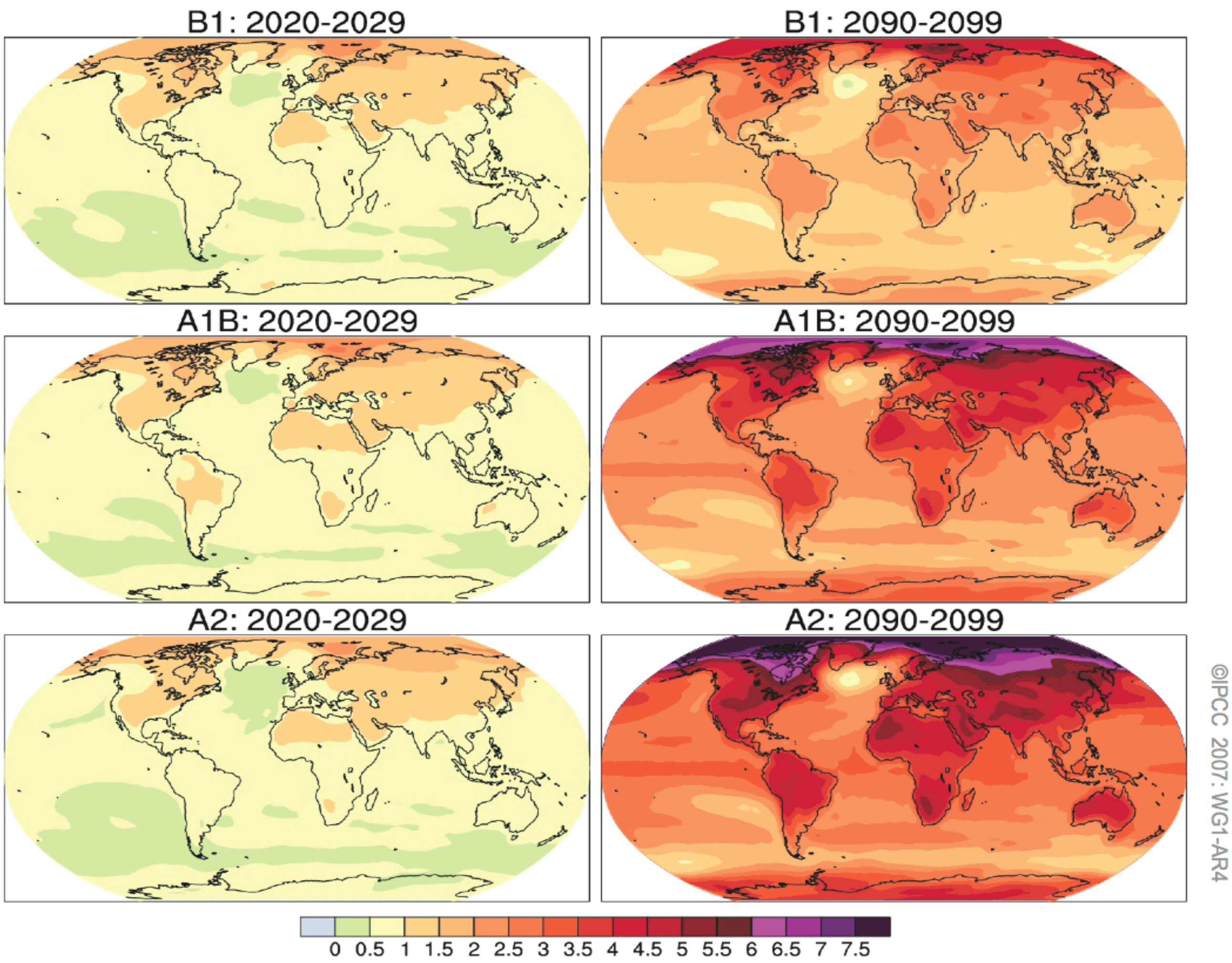


Projections of Future Changes in Climate

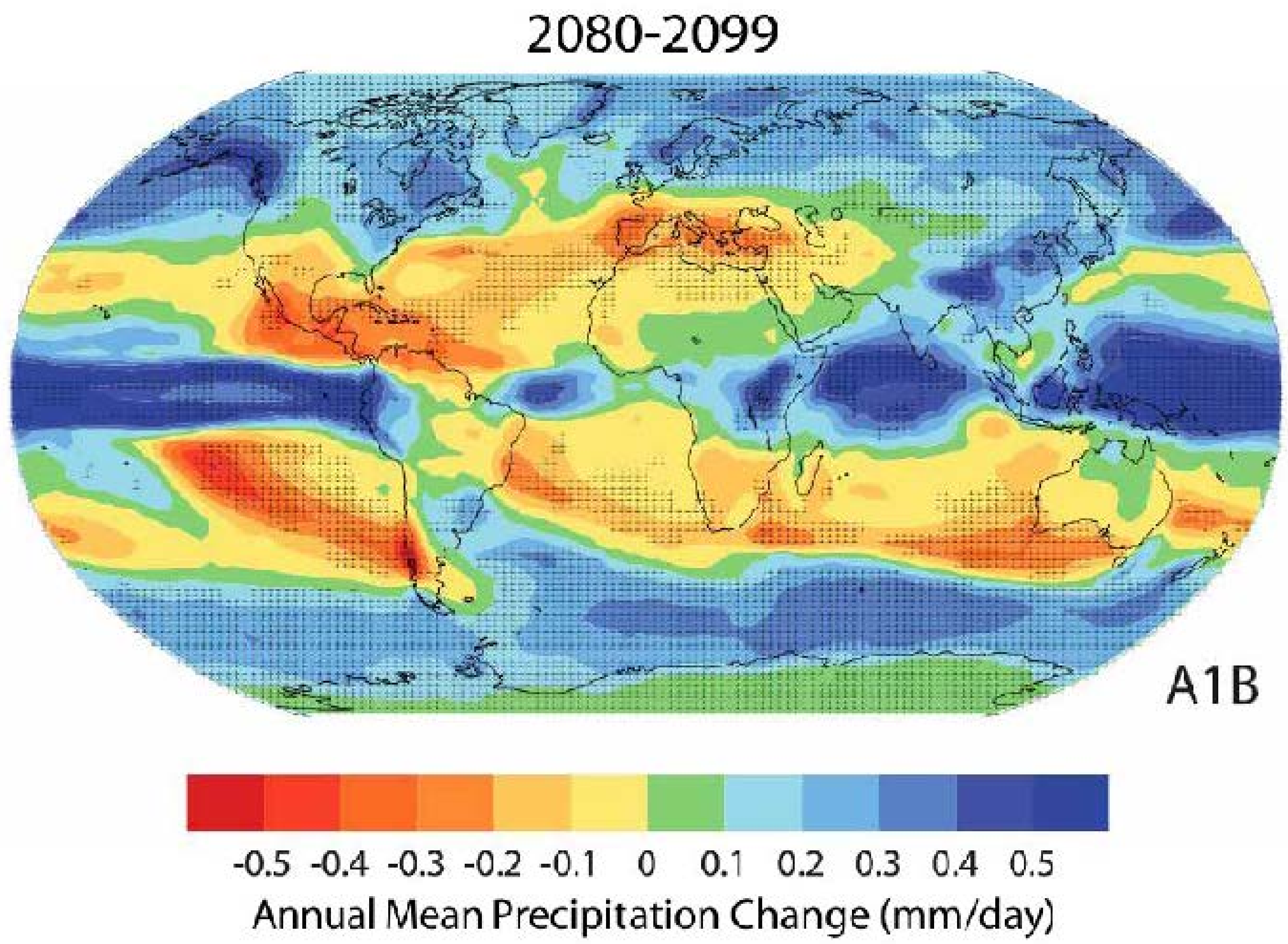
Projected warming in 21st century expected to be

greatest over land and at most high northern latitudes

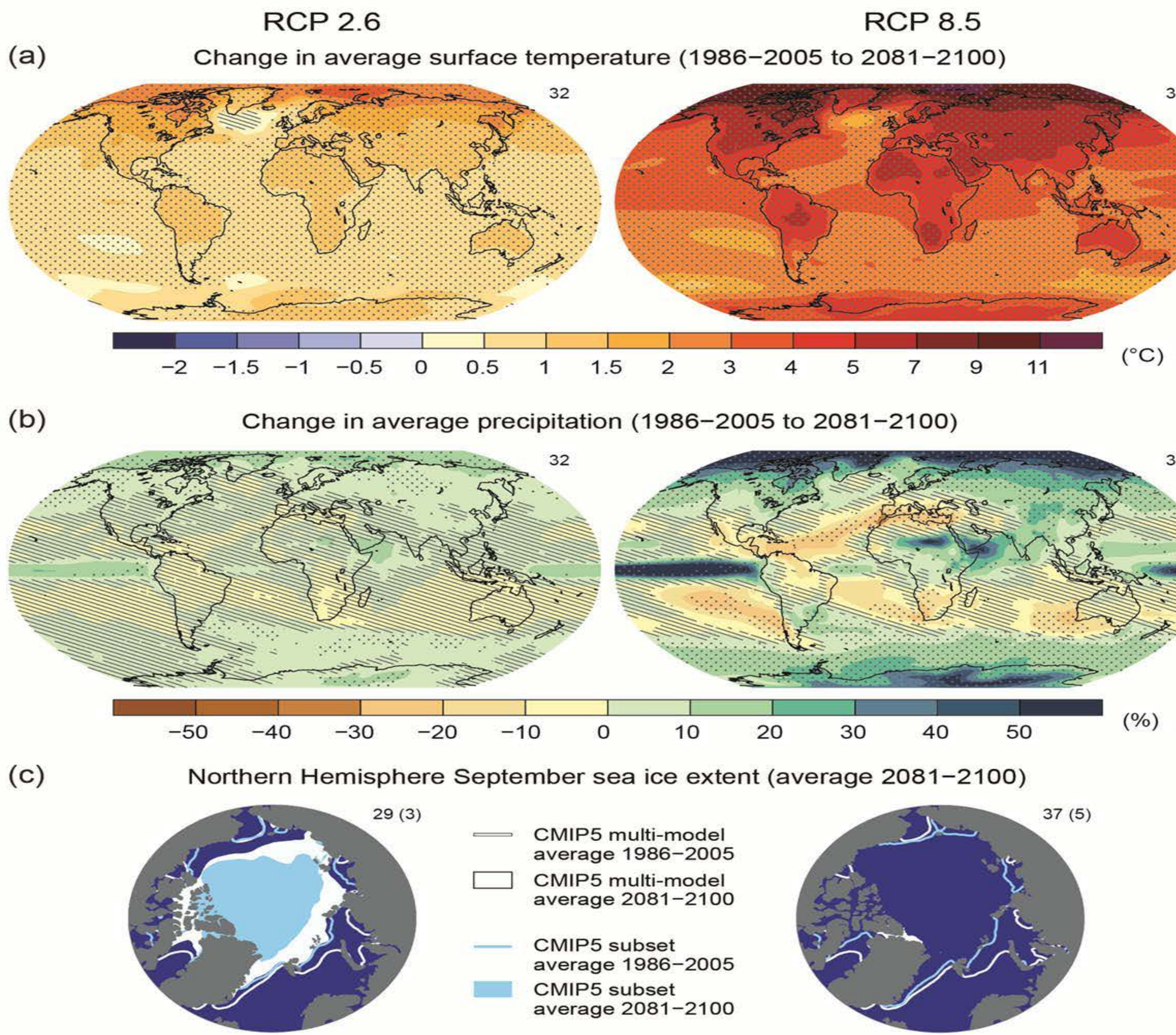
and least over the Southern Ocean and parts of the North Atlantic Ocean



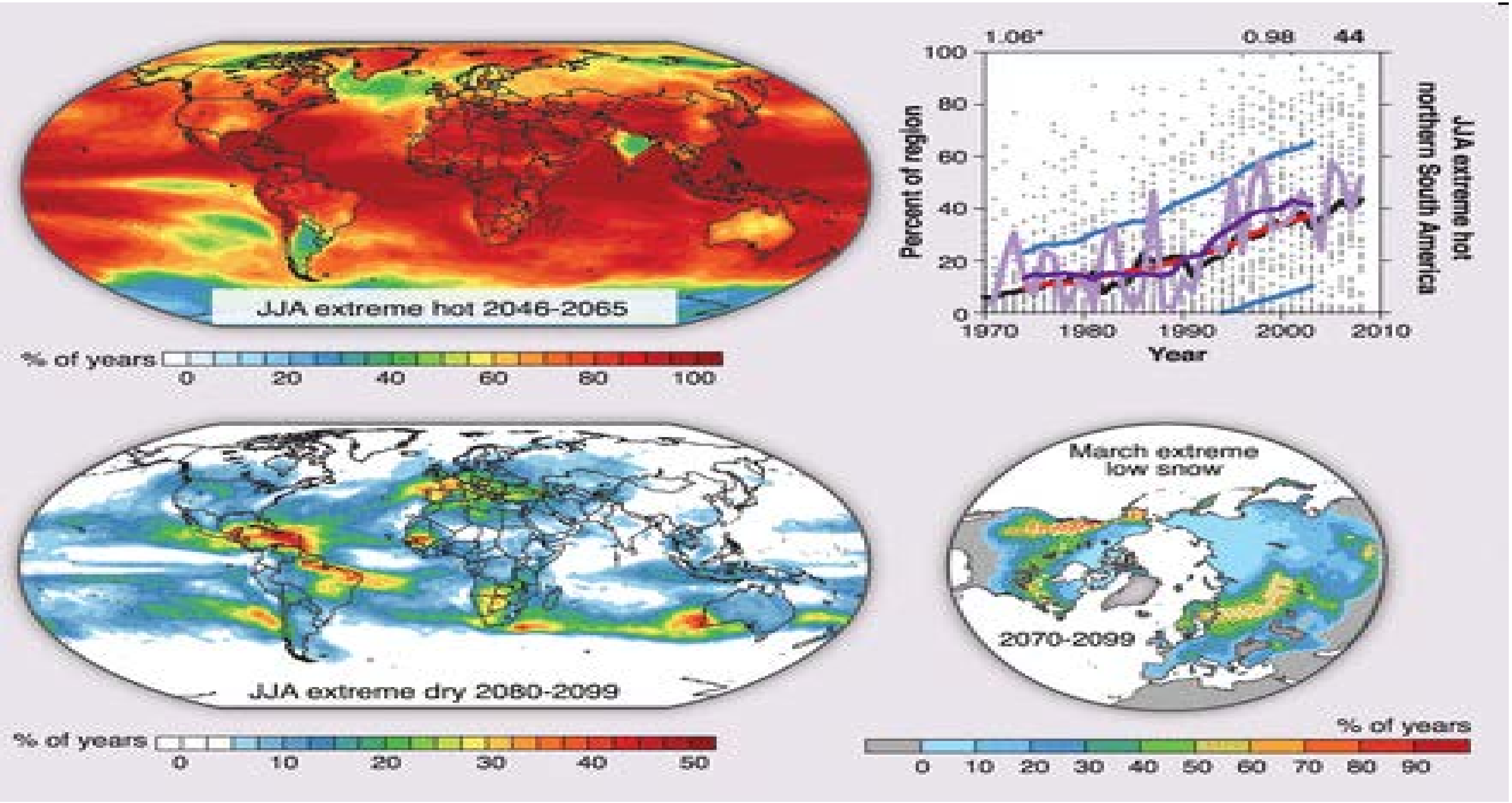
IPCC 4AR: Precipitation Projections



IPCC 2013

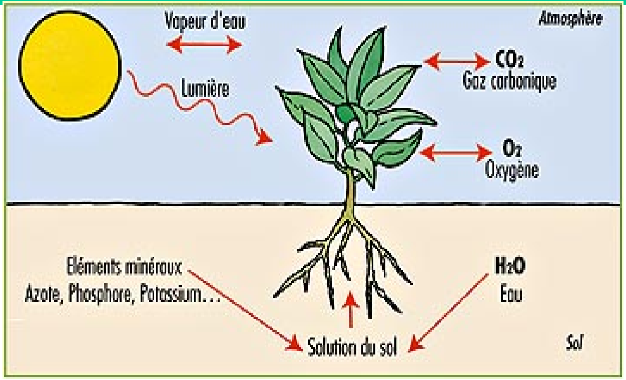

RCP 2.6
RCP 8.5
(a)
Change in average surface temperature (1986−2005 to 2081−2100)
32
39
−2 −1.5 −1 −0.5 0 0.5 1 1.5 2 3 4 5 7 9 11
(°C)
(b)
Change in average precipitation (1986−2005 to 2081−2100)
32
39
−50 −40 −30 −20 −10 0 10 20 30 40 50
(%)
(c)
Northern Hemisphere September sea ice extent (average 2081−2100)
29 (3)
37 (5)
CMIP5 multi-model average 1986−2005
CMIP5 multi-model average 2081−2100
CMIP5 subset average 1986−2005
CMIP5 subset average 2081−2100

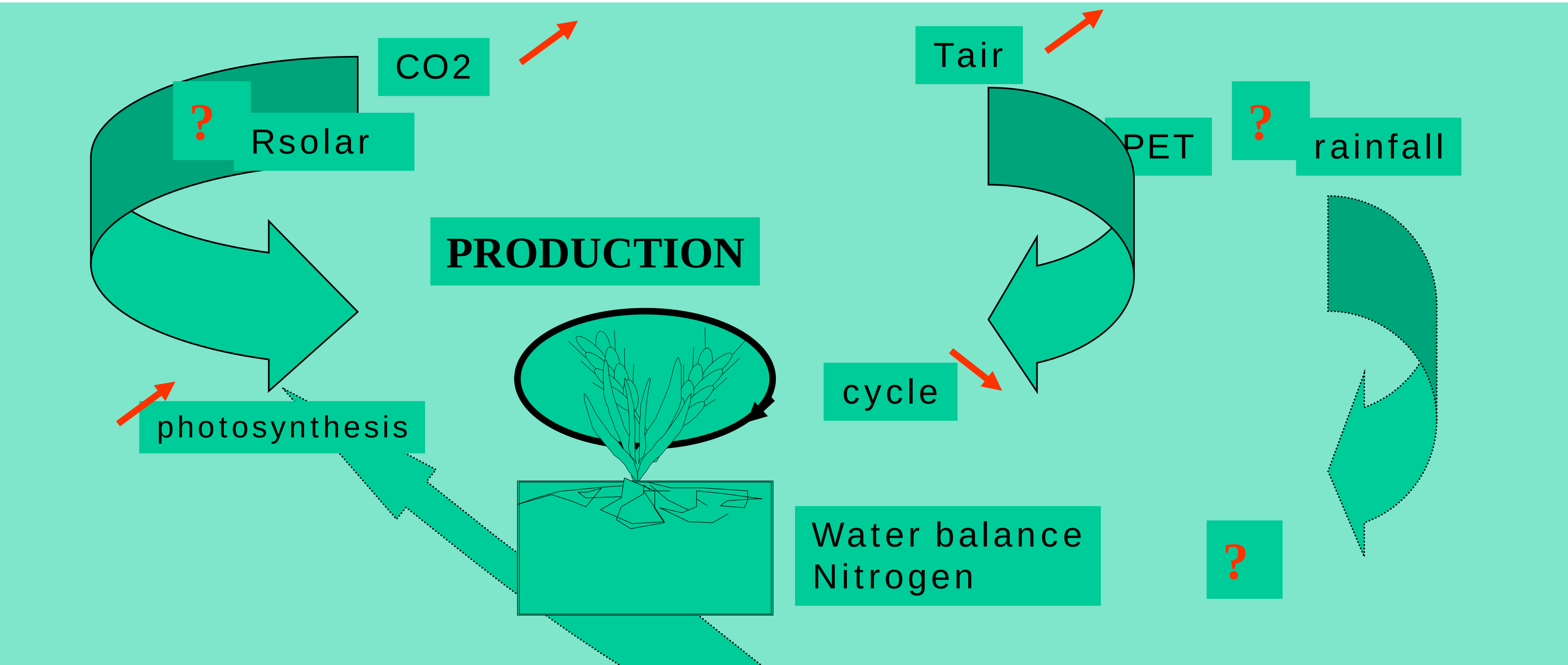
The increase of extremes



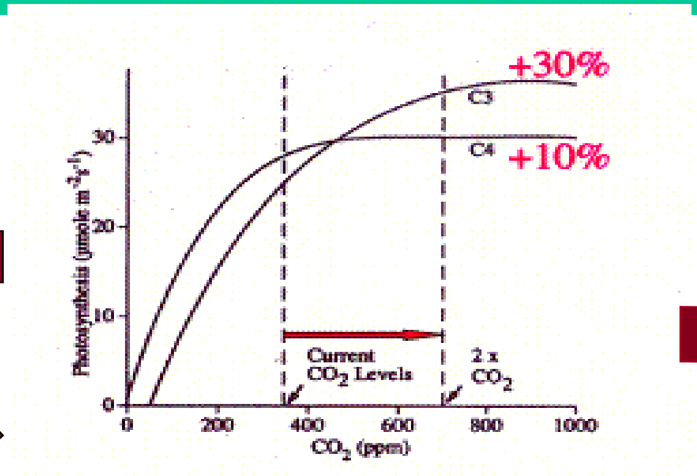
Diffenbaugh et Field 2013

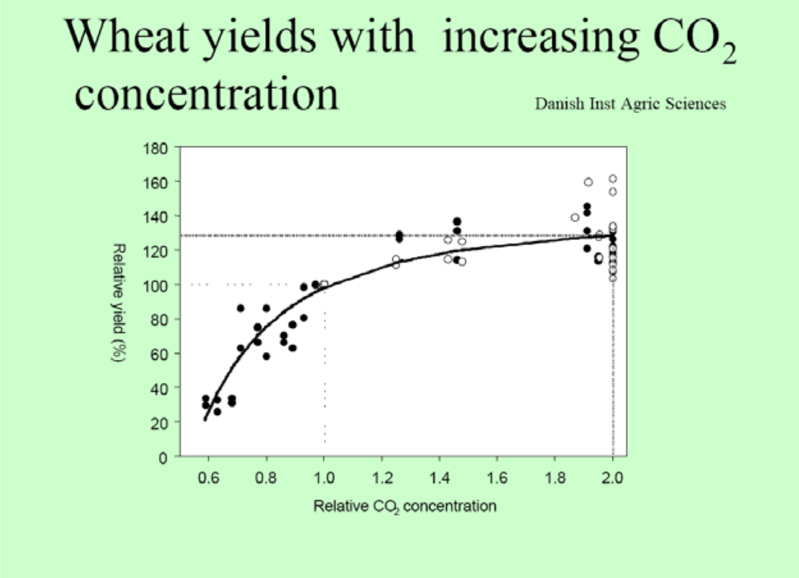
Impacts on plant production

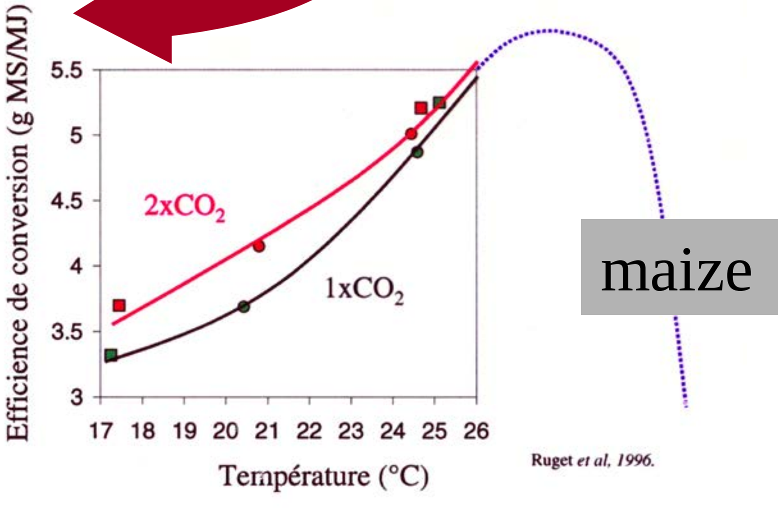




CO_2 and photosynthesis



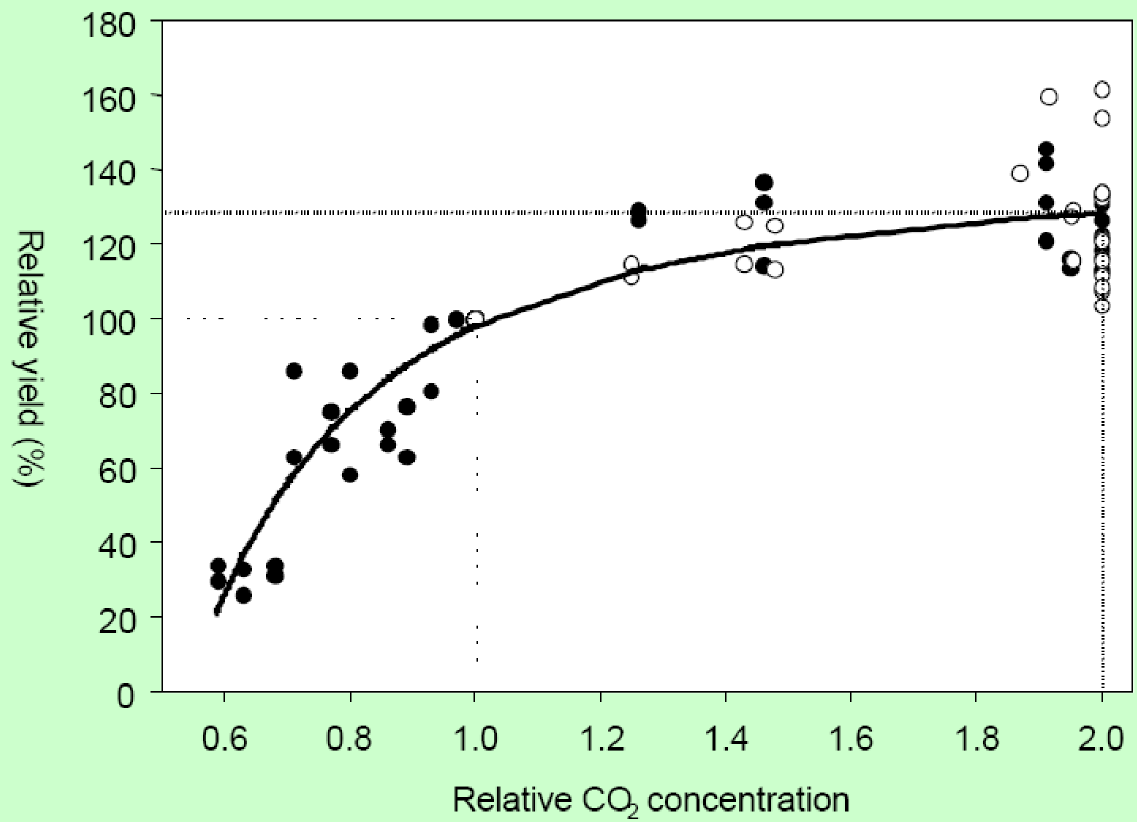




INRA

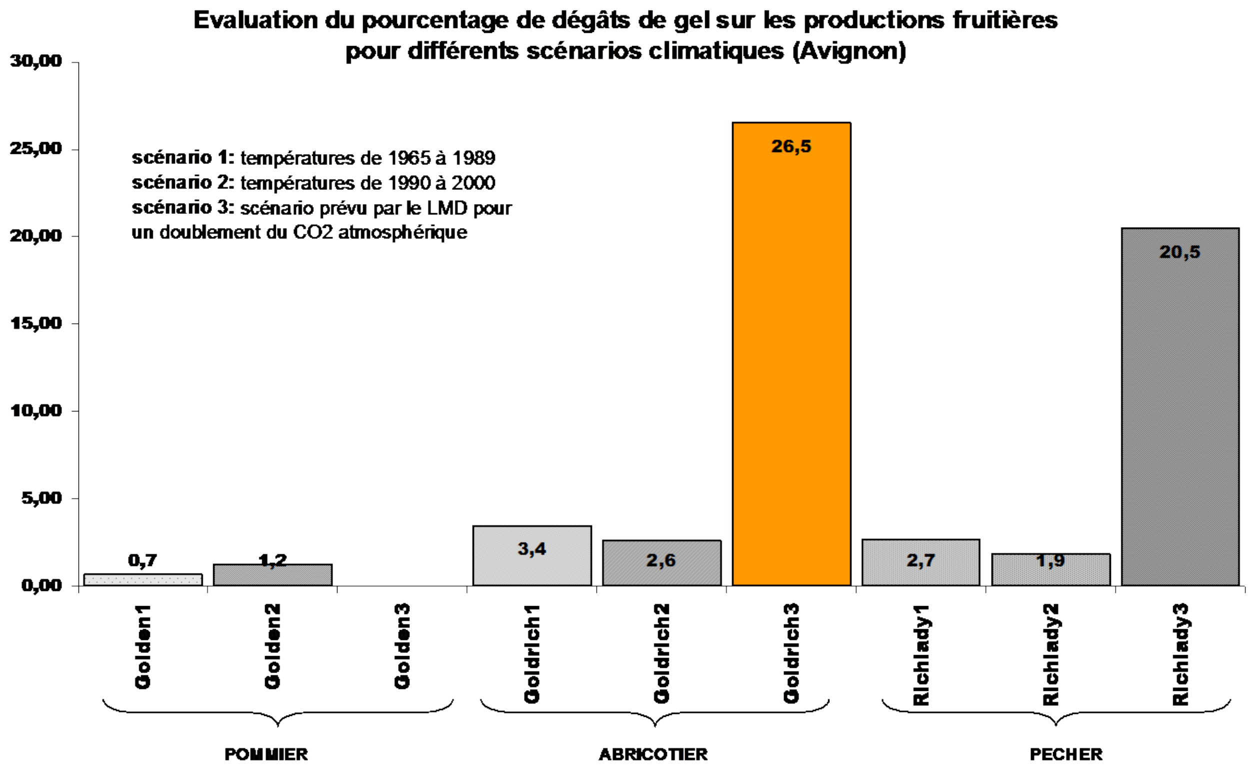
Wheat yields with increasing CO_2 concentration

Danish Inst Agric Sciences



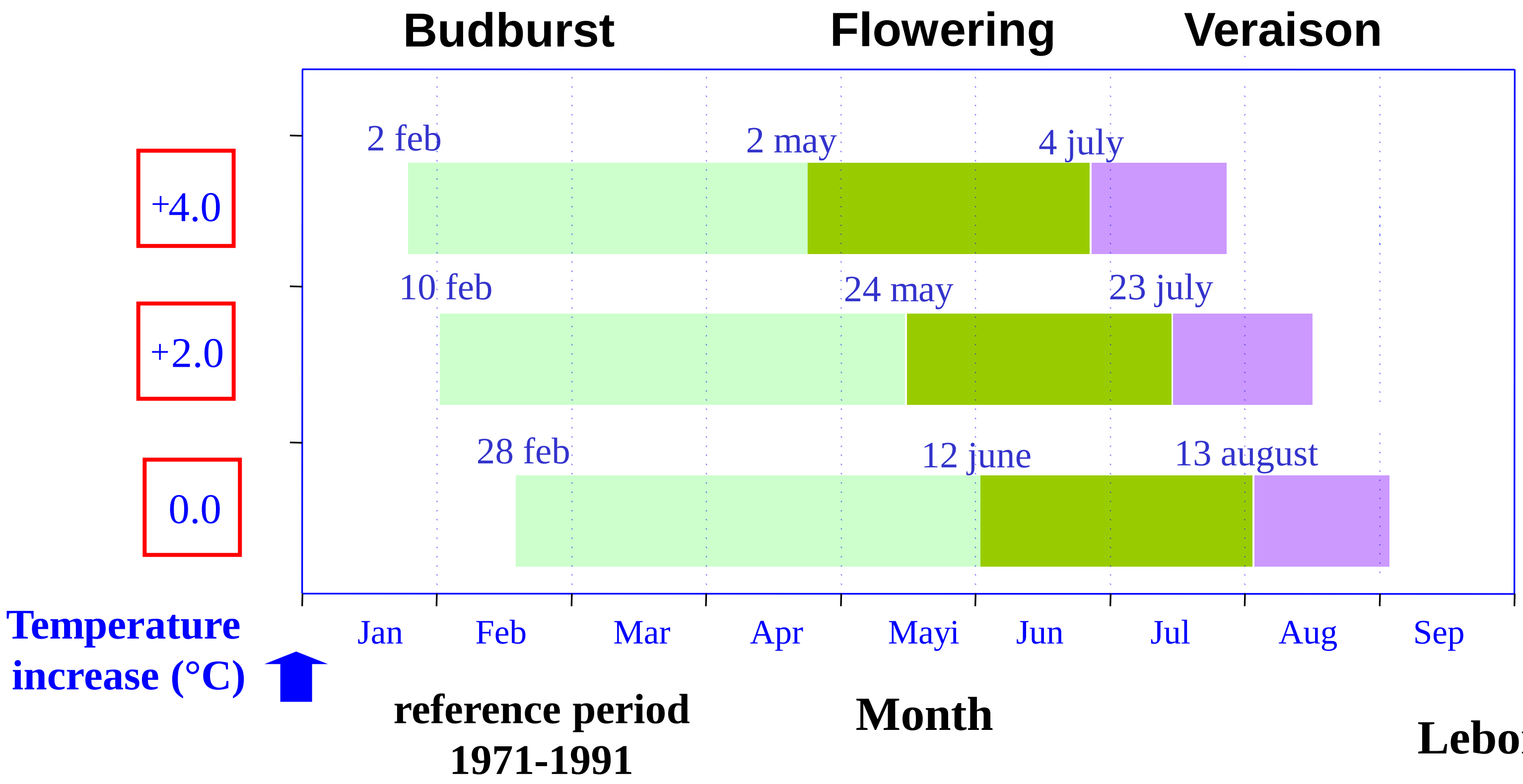
Phenology and fruit trees

problem of mild winters (dormancy break),
advance in phenology (flowering → frost risk/bad fruit setting)



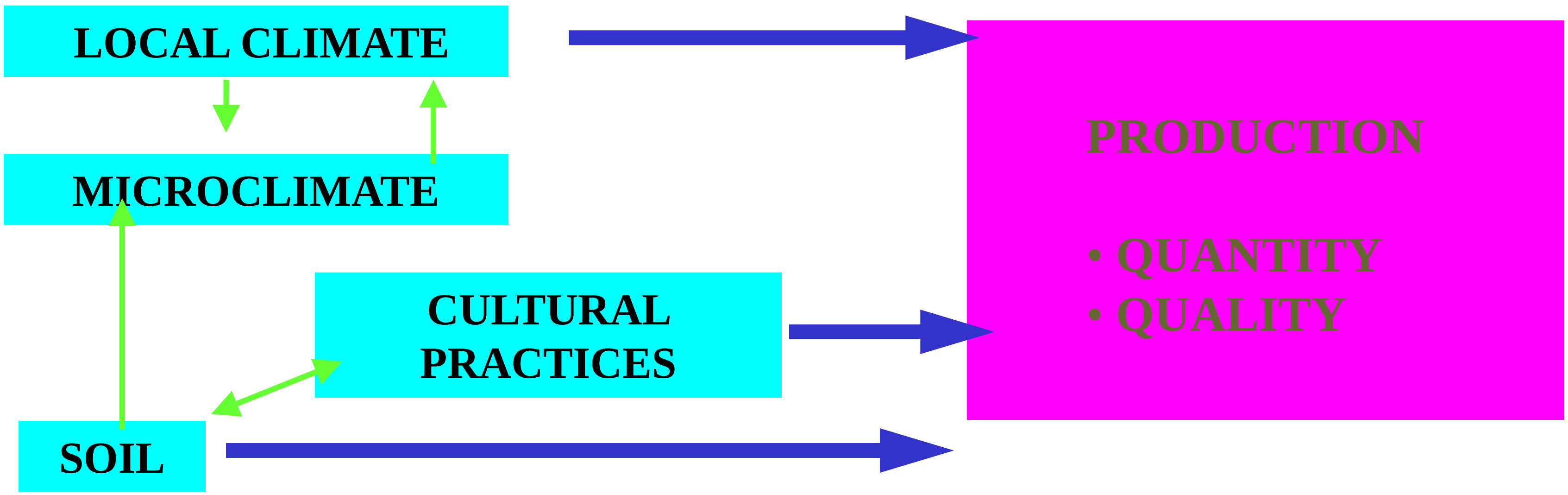
TOWARDS SHIFTS IN PHENOLOGY

An advance of ripening period towards the summer hottest period



Lebon (2002)

More inputs with crop models

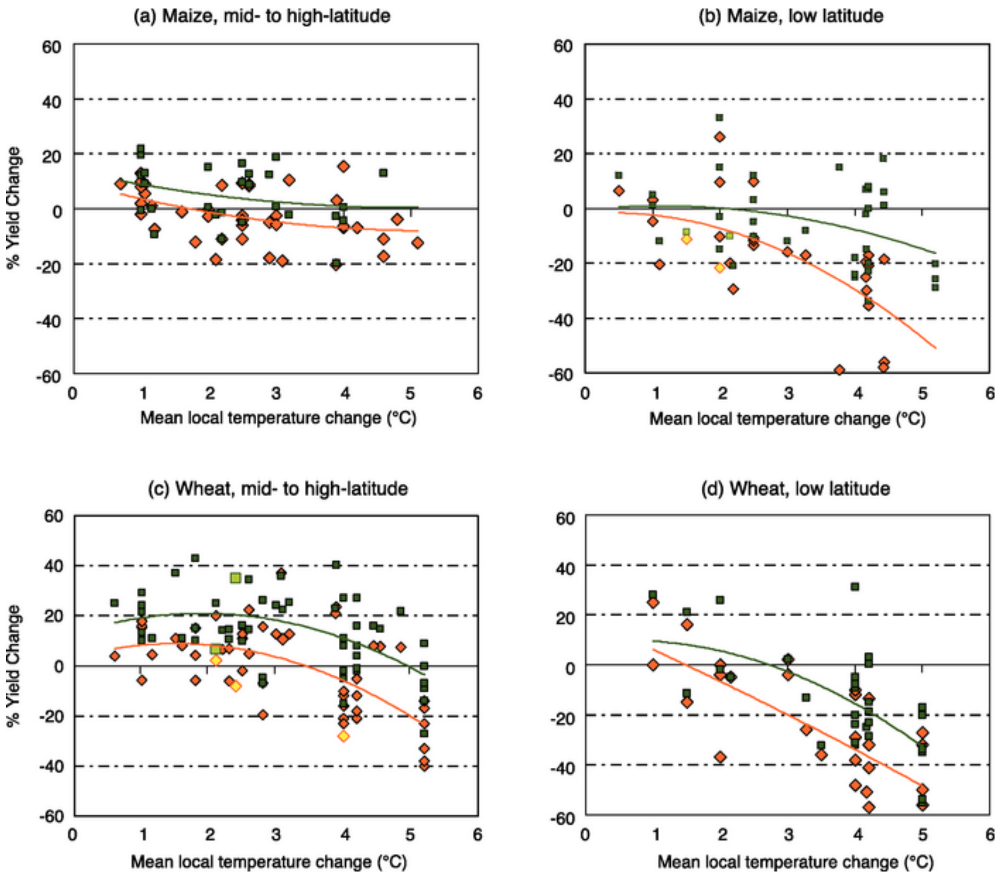


- **Integration of knowledge**

  Light microclimate, water budget, energy balance
- **Taking account of interactions**

  « climate x soil x cultural practices »
- **integration of quality criteria (sugar, acidity, biochemical components)**

Impacts on annual crops (IPCC 2007, WG II, ch5)



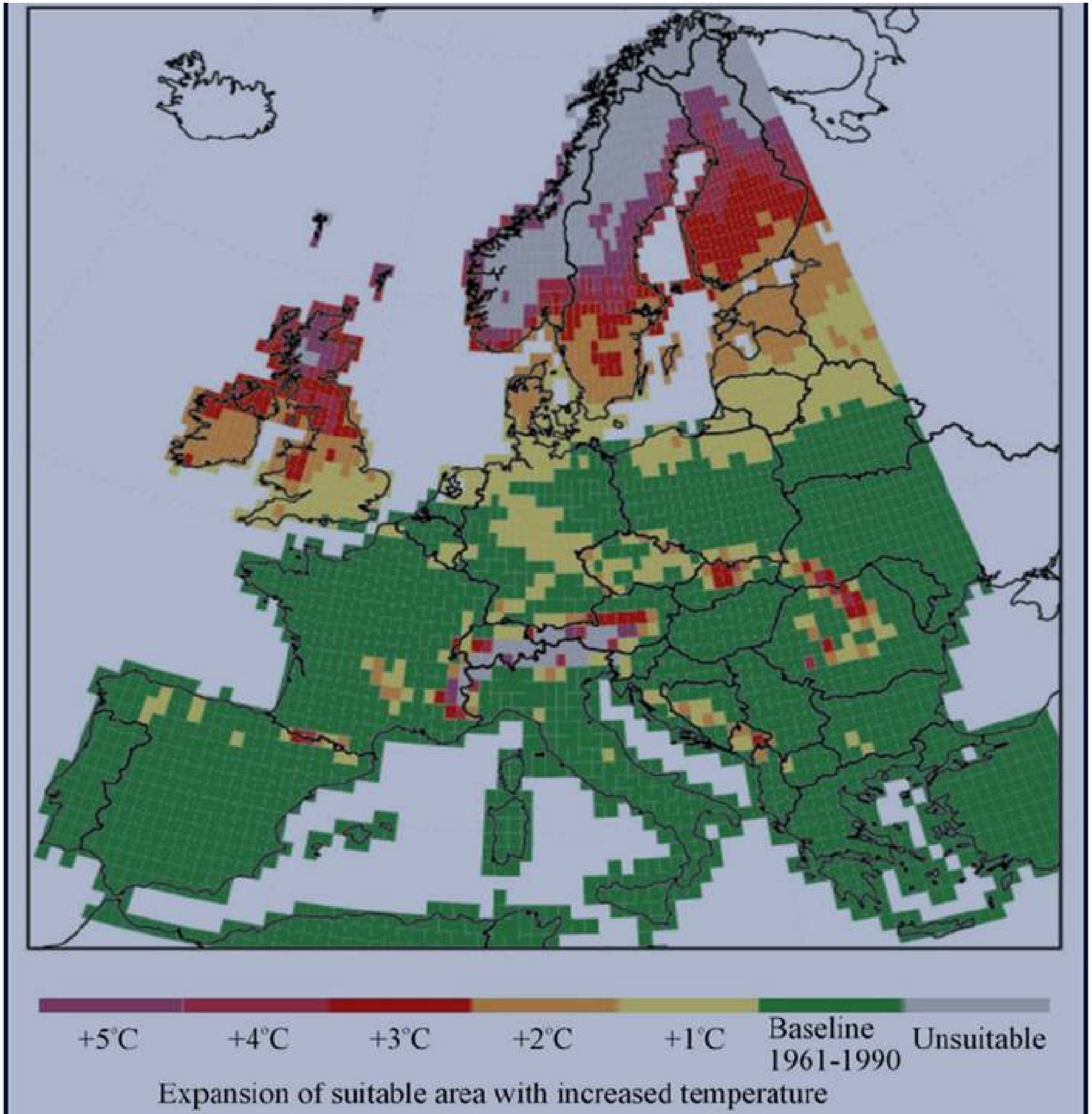


Fig.8. Suitability for grain maize cultivation with increasing temperature (after Parry, 2005)

Which impact for livestock? (IPCC 2007)

» Pastures and forage:

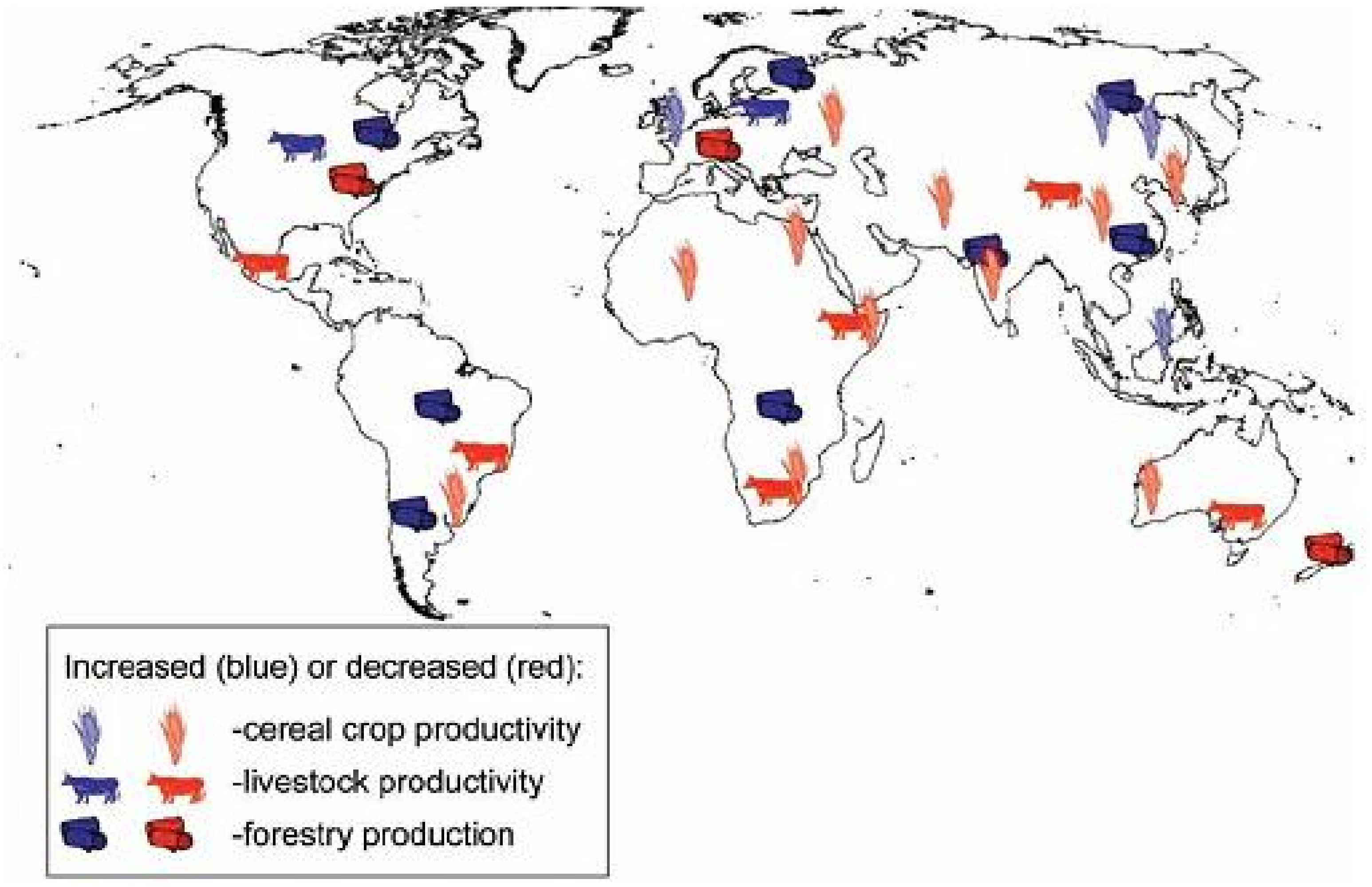
- production to increase in humid temperate grasslands (up to 2°C) and to decrease in arid and semi-arid regions
- plant community structure to be modified
- changes in forage quality and grazing behaviour are confirmed

- Animals

- thermal stress reduces productivity
- affects conception rates
- increases water requirements
- climate variability and droughts may lead to livestock loss

Few studies for tropical grasslands and rangelands

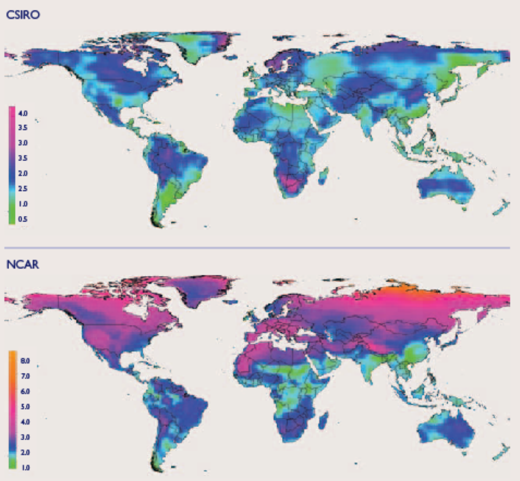
The global impact (IPCC AR4)



Projections of Future Changes in Climate

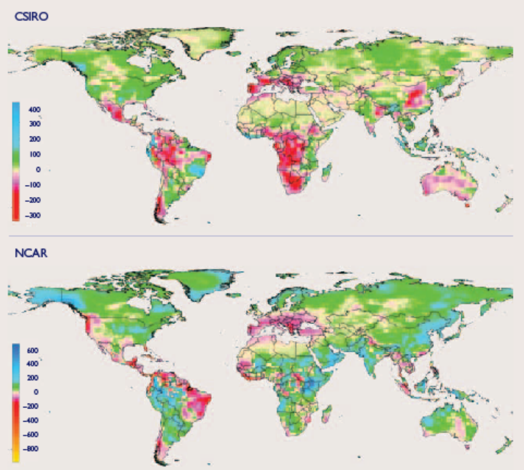
Because climate-change simulations are inherently uncertain, two climate models have been used to simulate future climate, using the A2[5] scenario of the IPCC's Fourth Assessment Report: the National Center for Atmospheric Research, US (NCAR) model and the Commonwealth Scientific and Industrial Research Organization, Australia (CSIRO) model. We refer to the combination of model runs with A2 inputs as the NCAR and CSIRO scenarios. Both scenarios project higher temperatures in 2050, resulting in higher evaporation and increased precipitation as this water vapor returns to earth. The "wetter" NCAR scenario estimates average precipitation increases on land of about 10 percent, whereas the "drier" CSIRO scenario estimates increases of about 2 percent. Figure 1 shows the change in average maximum temperature between 2000 and 2050 for the CSIRO and NCAR scenarios. Figure 2 shows changes in average precipitation. In each set of figures, the legend colors are identical; a specific color represents the same change in temperature or precipitation across the two scenarios.

Figure 1—Change in average maximum temperature (°C), 2000–2050



Source: Authors' calculations.

Figure 2—Change in precipitation (mm), 2000–2050



Source: Authors' calculations.

A quick glance at these figures shows that substantial differences exist across the two scenarios. For example, the NCAR scenario has substantially higher average maximum temperatures than does CSIRO. The CSIRO scenario has substantial precipitation declines in the western Amazon while NCAR shows declines in the eastern Amazon. The NCAR scenario has higher precipitation in Sub-Saharan Africa than does CSIRO. Northern China has both higher temperature and more precipitation under NCAR than under CSIRO. These figures qualitatively illustrate the range of potential climate outcomes using current modeling capabilities and provide an indication of the uncertainty in climate-change impacts.

IFPRI 2009

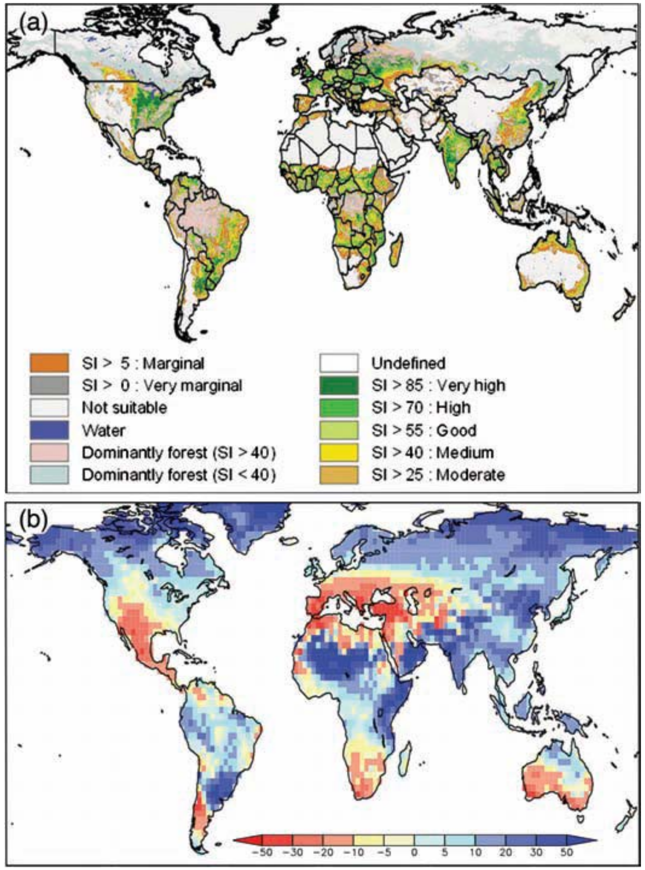
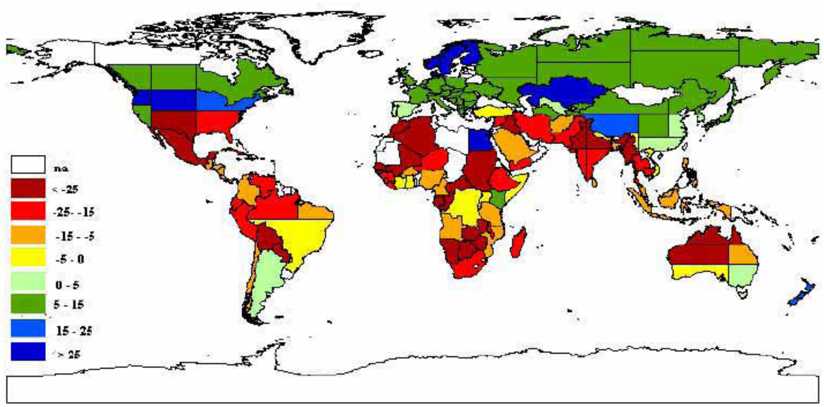


Figure 5.1. *(a) Current suitability for rain-fed crops (excluding forest ecosystems) (after Fischer et al., 2002b). SI = suitability index; (b)Ensemble mean percentage change of annual mean runoff between present (1981 to 2000) and 2100 (Nohara et al., 2006). From IPCC AR4*

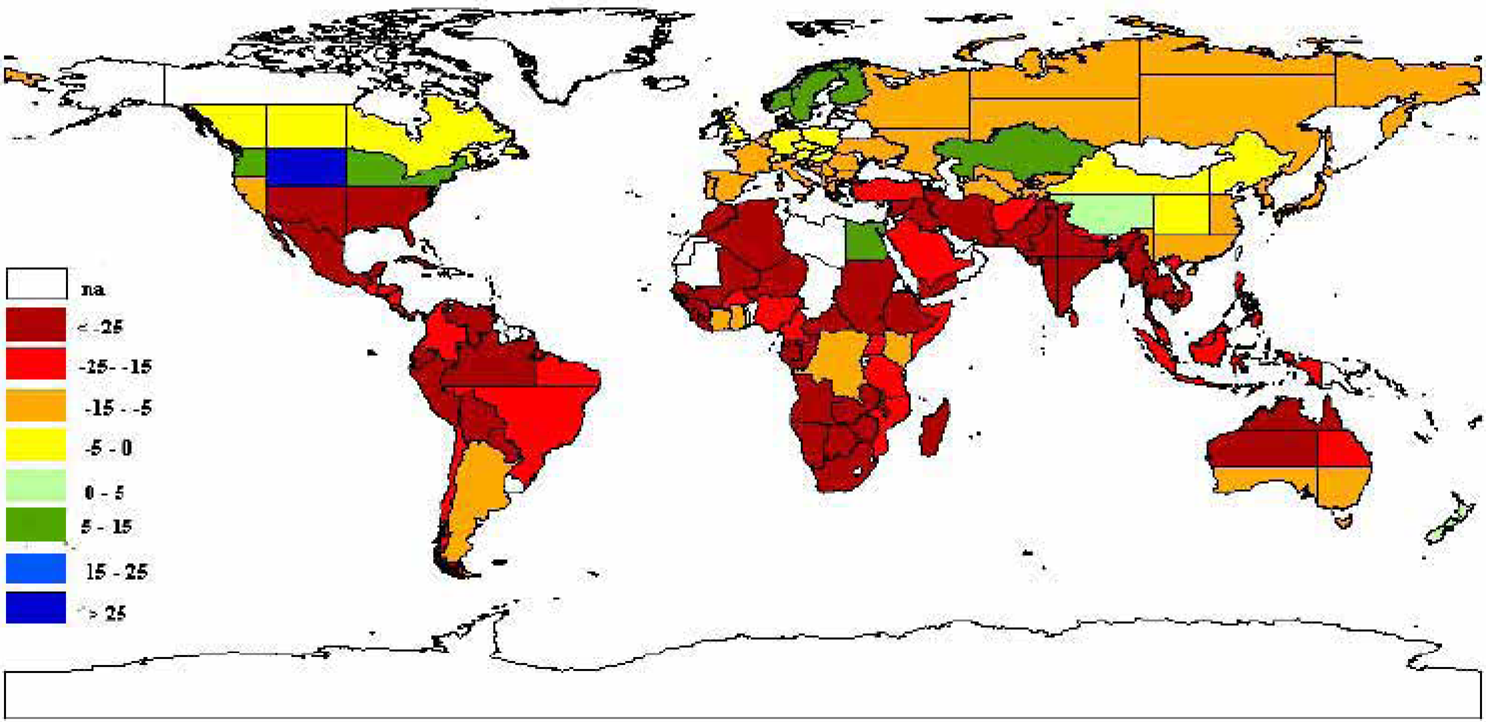
The accentuation of N/S contrast

Impact on Agricultural Productivity with Carbon Fertilization (percent)

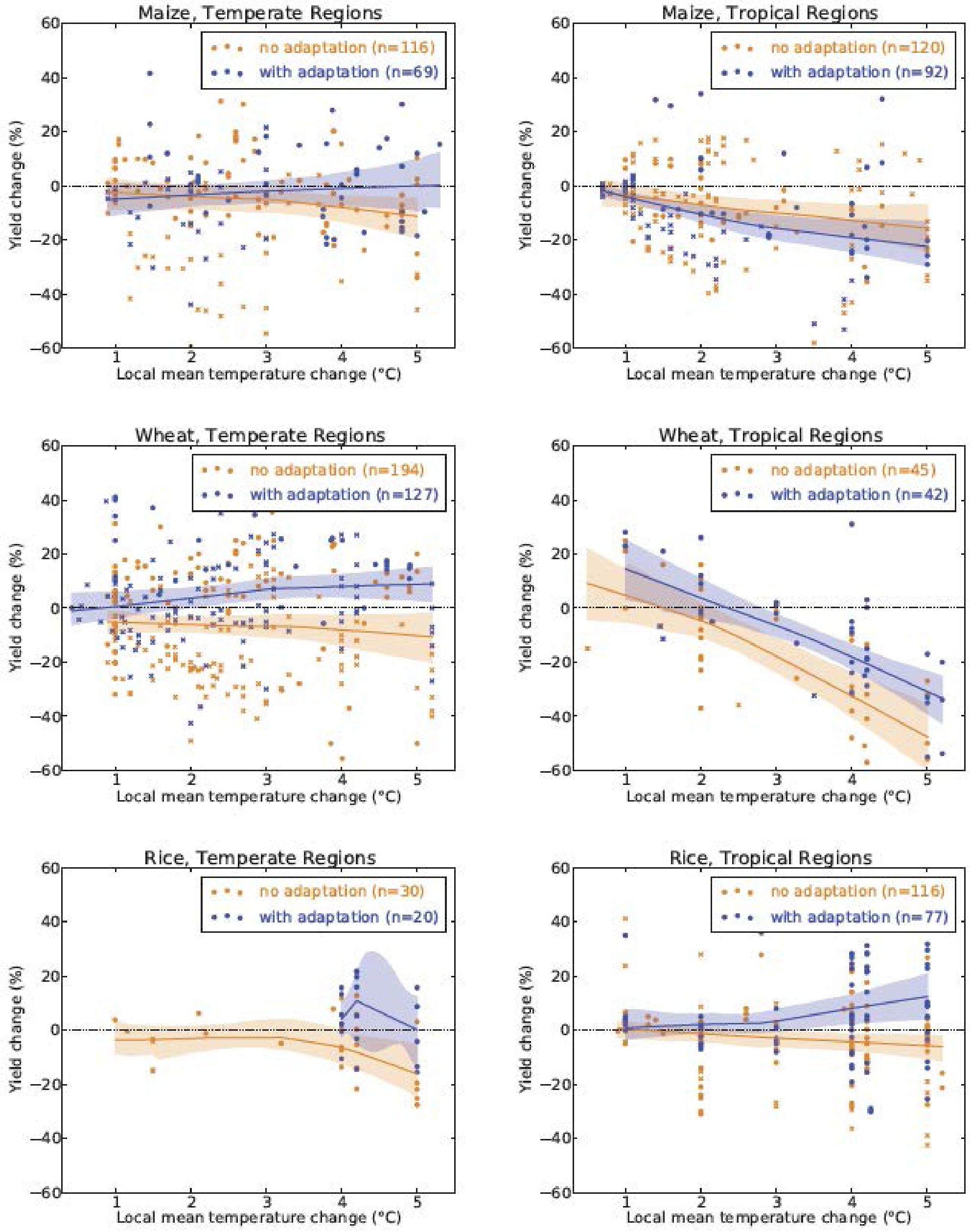


Cline 2007

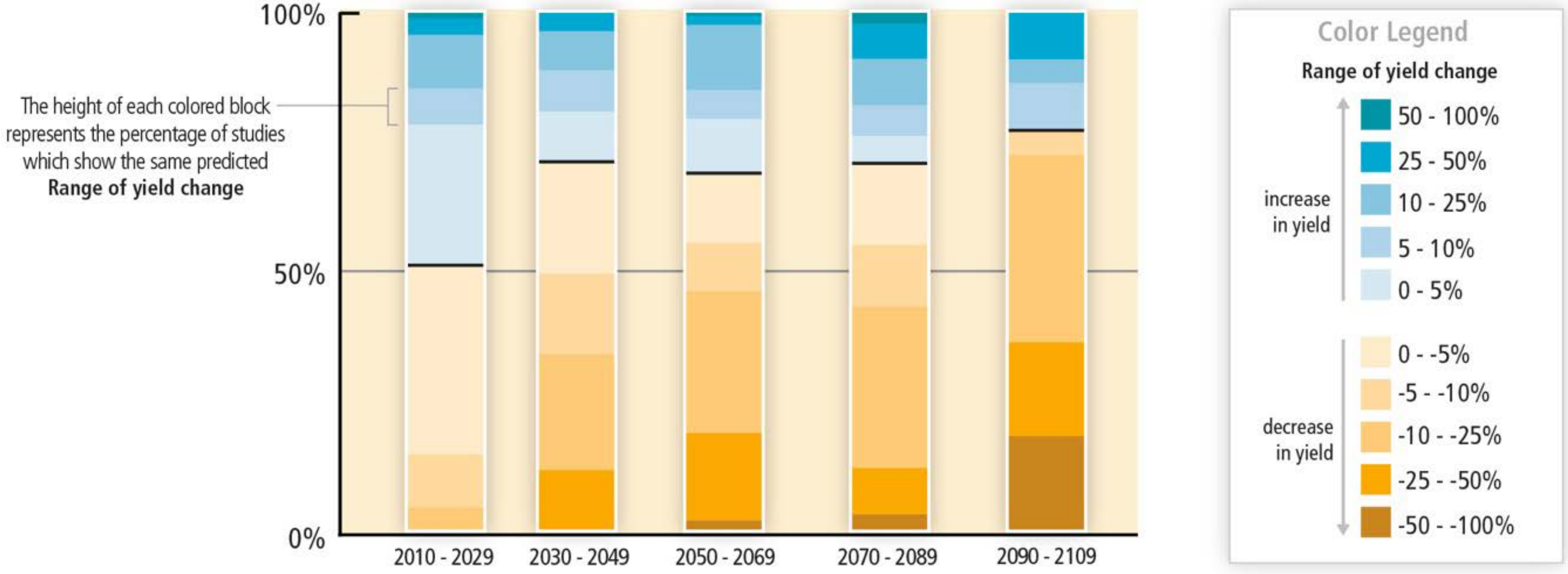
Impact on Agricultural Productivity without Carbon Fertilization (percent)

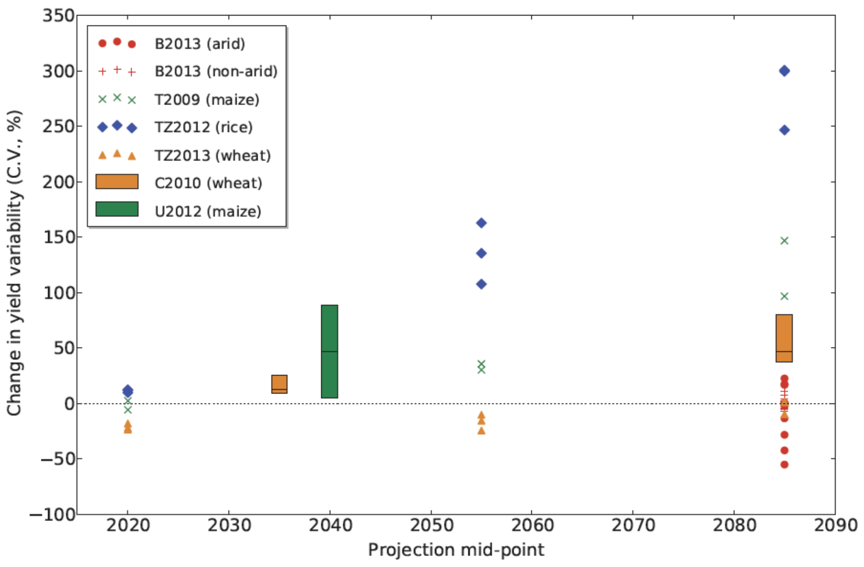


Cline 2007



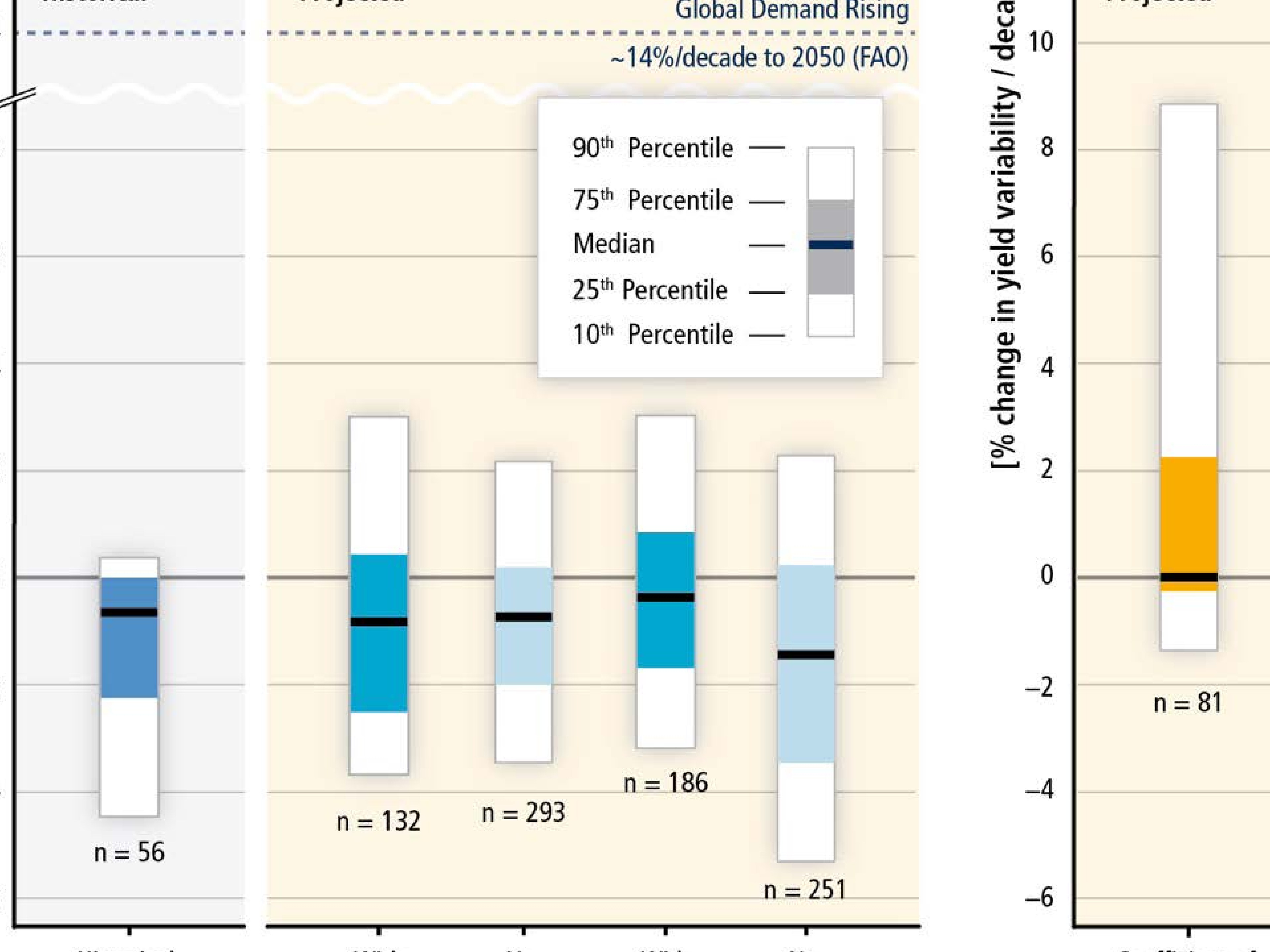
IPCC 2014 WG II, ch 7)





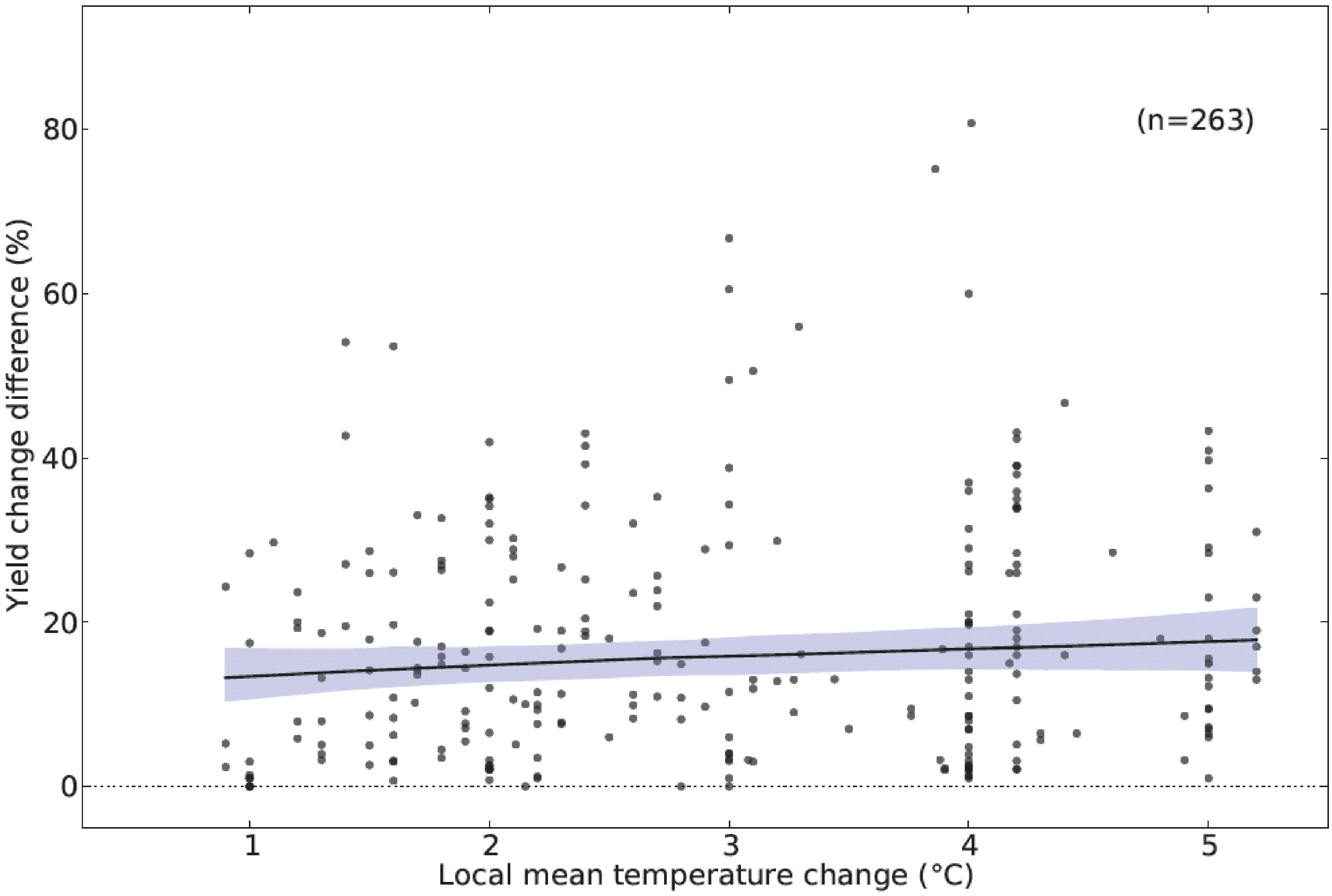
IPCC 2014, ch7

F
r
o
m

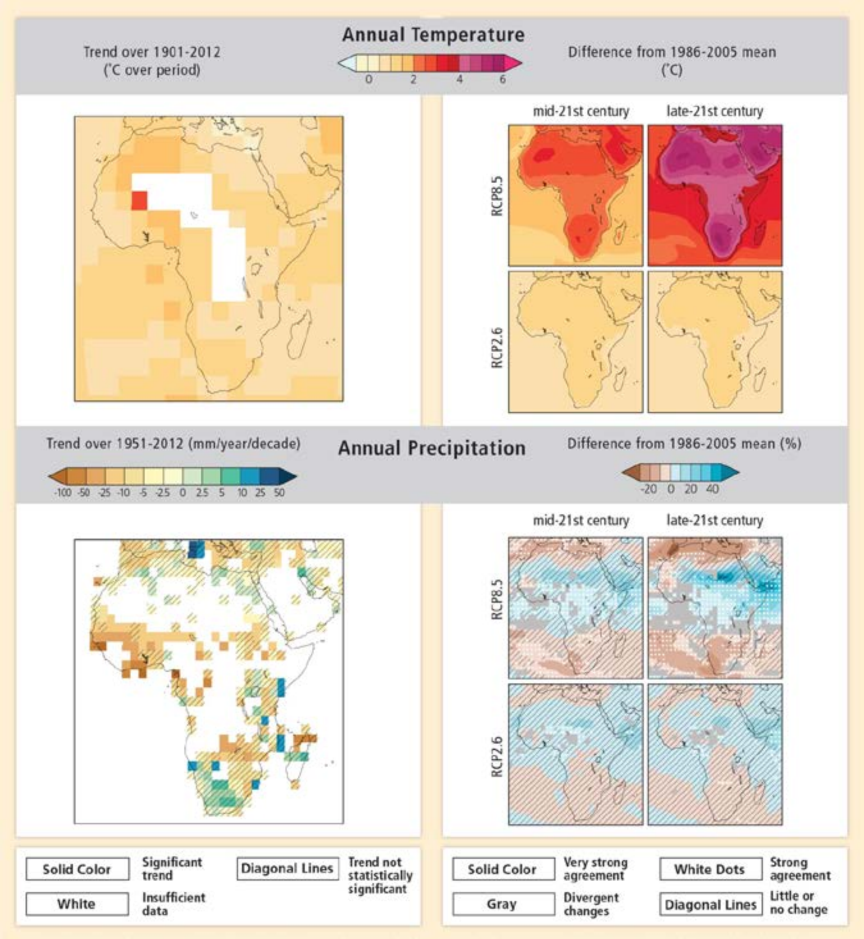


Global Demand Rising
~14%/decade to 2050 (FAO)
90th Percentile
75th Percentile
Median
25th Percentile
10th Percentile
n = 56
n = 132
n = 293
n = 186
n = 251
n = 81
10
8
6
4
2
0
−2
−4
−6

IPCC 2014, ch 7



From IPCC 2014, ch 22
Figure 22-1: Observed and simulated variations in past and projected future annual average precipitation and temperature



Crops in Africa (from IPCC 2014, ch 22)

- Climate change will interact with non-climate drivers and stressors to exacerbate vulnerability of agricultural systems, particularly in semi-arid areas (*high confidence*). Increasing temperatures and changes in precipitation are *very likely* to reduce cereal crop productivity. This will have strong adverse effects on food security.
- New evidence is also emerging that high-value perennial crops could also be adversely affected by temperature rise (*medium confidence*).
- Pest, weed and disease pressure on crops and livestock is expected to increase as a result of climate change combined with other factors (*low confidence*).
- Moreover, new challenges to food security are emerging as a result of strong urbanization trends on the continent and increasingly globalized food chains, whichrequire better understanding of the multi-stressor context of food and livelihood security in both urban and rural contexts in Africa.

Crops in Africa (from IPCC 2014, ch 22)

- **Climate change is *very likely* to have an overall negative effect on yields of major cereal crops across Africa, with strong regional variability in the degree of yield reduction (*high confidence*).**
- **One exception** is in eastern Africa (maize production above roughly 1,700 m in elevation, although the majority occurs at lower elevations thereby implying a potential change in the distribution of maize **cropping. Maize-based systems, particularly in southern Africa, are among the most vulnerable** to climate change:estimated yield losses at mid-century range from 18% for southern Africa to 22% aggregated across SSA, with yield losses for South Africa and Zimbabwe in excess of 30%.
- **Simulations that combine all regions south of the Sahara suggest consistently negative effects of climate change on major cereal crops in Africa**, from 2% for sorghum to 35% for wheat by 2050 under an A2 scenario. Studies in North Africa also indicate a high vulnerability of wheat production to projected warming trends. In West Africa, temperature increases above 2° C are estimated to counteract positive effects on millet and sorghum yields of increased precipitation,with negative effects stronger in the savannah than in the Sahel, and with modern cereal varieties compared with traditional ones

Crops in Africa (from IPCC 2014, ch 22)

- Several recent studies since the AR4 indicate that climate change will have variable impacts on non-cereal crops, with both production losses and gains possibe. Suitability for growing cassava is estimated to increase with the greatest improvement in suitability in eastern and central Africa. Bean yields in Eastern Africa are estimated to experience yield reduction. For peanuts, some studies indicate a positive effect and others a negative one. Banana and plantain production could decline in West Africa and lowland areas of East Africa, whereas in highland areas of East Africa it could increase with temperature rise.
- Suitable agro-climatic zones for growing economically important perennial crops are estimated to significantly diminish, largely due to the effects of rising temperatures .Under an A2 scenario, by midcentury,suitable agro-climatic zones that are currently classified as very good to good for perennial crops may become more marginal, and what are currently marginally suitable zones may become unsuitable; the constriction of rop suitability could be severe in some cases (Table 22-4). Movement of perennial crops to higher altitudes would serve to mitigate the loss of suitability at lower altitudes but this option is limited. Loss of productivity of high-values such as tea, coffee and cocoa would have detrimental impacts on export earnings.

Projections with crop models (IPCC 2014)

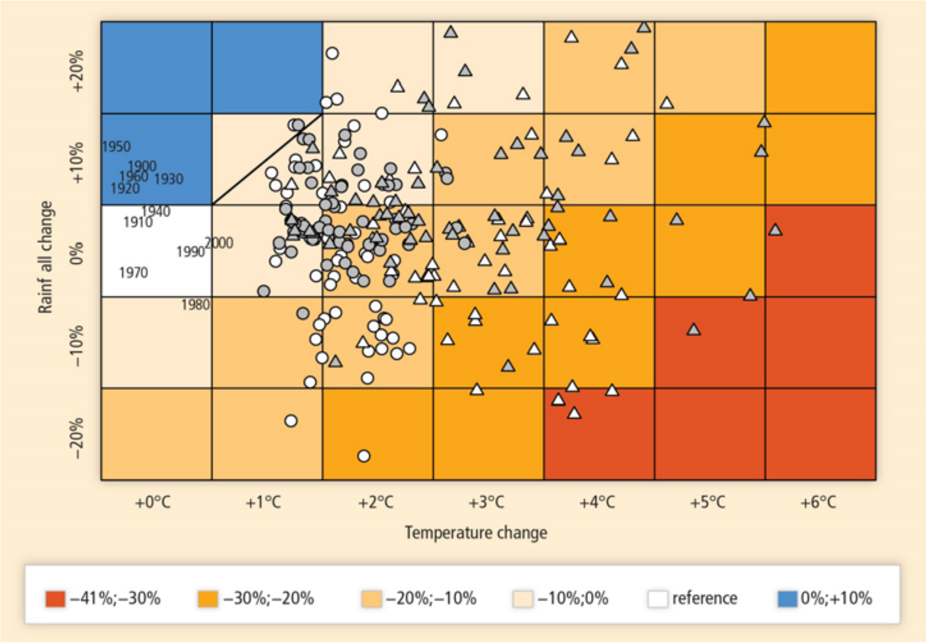


Figure 22-5: The effect of rainfall and temperature changes on mean crop yield. Mean crop yield change (%) relative to the 1961–90 baseline for 7 temperatures (x-axis) and 5 rainfall (y-axis) scenarios. Results are shown as the average over the 35 stations across West Africa and the 6 cultivars of sorghum and millet. White triangles and circles are the projected anomalies computed by several CMIP3 GCMs and three IPCC emission scenarios (B1, A1B, A2) for 2071–90 and 2031–50, respectively. Projections from CMIP5 GCMs and three RCPs (4.5, 6.0 and 8.5) are represented by grey triangles and circles. Models and scenarios names are displayed in figure S2 (available at stacks.iop.org/ERL/8/014040/mmedia). Past observed climate anomalies from CRU data are also projected by computing 10-year averages (e.g. '1940' is for 1941–50). All mean yield changes are significant at a 5% level except boxes with a diagonal line. Source: Sultan et al., 2013

Livestock in Africa (from IPCC 2014)

- Livestock systems in Africa face multiple stressors that can interact with climate change and variability to amplify the vulnerability of livestock-keeping communities
- Loss of livestock under prolonged drought conditions is a critical risk given the extensive rangeland in Africa that is prone to drought. (particular concern for regions that are projected to become drier with climate change, such as Northern and Southern Africa)
- Adequate provision of water for livestock production could become more difficult (drinking water provision for livestock is critical)
- Livestock production will be indirectly affected by water scarcity through its impact on crop production and subsequently the availability of crop residues for livestock feeding
- The extent to which increased heat stress associated with climate change will affect livestock productivity has not been well established, particularly in the tropics and sub-tropics.Higher temperatures in lowland areas of Africa could result in reduced stocking of dairy cows in favor of cattle ,a shift from cattle to sheep and goats and decreasing reliance on poultry.Livestock keeping in highland areas of East Africa, which is currently cold-limited, would potentially benefit from increased temperatures

Local adaptation for cropping systems

- genetic material (precocity, cycle duration, thermal optimum, chilling requirements, frost sensitivity ..)
- adjustment of cultural practices : sowing dates, fertilization/irrigation,...
- coping with pests and diseases

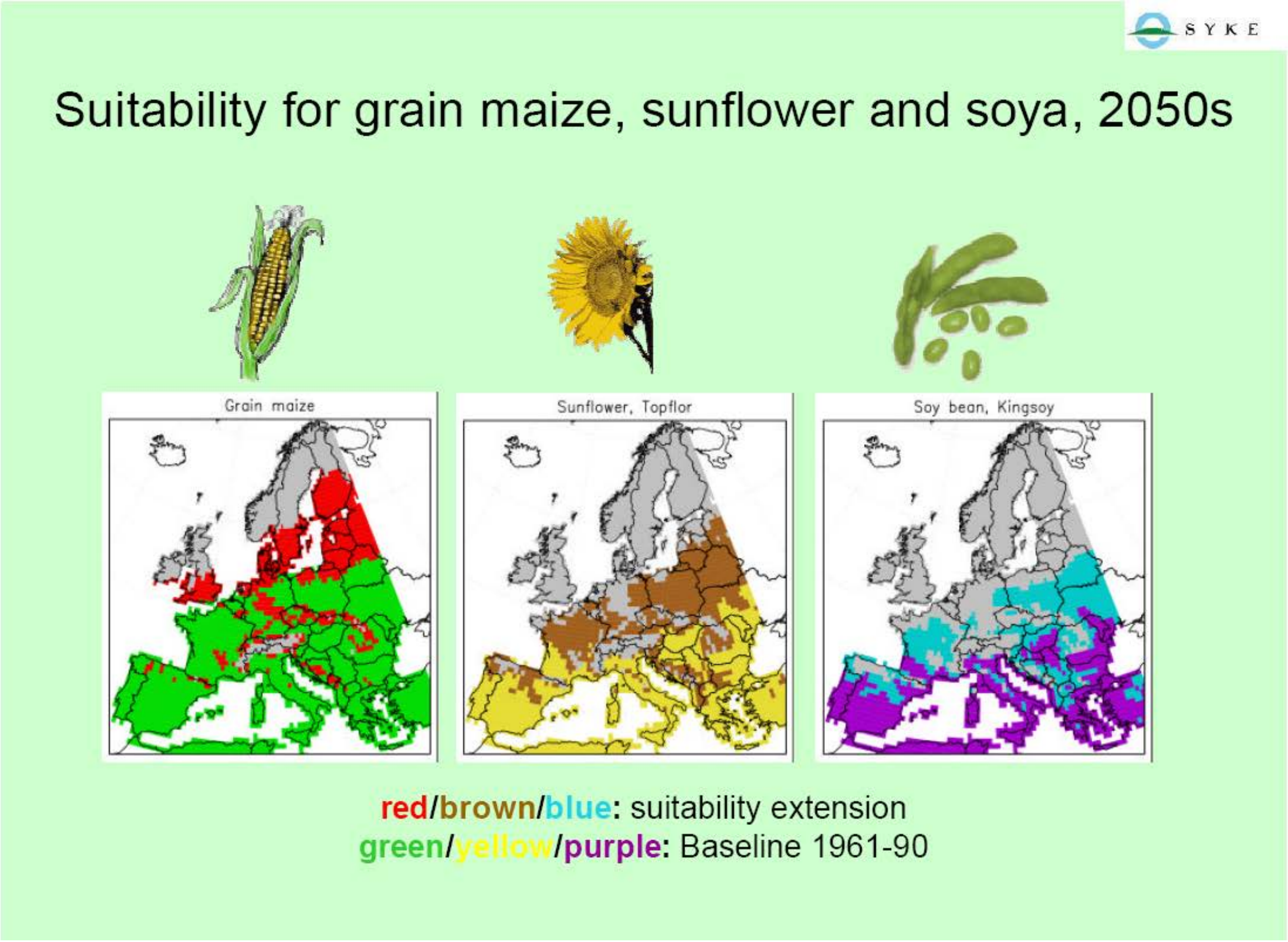
Adaptation by geographical displacement?

- + 1° ~ 200km towards north or 150m in altitude
- up to now, few evidences of recent evolution
- necessity to consider displacements in production zones (révision of potentialities , introduction of new crops).. but what about the economical context
- and the ‘ terroirs’ (they cannot be delocalized !!) ?

Changes in suitability (IPCC 2014)

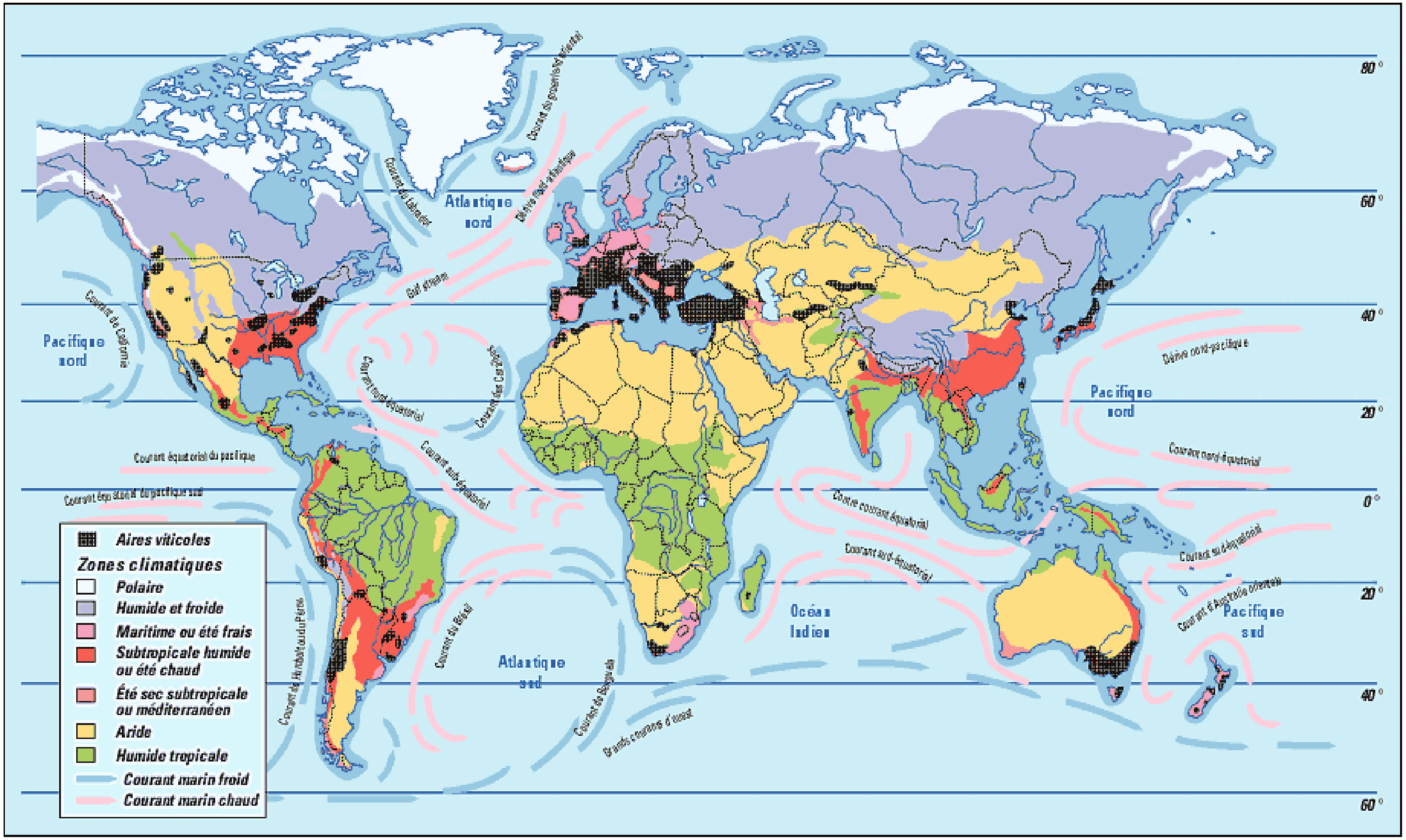
Table 22-4: Projected changes in agro-climatic suitability for perennial crops in Africa by mid-century under A2 scenario

- **Coffee**: increased suitability at high latitudes; decreased suitability at low latitudes (Kenya)
- **Tea:** decreased suitability for Uganda; increased suitability at high latitudes and decreased suitability at low latitudes for Kenya
- **Cocoa :** constant or increased suitability at high latitudes; decreased suitability at low latitudes for Ghana, Côte d'Ivoire
- **Cashew:** increased suitability (Ghana, Côte d'Ivoire)
  Cotton: decreased suitability (Ghana, Côte d'Ivoire)


SYKE
Suitability for grain maize, sunflower and soya, 2050s
Grain maize
Sunflower, Topflor
Soy bean, Kingsoy
red/brown/blue: suitability extension
green/yellow/purple: Baseline 1961-90

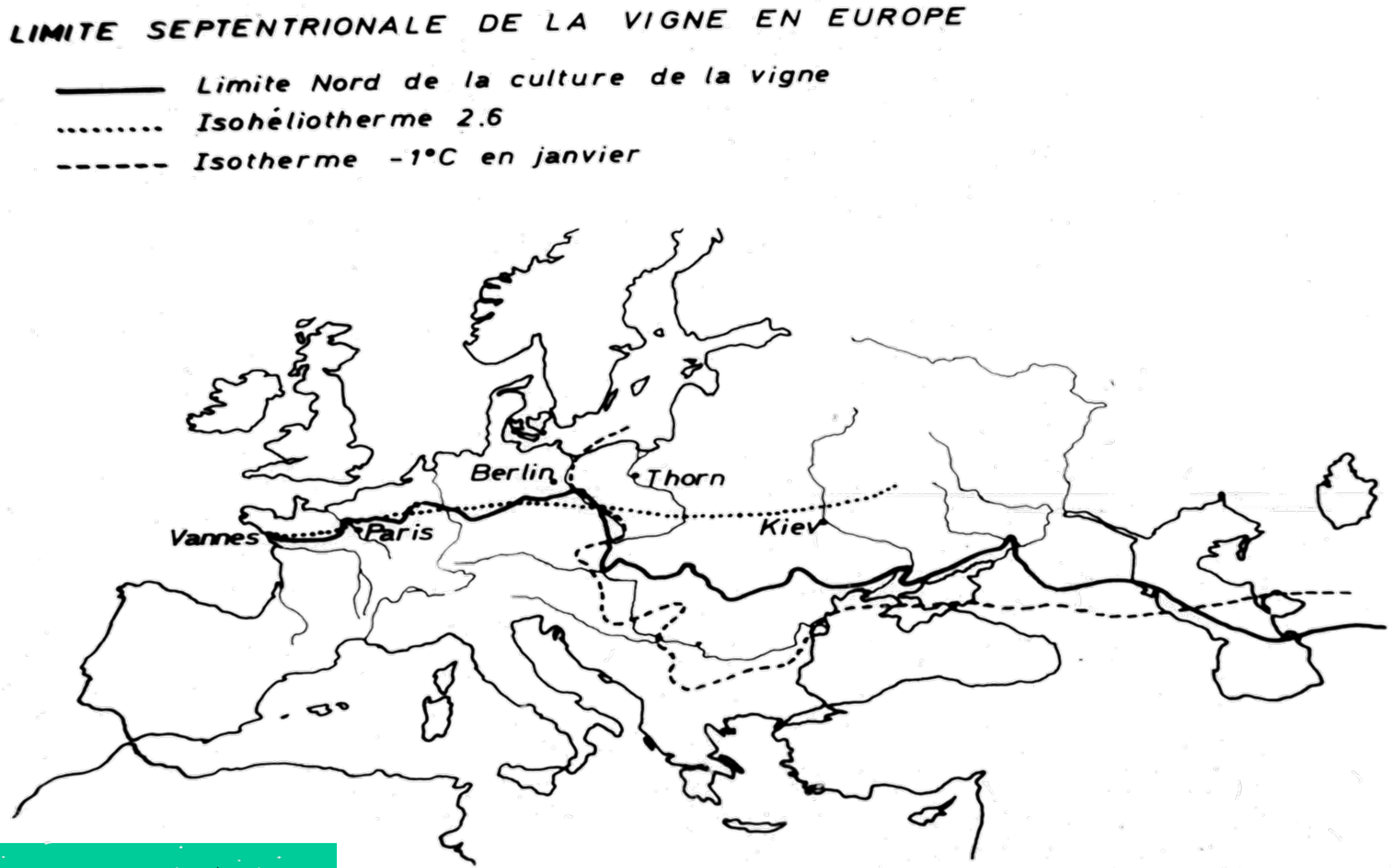
Parry 2005

Vine cultivation is closely related to climate on a global scale



Revue des œnologues, n°96, juillet 2000

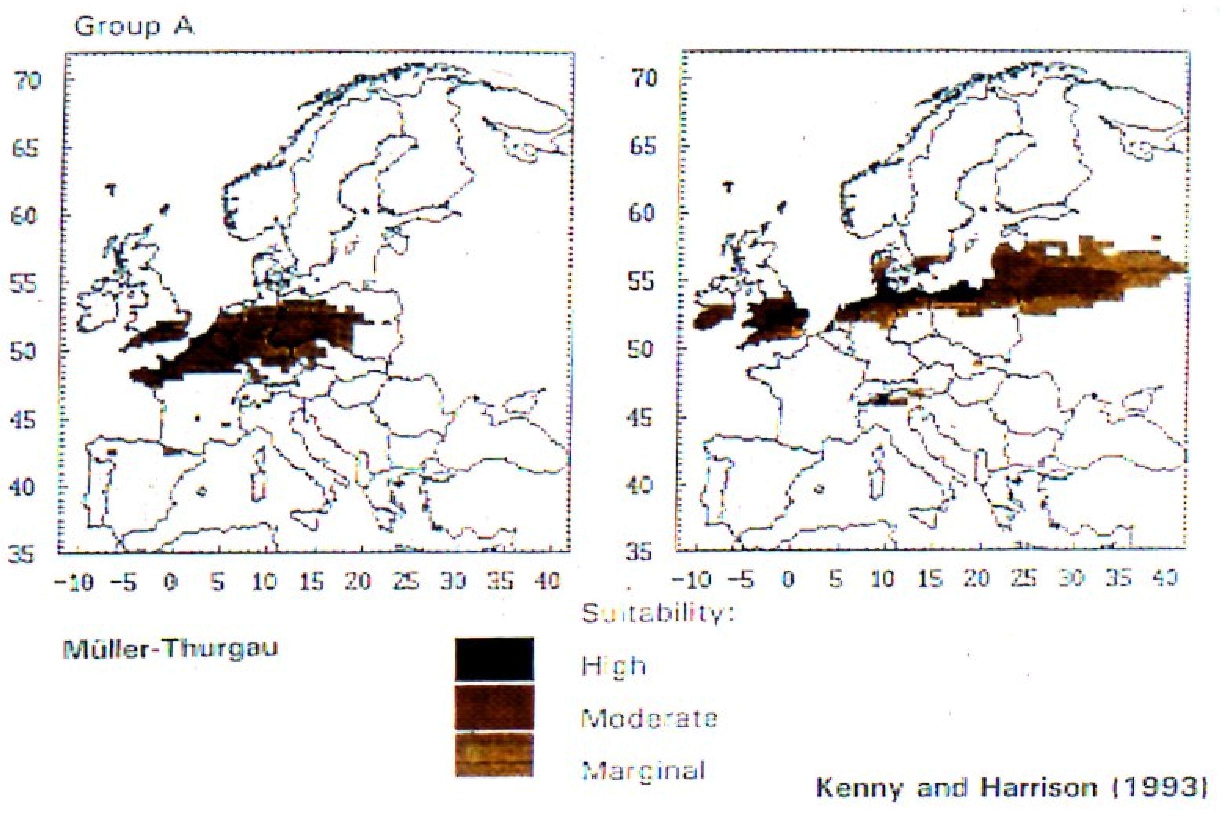
Its northern limits in Europe



(Branas 1946)

Vine will be very sensitive to climate change

- **in the geographical extent of potential cultivation**



CLimate Change Adaptability of WINE

FOCUS 43/2002 & other NEWS

CLAWINE

P I K

IPCC TAR WG 2

Grapevine:

- suitable area expands northwards into central and northern England and eastwards into parts of eastern Poland, Romania, Belorussia and the Ukraine.
- Increasing yield in southern England and Brandenburg

<u>CBS News</u>

Britain: Great New Wine Region?

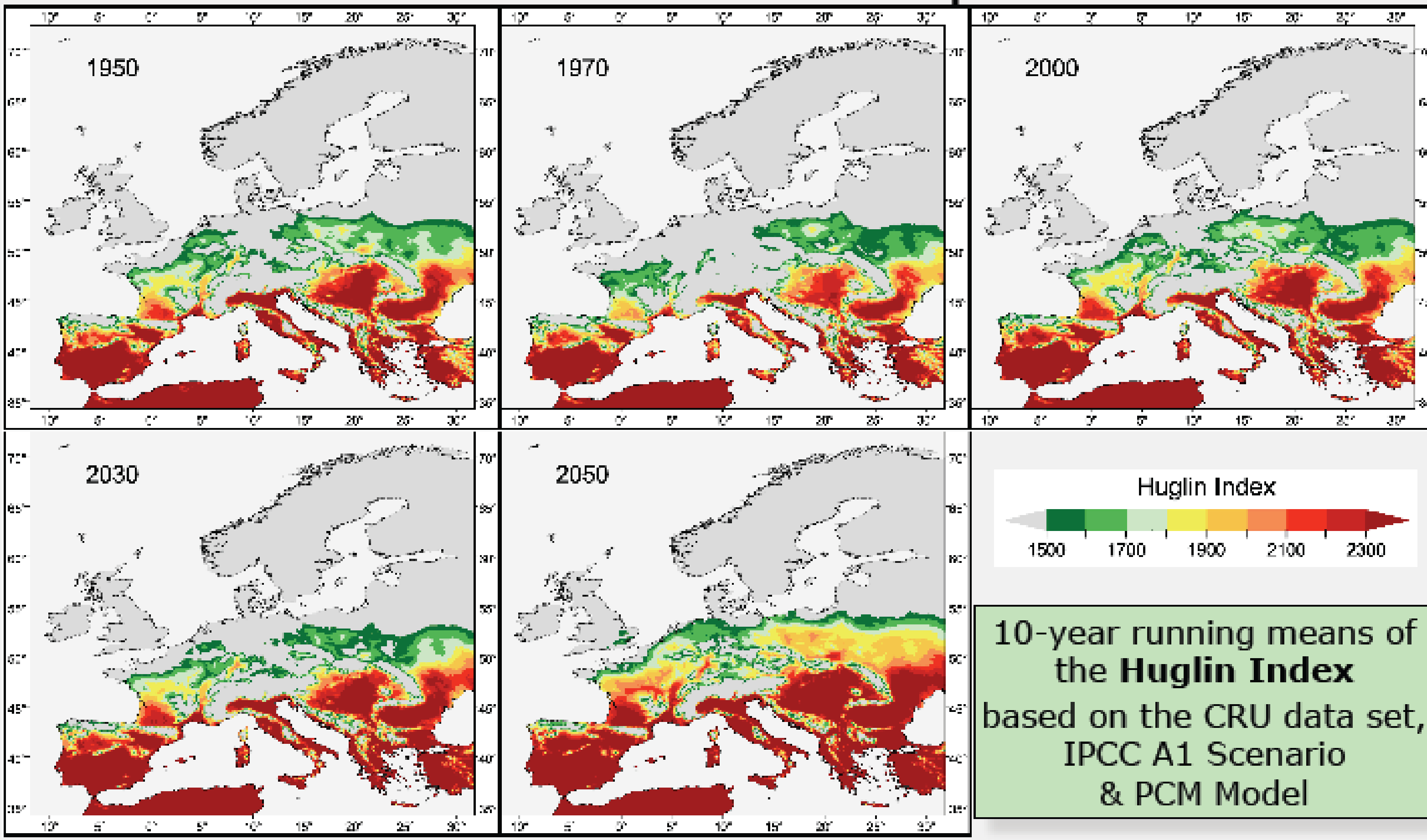
• *A Change In Climate Could Make It Happen*

„Tell a Frenchman that you're growing wine in England, and he thinks it's a bit of a joke."

Ian Berwick,
Bruisyard Vineyards

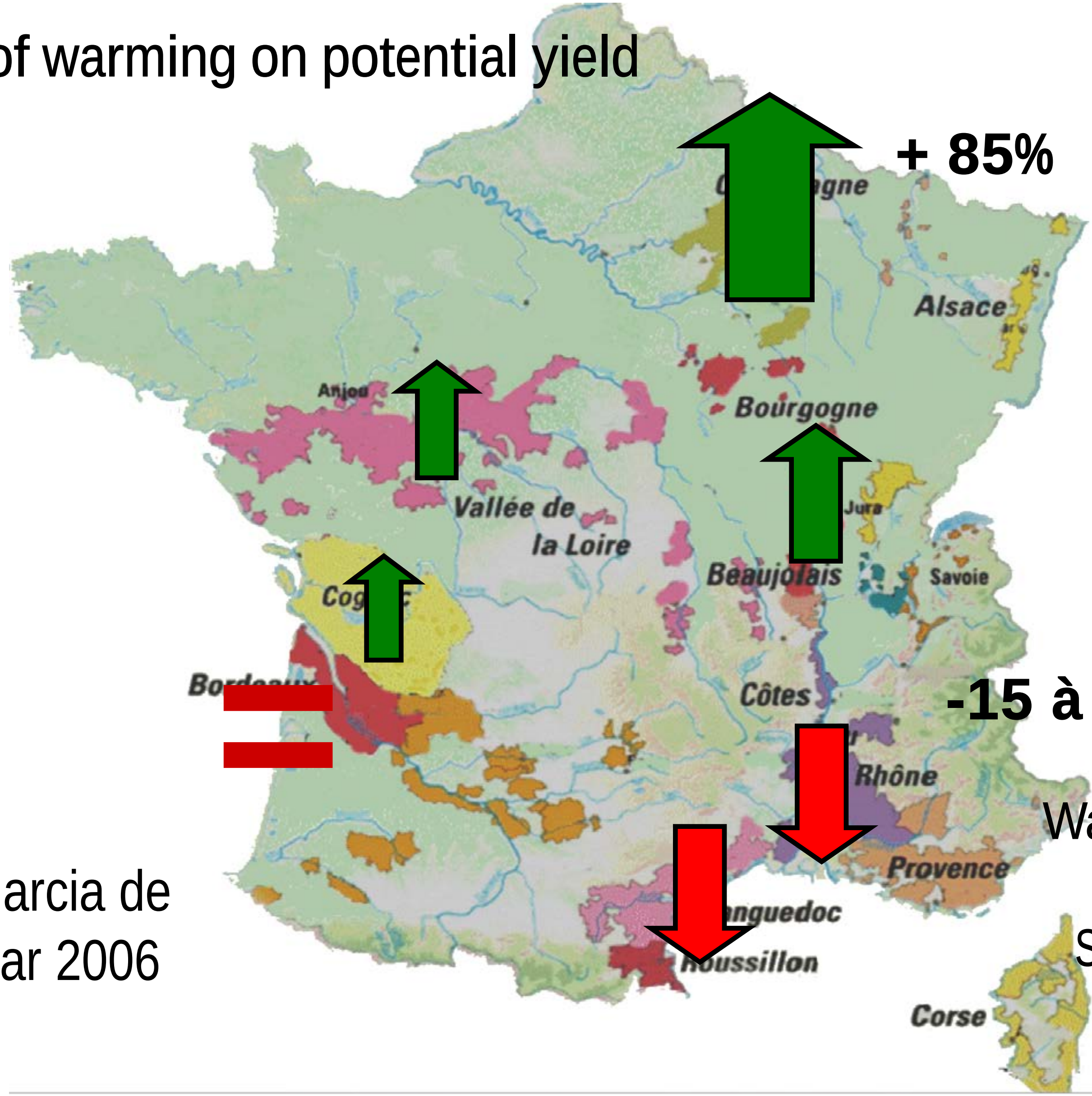
SAXMUNDHAM, England, April 06,2000

Climate Change Impact Assessment for Viticulture in Europe



Stock, PIK

Effect of warming on potential yield



+ 85%

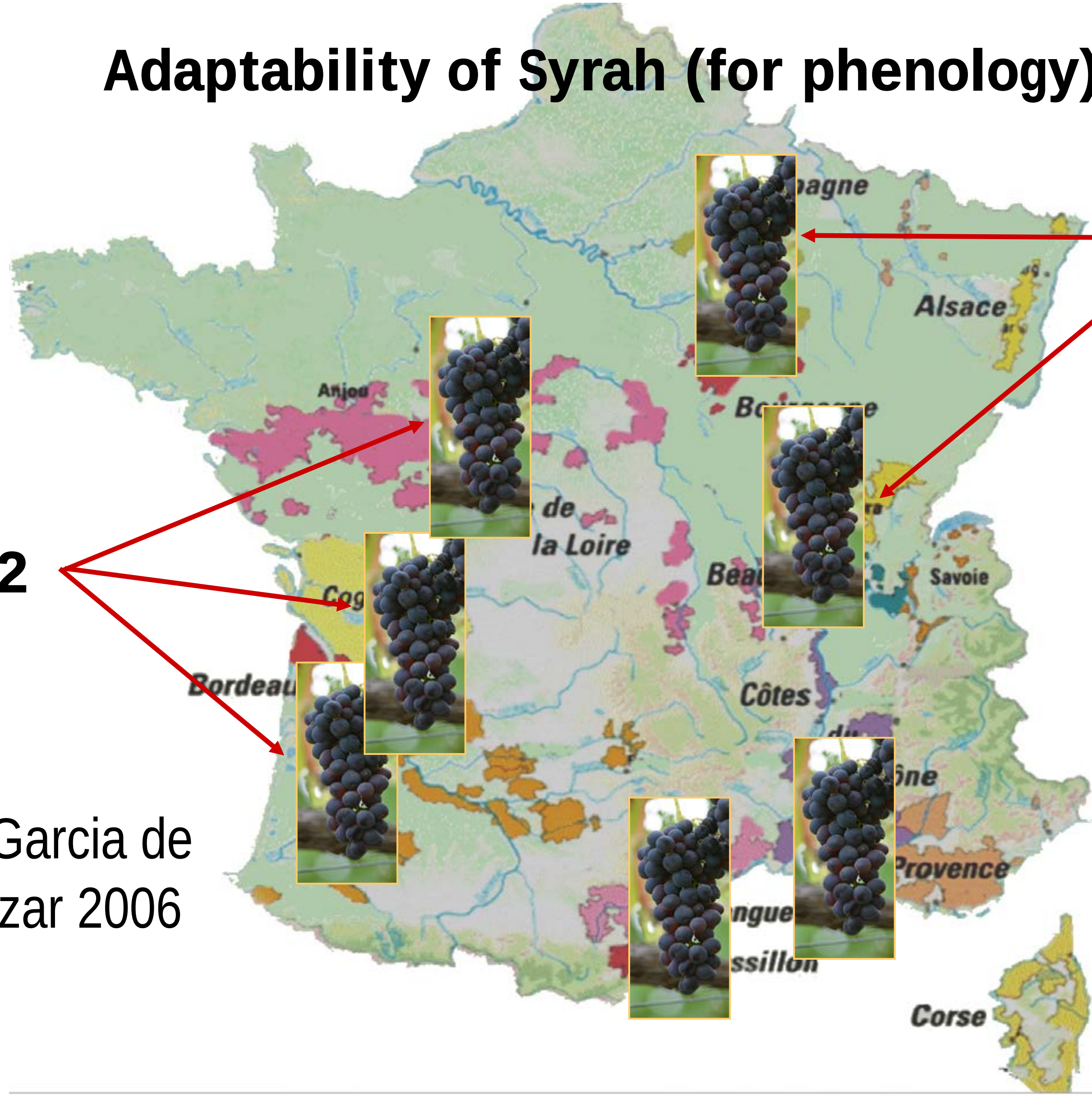
-15 à - 35%

Water and heat tress
Shortening of cycle

PhD Garcia de Cortazar 2006

Intensité dépend du type du sol

Adaptability of Syrah (for phenology)



A2

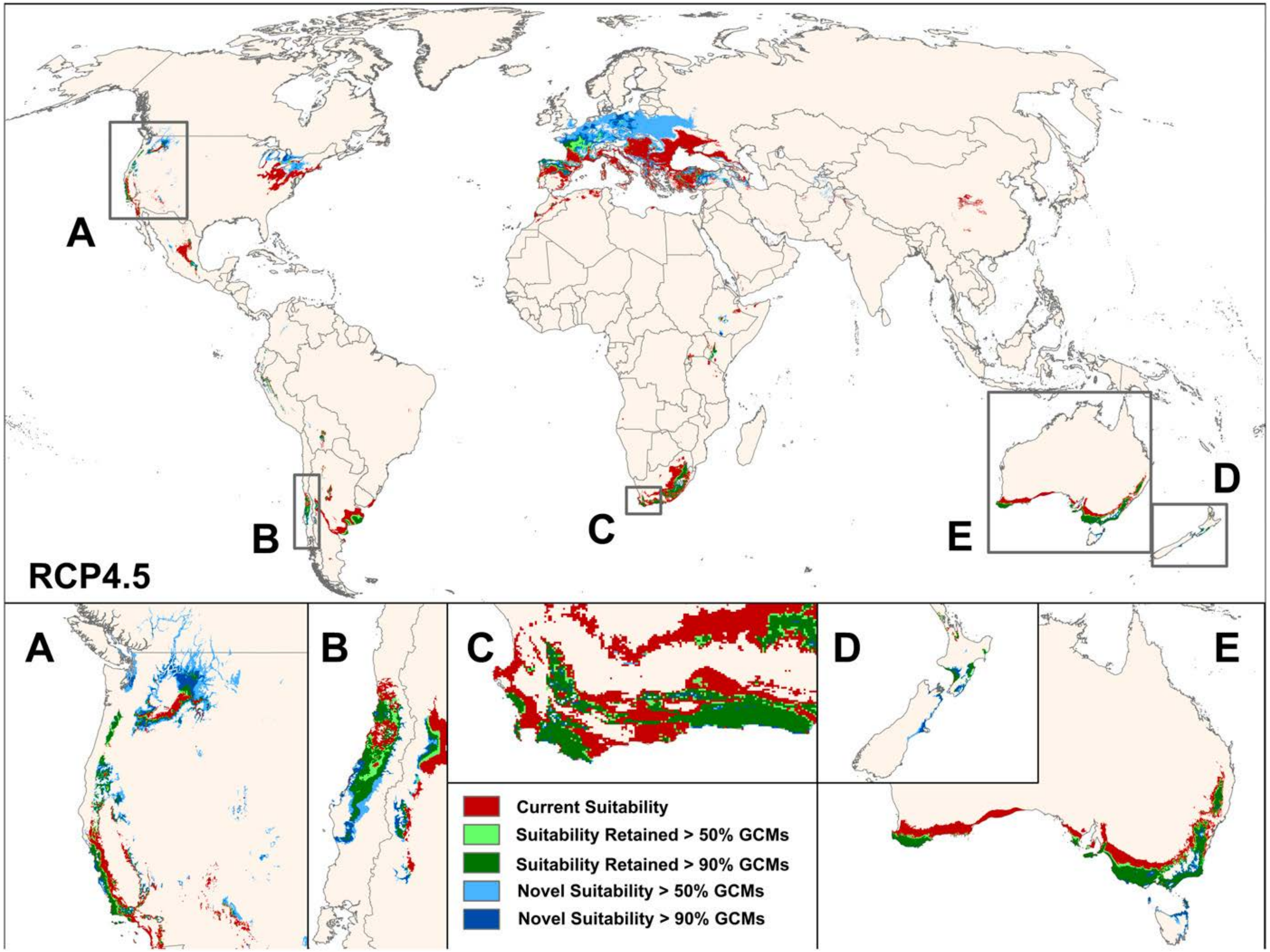
B2

harvest
219.1 gr sugar/l

Before end of September

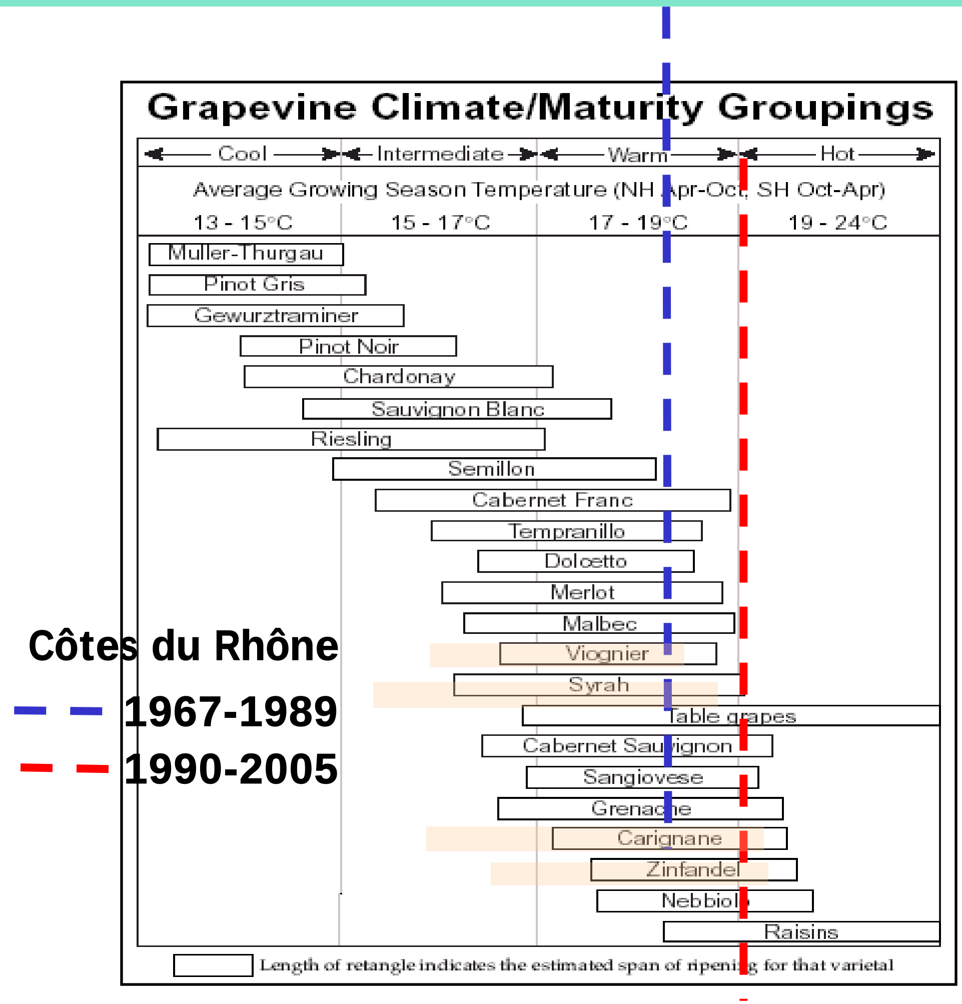
PhD Garcia de Cortazar 2006

Which future for vine production?



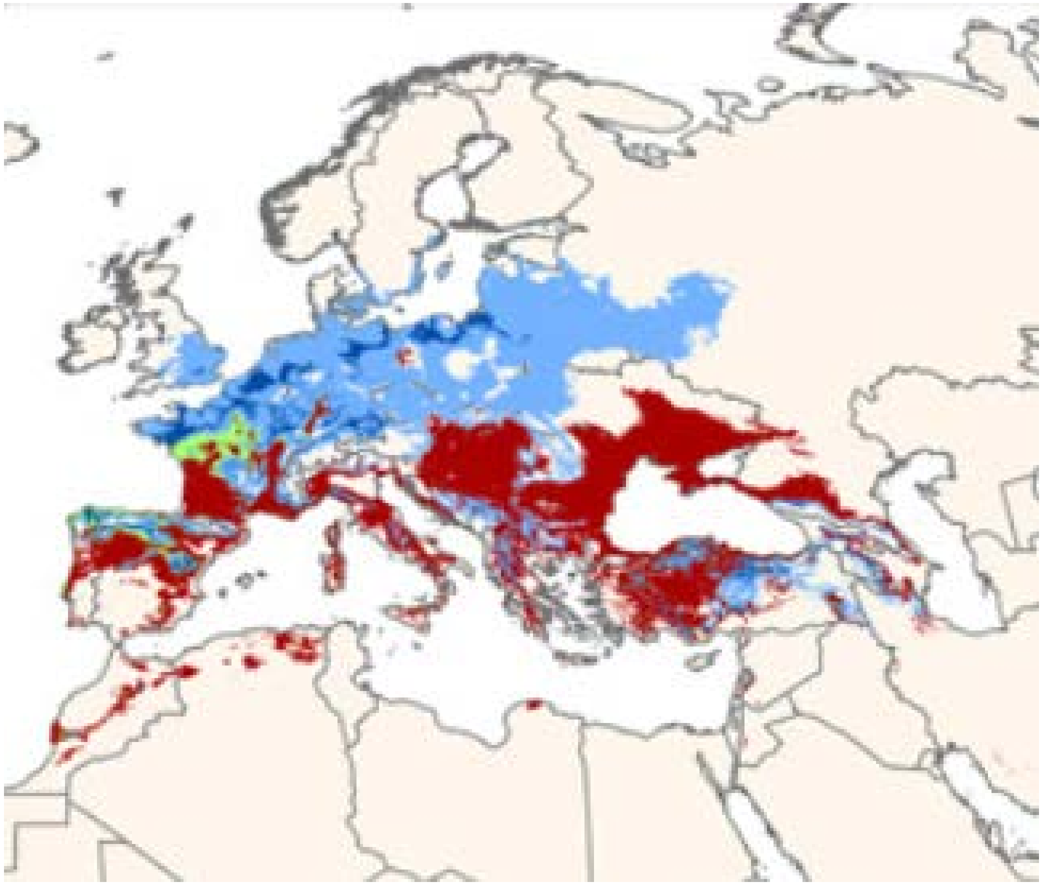
Hannah et al (2013)

A possible range for adaptation



Source: Jones, 2002, 2004, 2005

Questions about the potential ‘niche’ approach

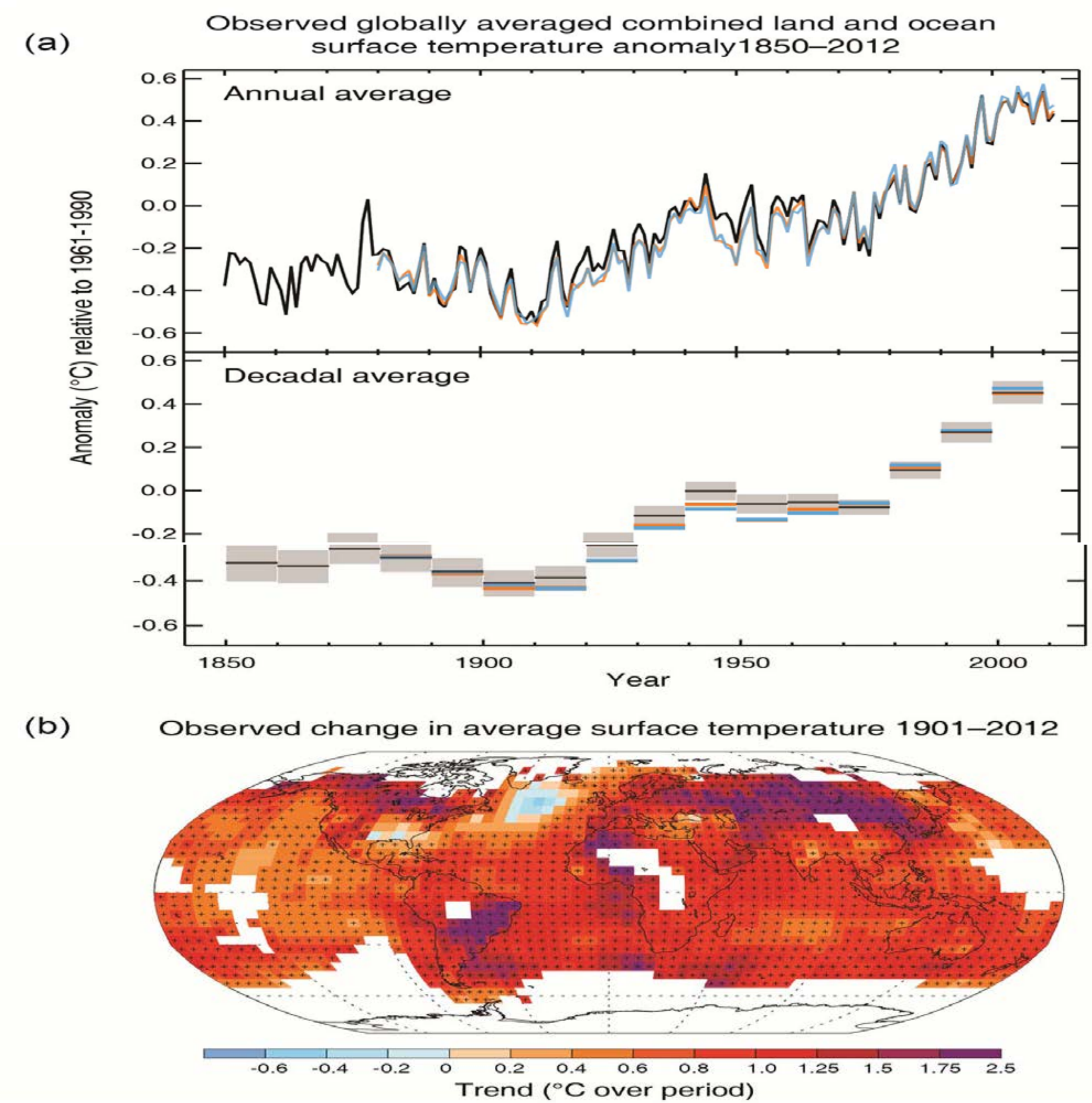


Hannah et al (2013)

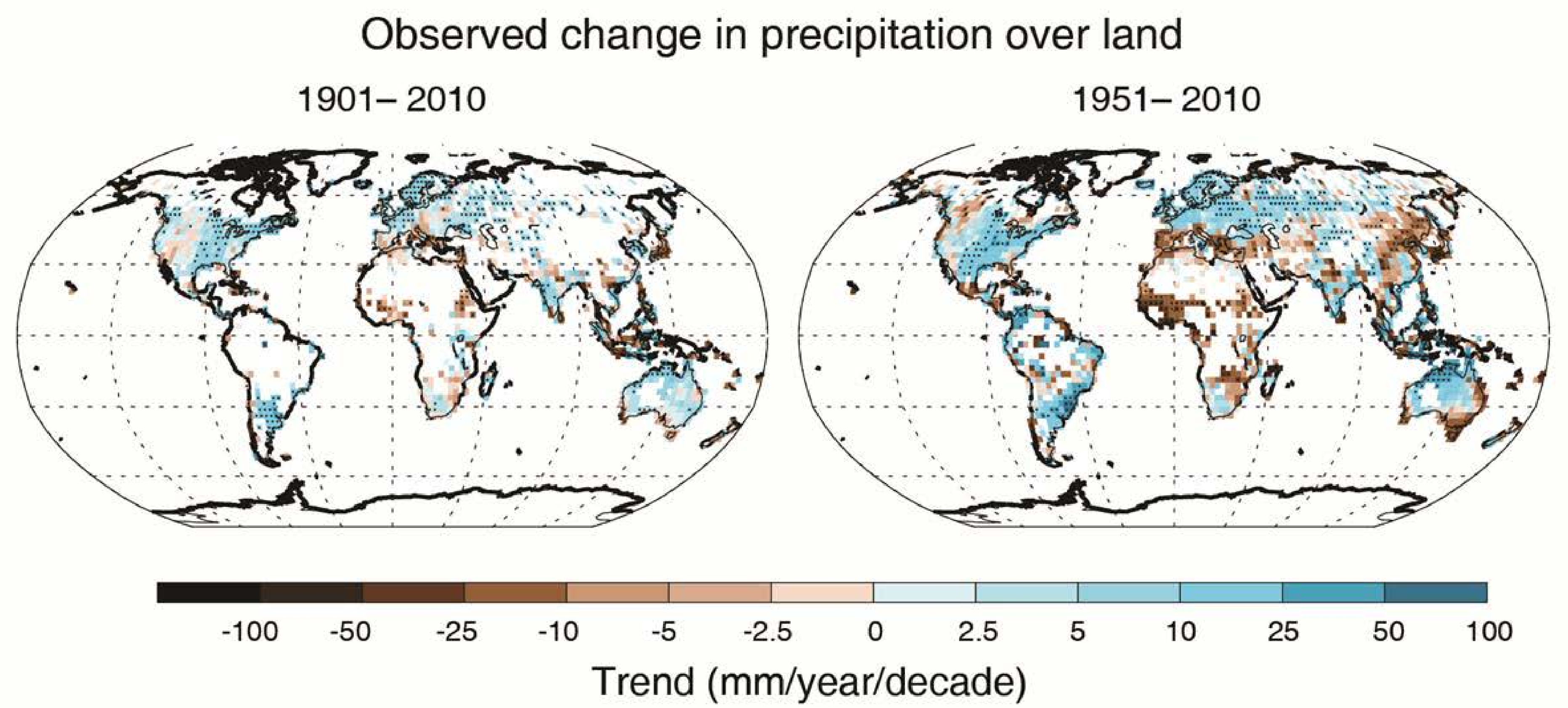
Research gaps (IPCC 2014)

- Socioeconomic and environmental tradeoffs of biofuel production, especially the effect on land use change and food and livelihood security; better agronomic characterization of biofuel crops to avoid
- maladaptive decisions with respect to biofuel production
- vulnerability to and impacts of climate change on food systems (production, transport, processing,storage, marketing and consumption)
- impacts of climate change on urban food security, and dynamic of rural-urban linkages in vulnerability and adaptive capacity
- impacts of climate change on food safety and quality

IPCC 2013



(a)
Observed globally averaged combined land and ocean surface temperature anomaly1850–2012
Annual average
Decadal average
Anomaly (°C) relative to 1961-1990
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
1850
1900
1950
2000
Year
(b)
Observed change in average surface temperature 1901–2012
-0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1.0 1.25 1.5 1.75 2.5
Trend (°C over period)



Observed change in precipitation over land
1901– 2010
1951– 2010
-100
-50
-25
-10
-5
-2.5
0
2.5
5
10
25
50
100
Trend (mm/year/decade)

IPCC 2013

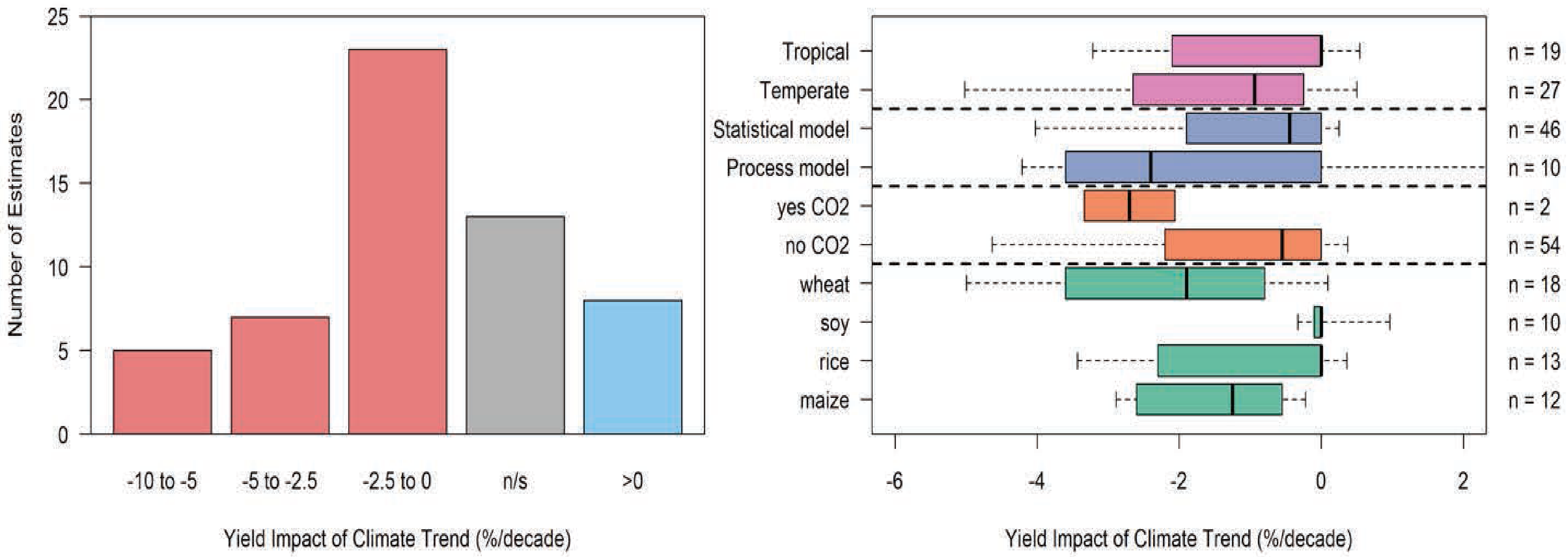


Figure 7-2: Summary of estimates of the impact of recent climate trends on yields for four major crops. Studies were taken from the peer-reviewed literature and used different methods (i.e., physiological process-based crop models or statistical models), spatial scales (stations, provinces, countries, or global), and time periods (median length of 29 years). Some included effects of positive CO2 trends (7.3.2.1.2) but most did not. (a) shows number of estimates with different level of impact (% yield per decade), (b) shows boxplot of estimates separated by temperate vs.tropical regions, modelling approach (process-based vs. statistical), whether CO2 effects were included, and crop.

From IPCC 2014

History of food prices (IPCC 2014, ch 7)

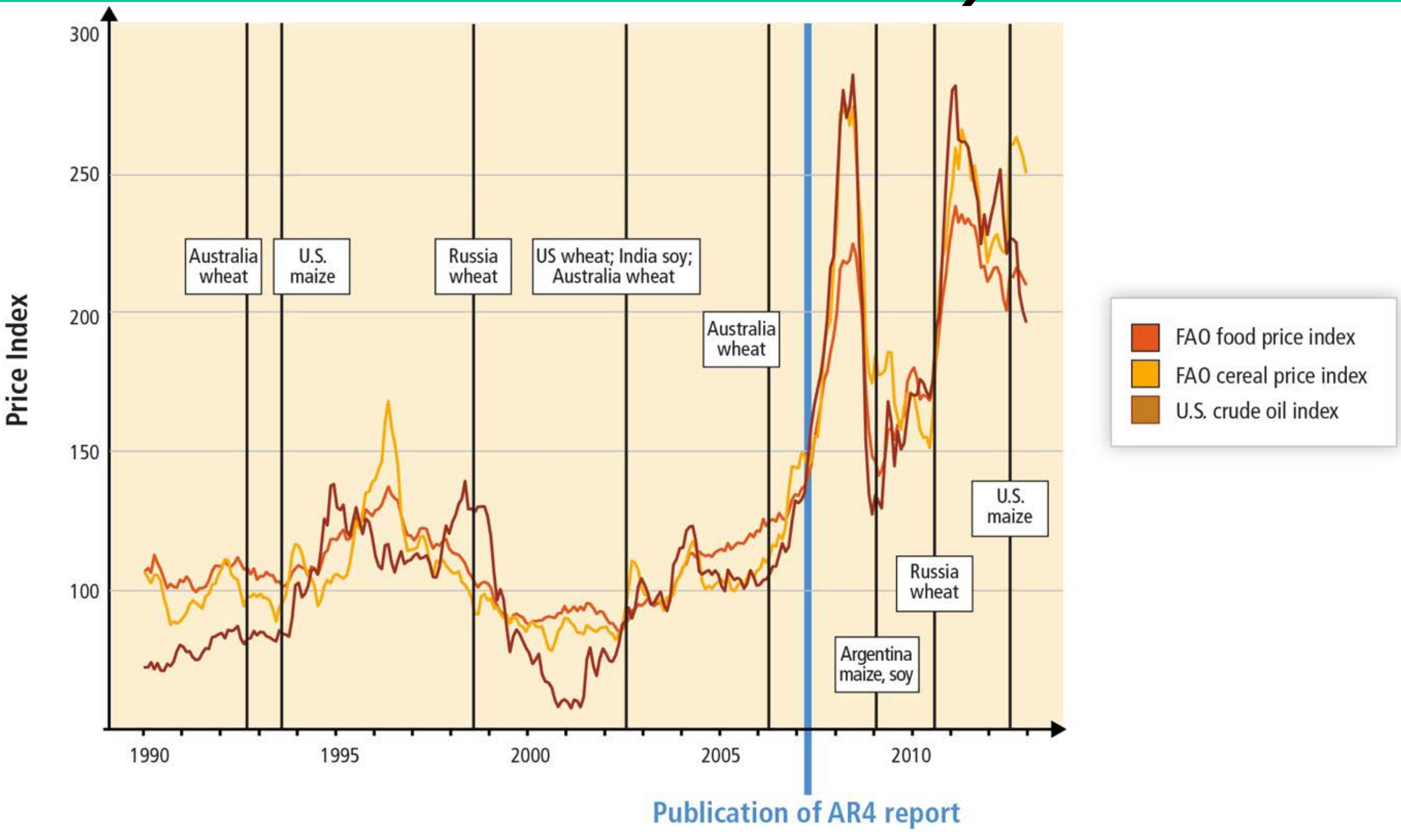
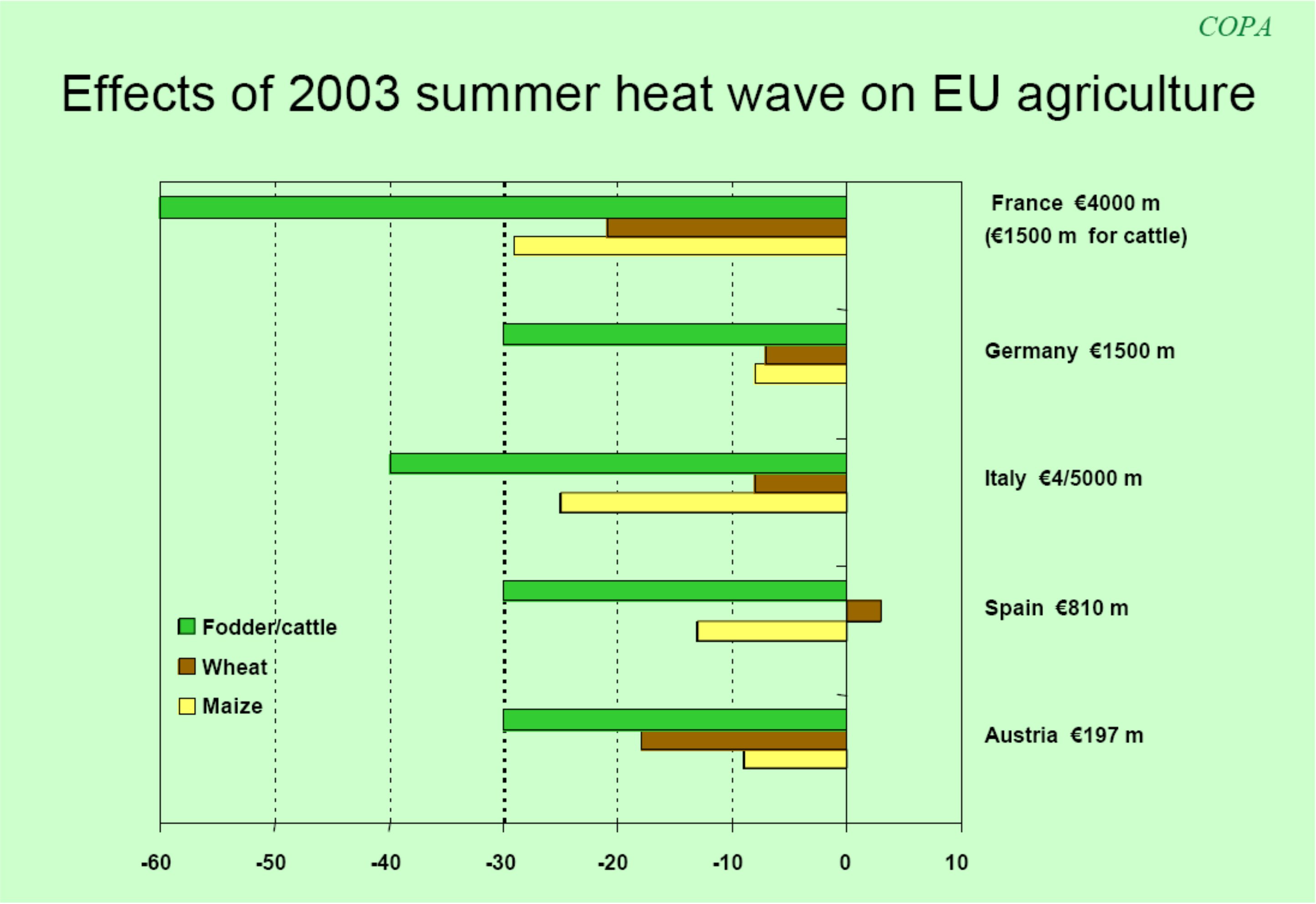
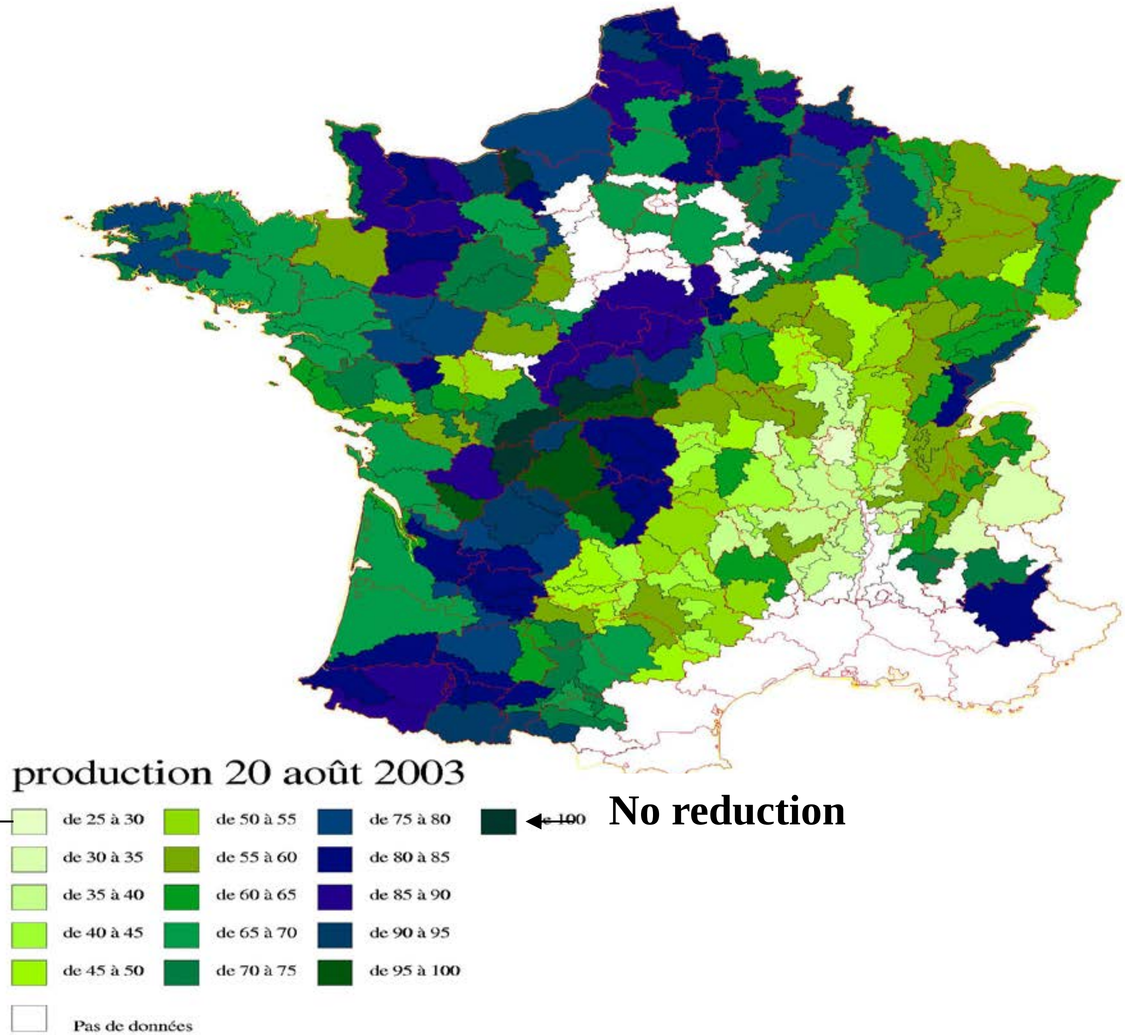


Figure 7-3: Since the AR4 report, international food prices have reversed historical downward trend. Plot shows history of FAO food and cereal price index (composite measures of food prices), with vertical lines indicating events when a top 5 producer of a crop had yields 25% below trend line (indicative of a seasonal climate extreme).


COPA
Effects of 2003 summer heat wave on EU agriculture
France €4000 m
(€1500 m for cattle)
Germany €1500 m
Italy €4/5000 m
Spain €810 m
Austria €197 m
Fodder/cattle
Wheat
Maize
-60
-50
-40
-30
-20
-10
0
10

Parry 2005

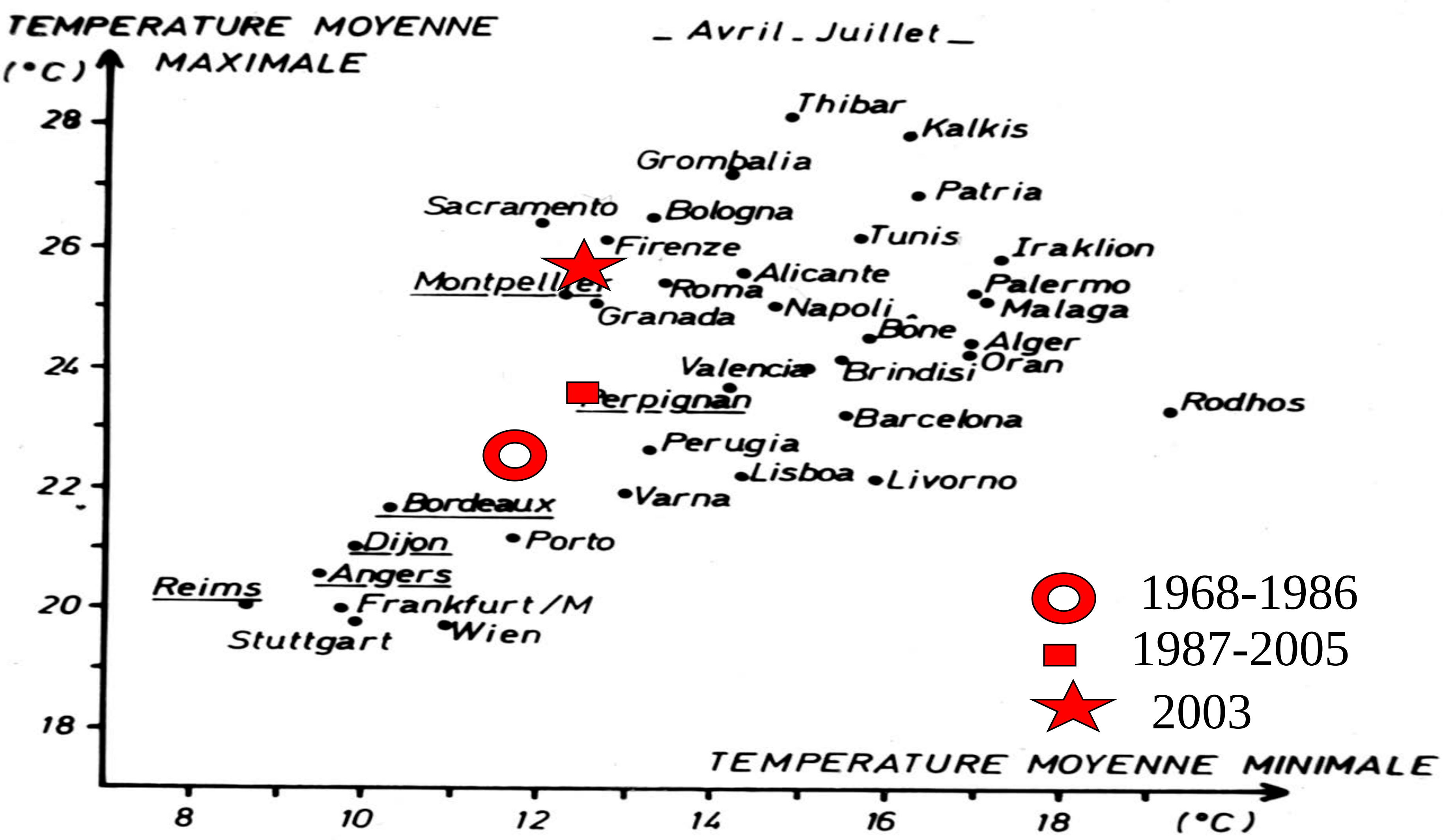
Reduction in pasture cumulative production related to the previous 15 yr mean-value



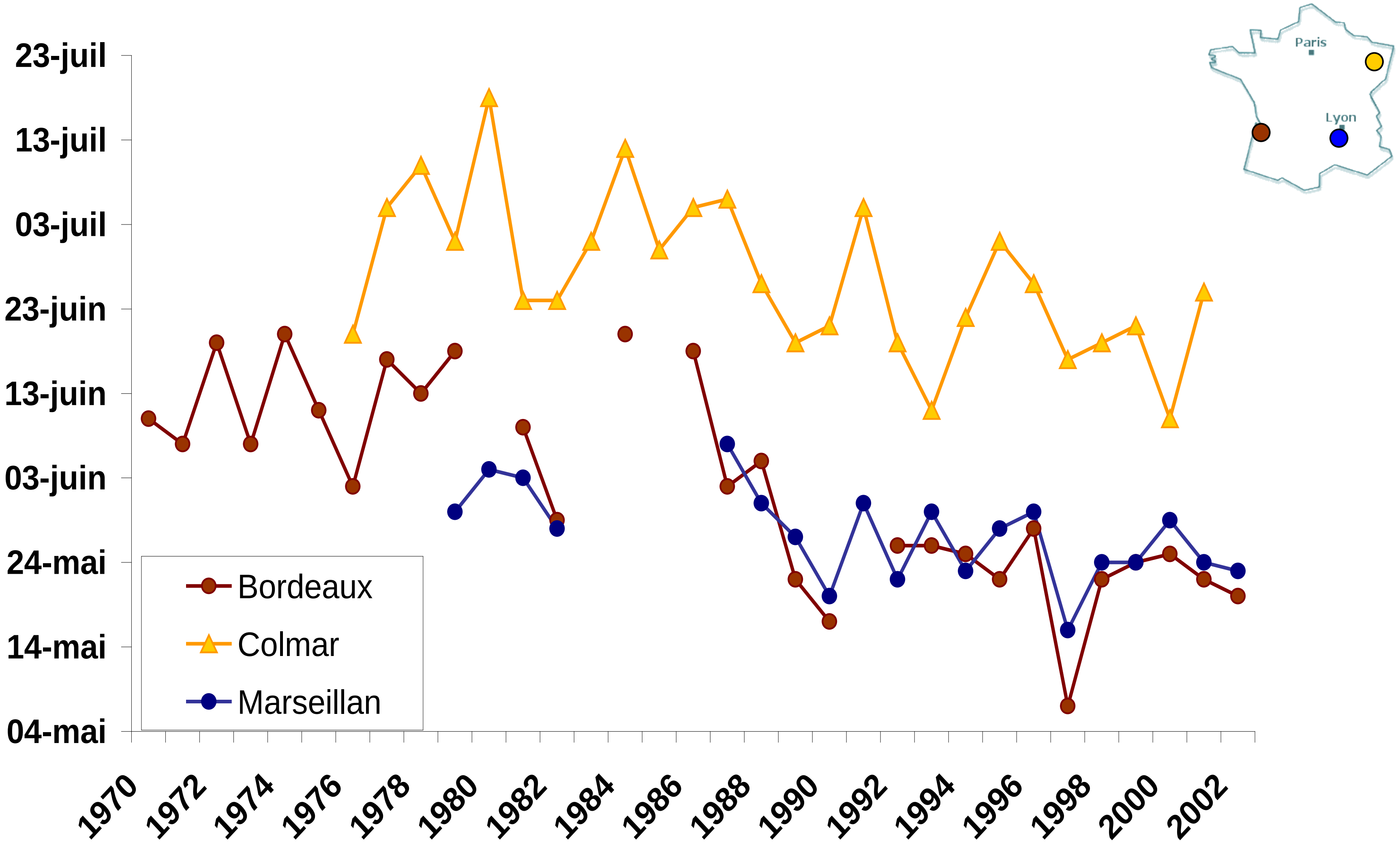
-25-30 % ← de 25 à 30

No reduction ← 100

The recent changes



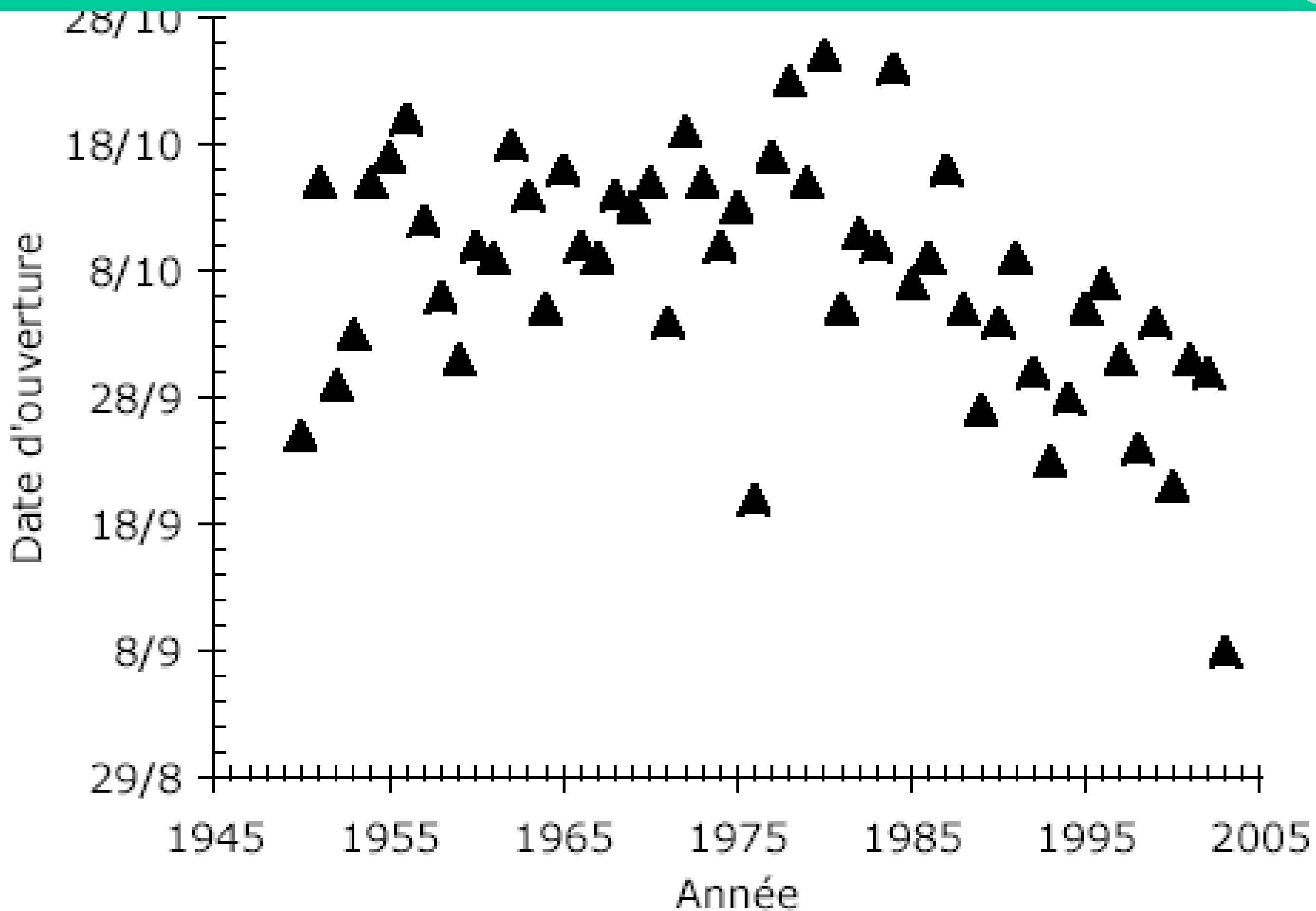
Observed trends in phenology



Flowering of Chasselas

Observed trends in harvest date

Alsace



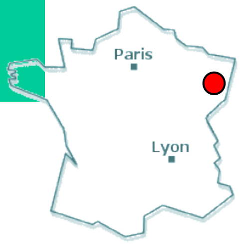
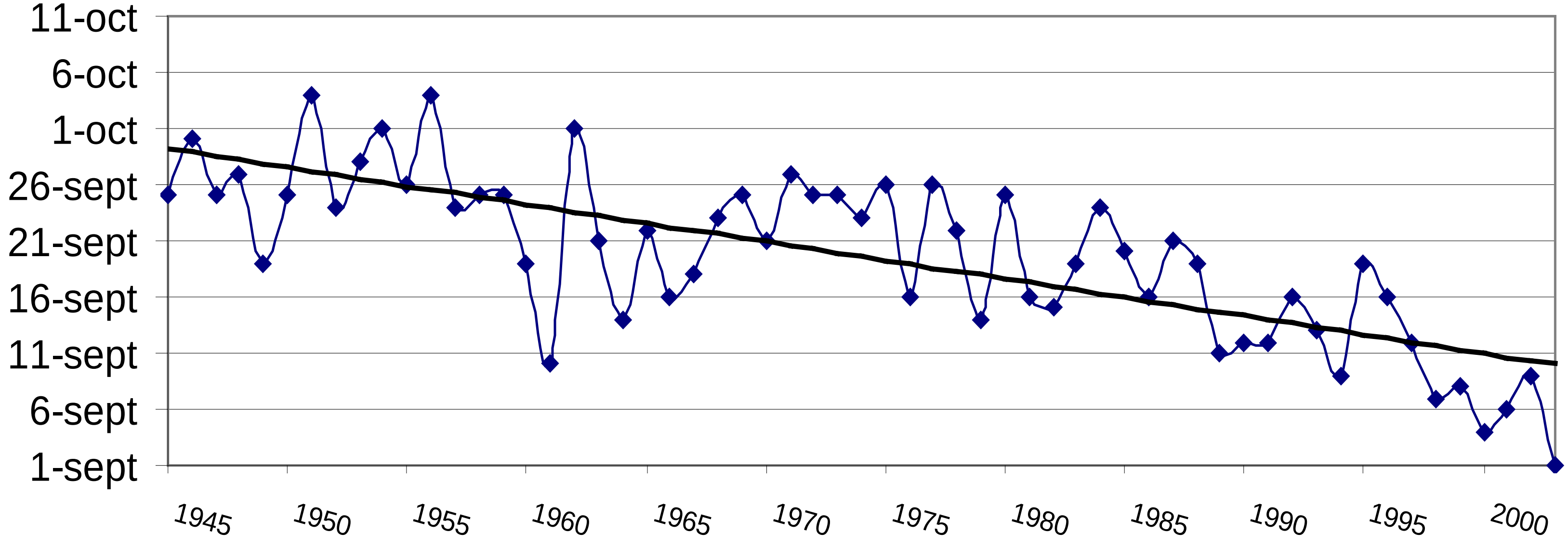


Figure 5 : Date d'ouverture des vendanges en Alsace. Source ITV Alsace.

Duchêne, 2004

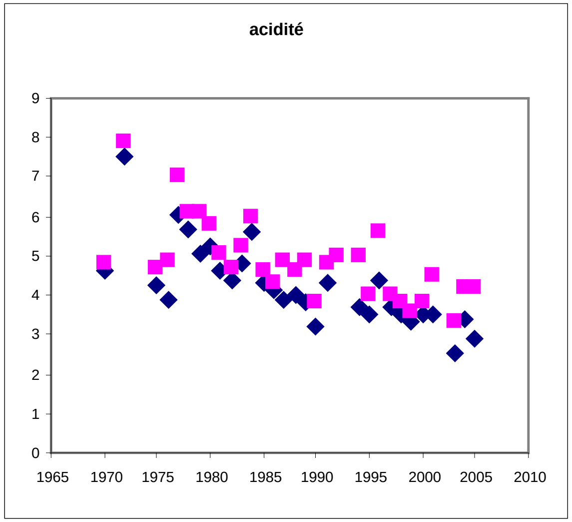
Observed trends in harvest date Côtes-du-Rhône

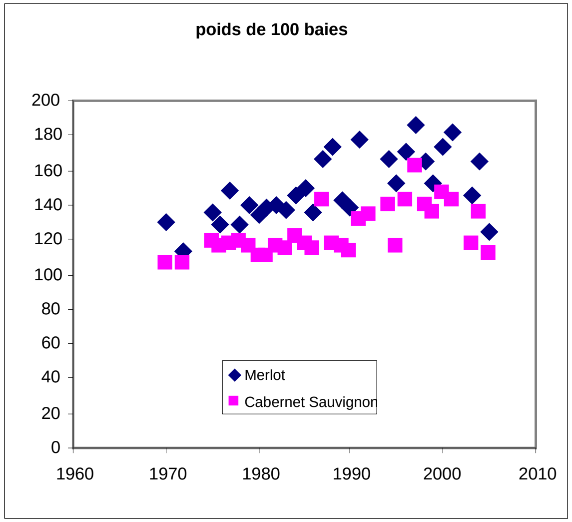
DATE DE DEBUT VENDANGES A CHATEAUNEUF DU PAPE depuis 1945

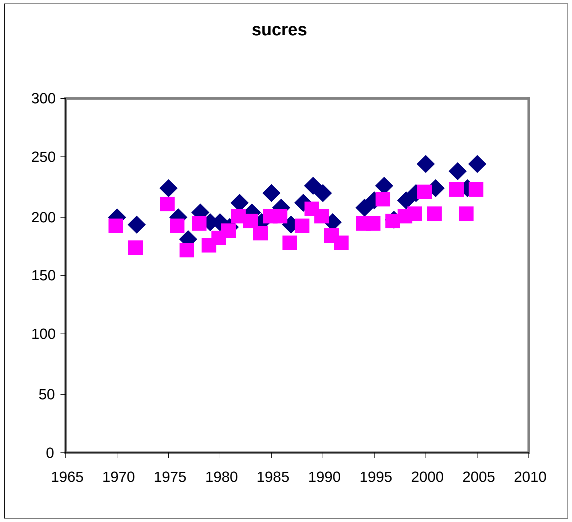


Ganichot, 2002

Sugar content is increasing , and acidity is decreasing

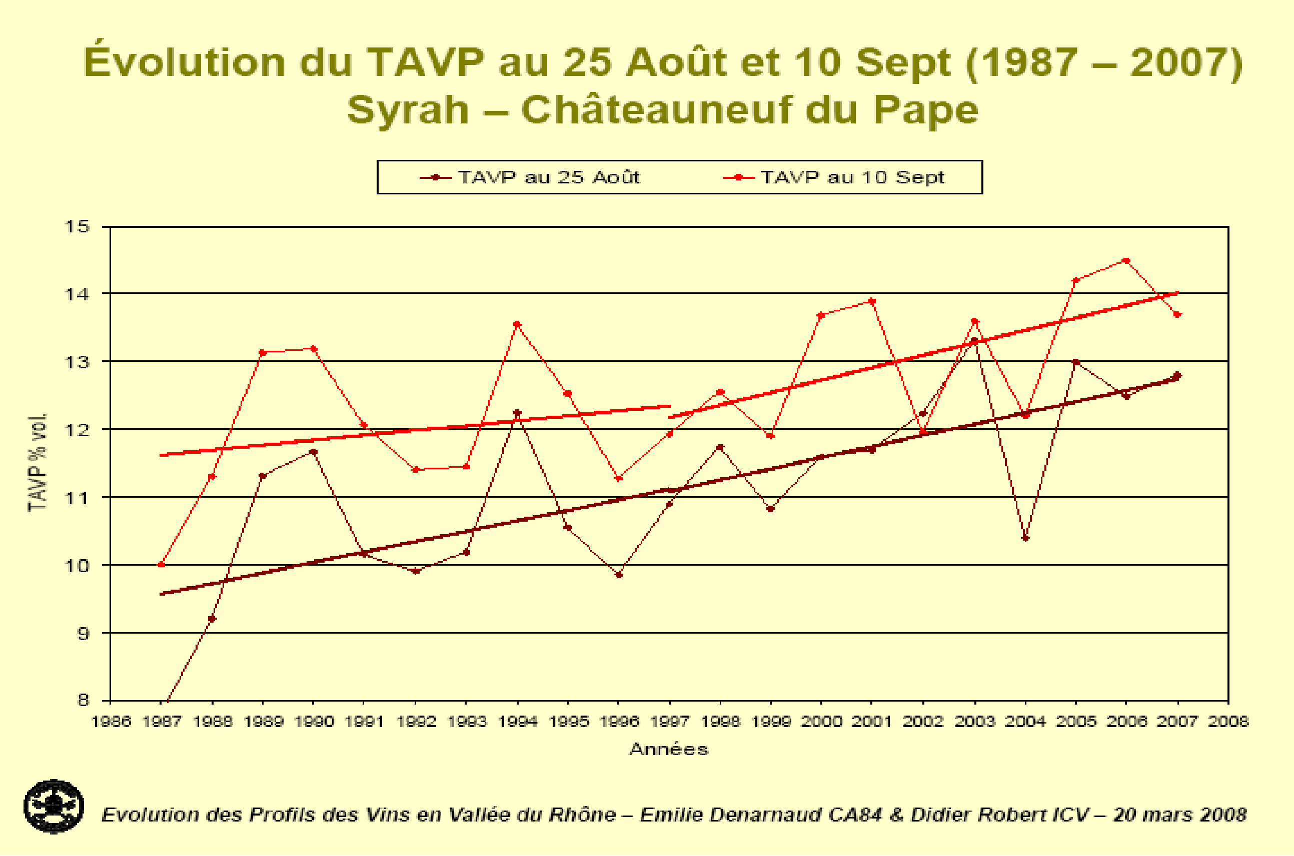






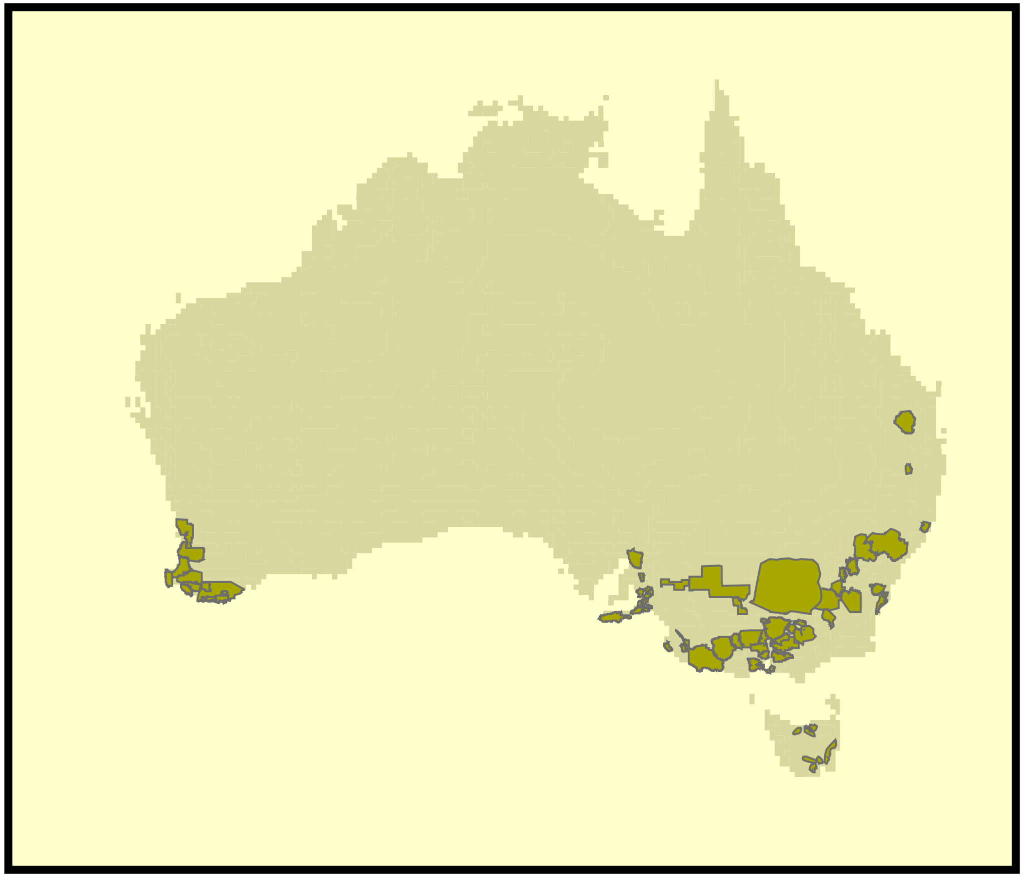
Bordeaux

A strong increase in alcoohol content



Côtes-du-Rhône

Results: Other Studies



Phenological Shifts vary by region and variety:

Budburst
6-13 days earlier by 2050

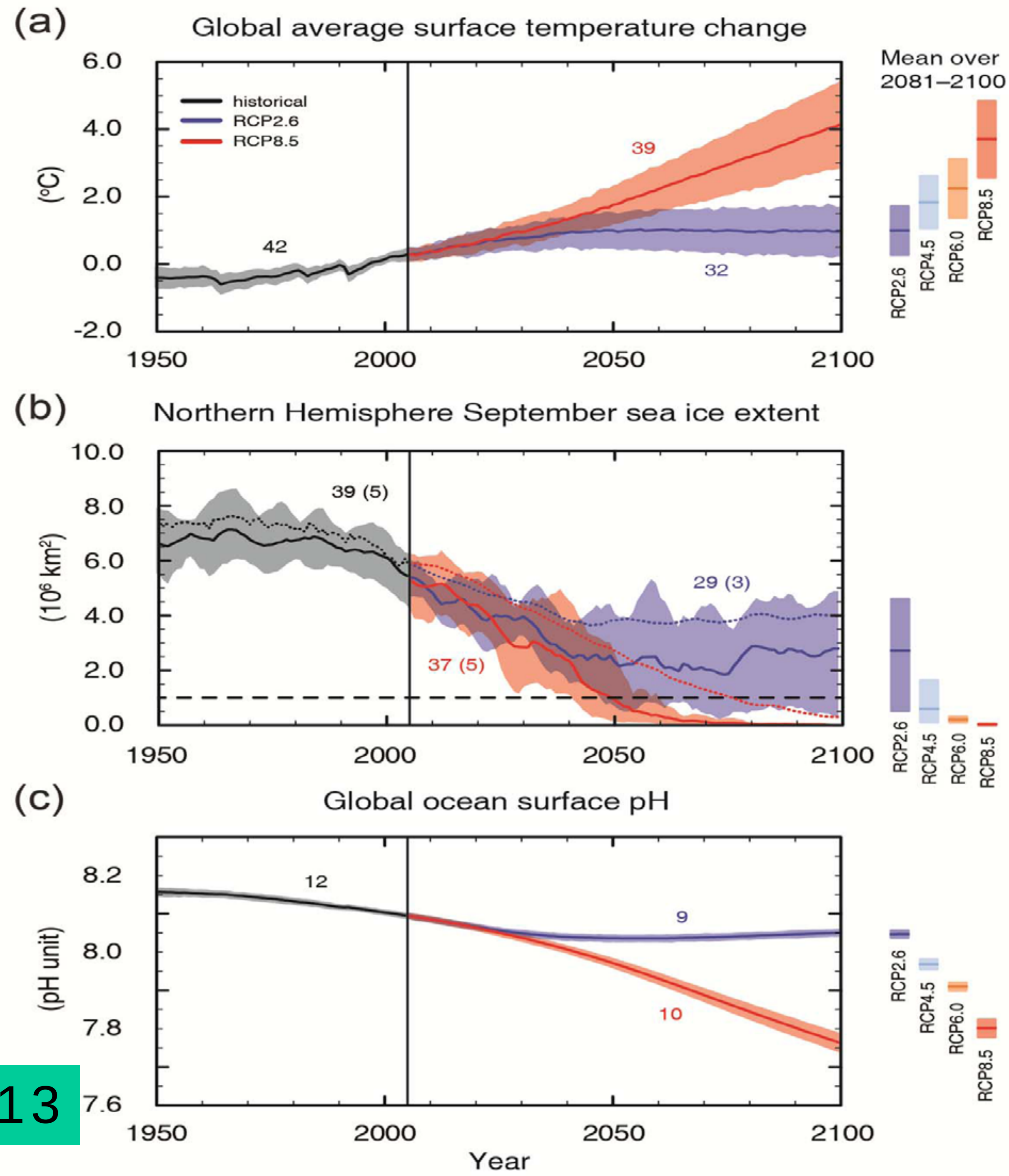
Harvest
9-18 days earlier by 2050

Season Duration
15-31 days earlier by 2050

Winegrape Quality impacts also vary by region and variety:

-12 to -57 percent by 2050

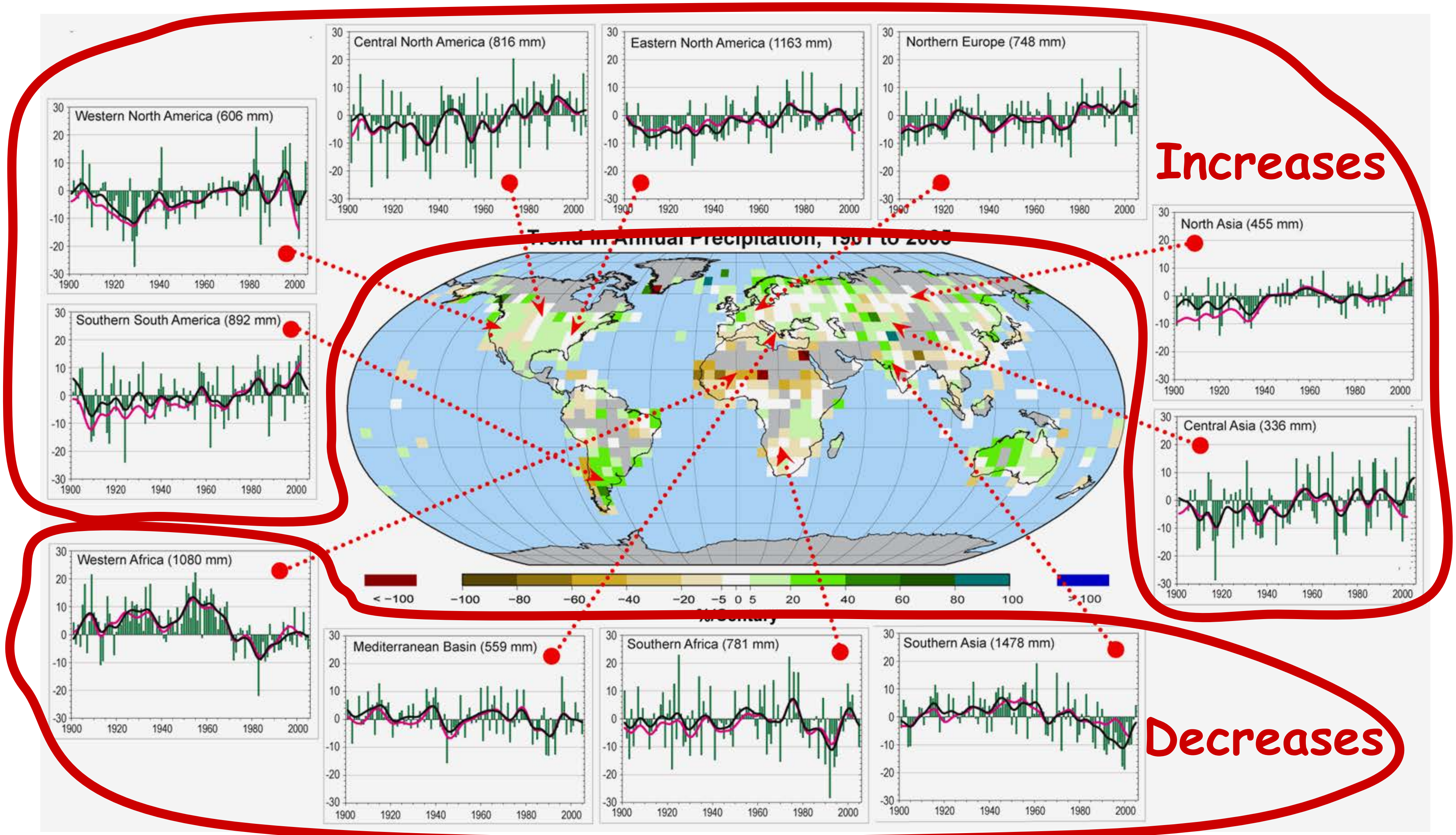
Webb's Phd - 2006



(a)
Global average surface temperature change
Mean over 2081–2100
historical
RCP2.6
RCP8.5
(°C)
6.0
4.0
2.0
0.0
-2.0
42
39
32
1950
2000
2050
2100
RCP2.6
RCP4.5
RCP6.0
RCP8.5
(b)
Northern Hemisphere September sea ice extent
(10^6 km^2)
10.0
8.0
6.0
4.0
2.0
0.0
39 (5)
29 (3)
37 (5)
1950
2000
2050
2100
RCP2.6
RCP4.5
RCP6.0
RCP8.5
(c)
Global ocean surface pH
(pH unit)
8.2
8.0
7.8
7.6
12
9
10
1950
2000
2050
2100
Year
RCP2.6
RCP4.5
RCP6.0
RCP8.5

IPCC 2013

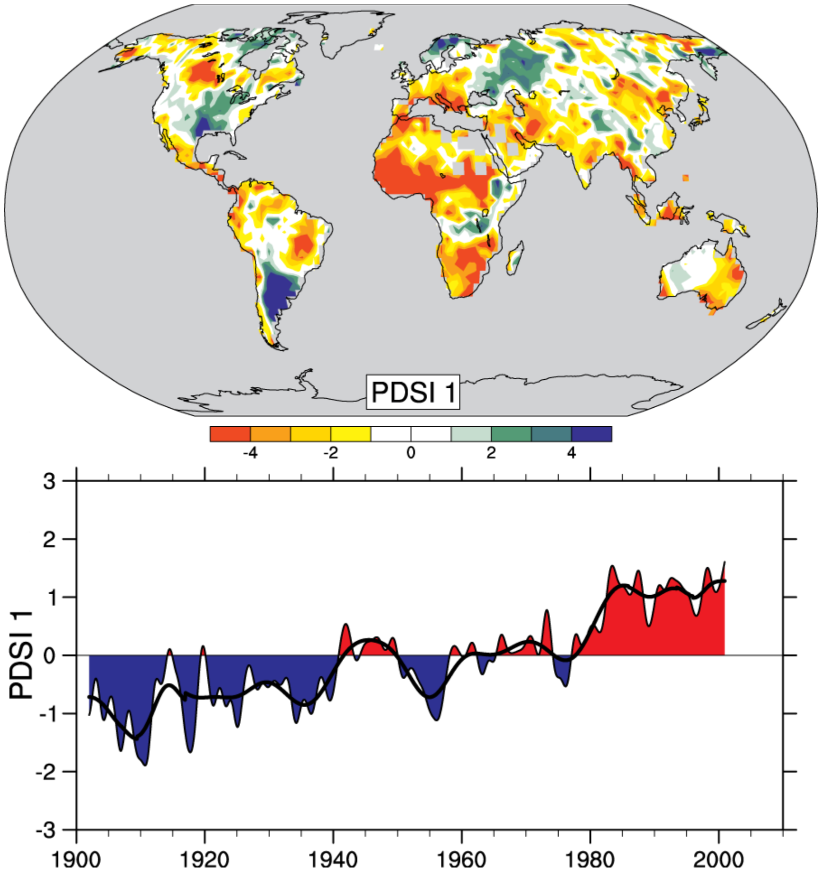
Land precipitation is changing significantly over broad areas



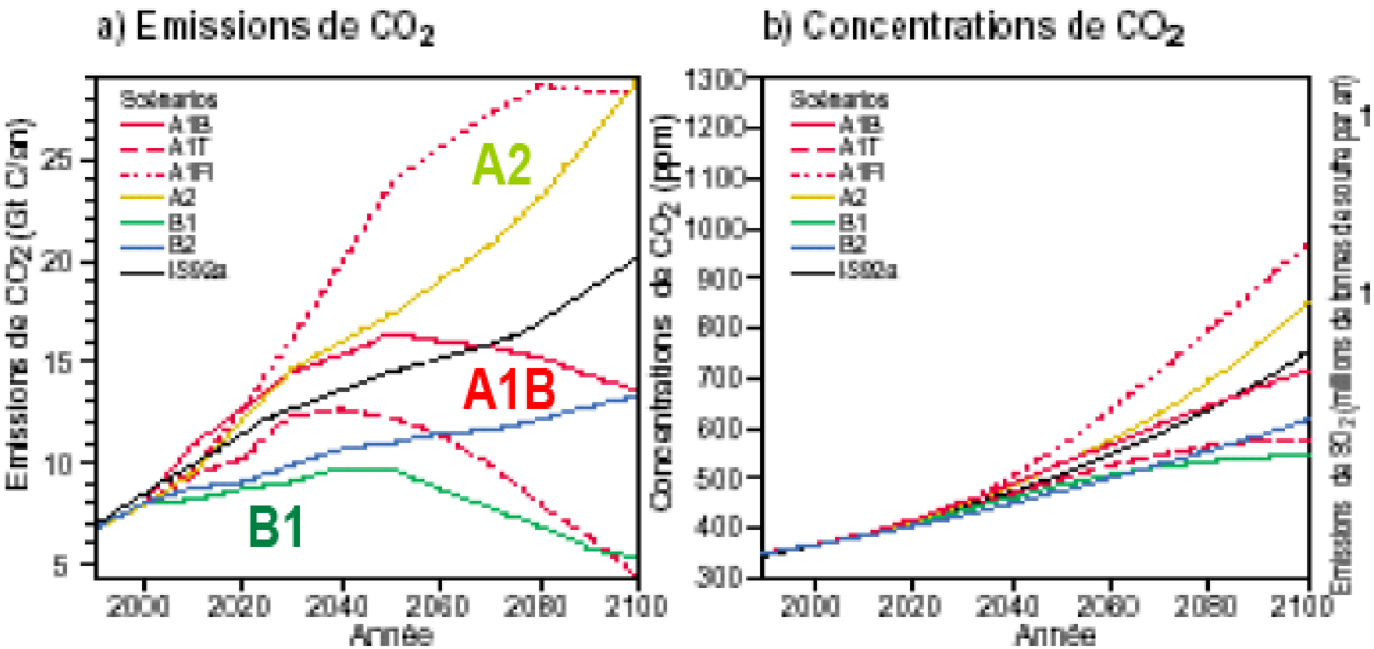
Smoothed annual anomalies for precipitation (%) over land from 1900 to 2005; other regions are dominated by variability.

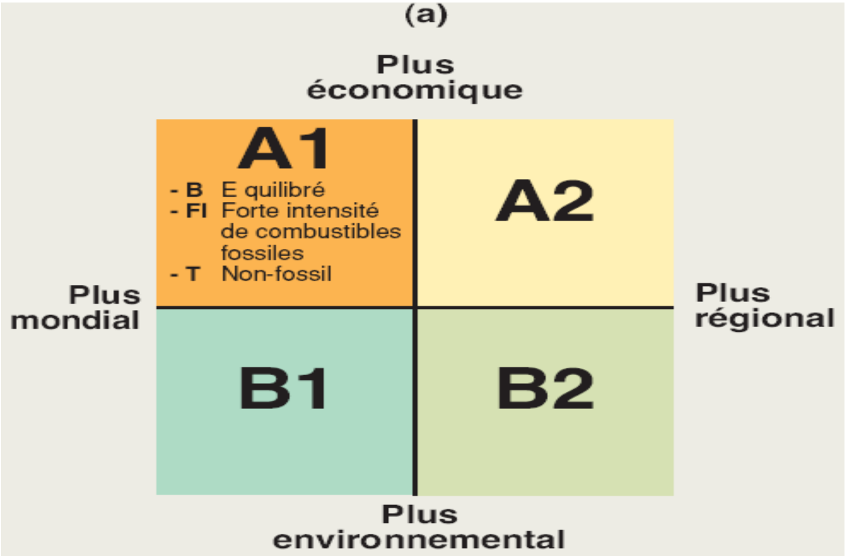
IPCC 2007

The extent of droughts



IPCC 2007





Jean Jouzel 2009

New scenarios (IPCC 2013)