X International Mango Symposium
3-7 June 2013, Punta Cana, Dominican Republic
Mango: Opportunities and Challenges in the 21st Century

Climate change and its probable impacts on mango production and cultivation

Frédéric Normand, Pierre-Eric Lauri, Jean-Michel Legave

cirad

INRA SCIENCE & IMPACT

Outline

1- What is climate change ?

2- What are the expected changes for the climate ?

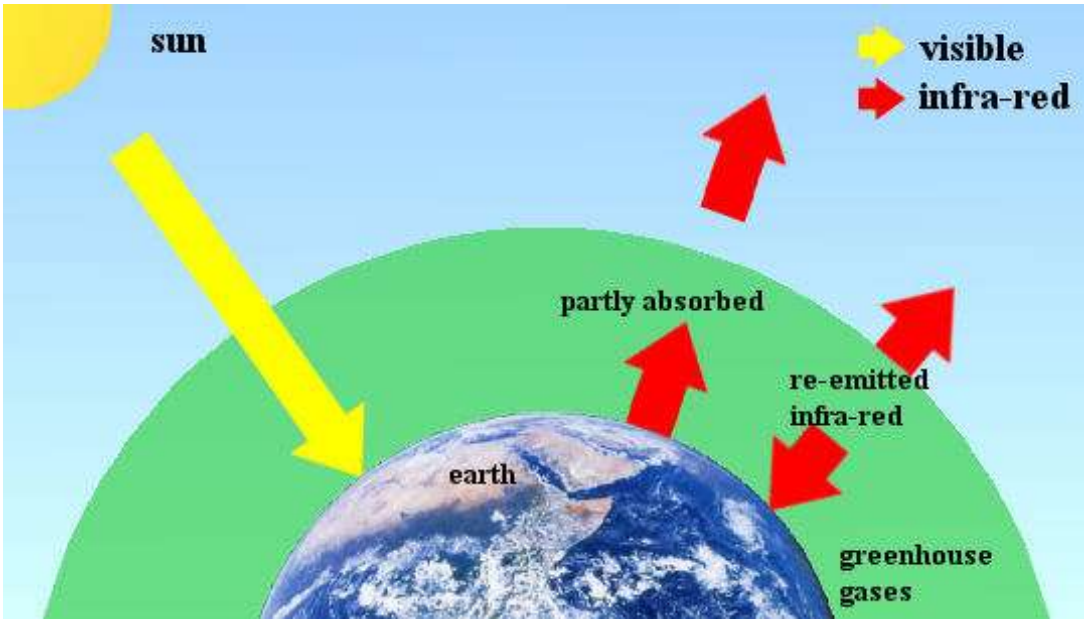
3- The effects of climatic variables on key processes for mango production

4- Expected consequences of climate change on mango cultivation

5- How to adapt mango cultivation to climate change ?

6- Conclusion

The greenhouse effect



- **It is a natural phenomenon**
- **but more greenhouse gases**
  - **→ higher atmospheric and earth temperatures**
  - **→ physical atmospheric disturbance**
  - **→ climate change**

Climate change : climatic changes expected further to the increase of atmospheric concentration of greenhouse gases.

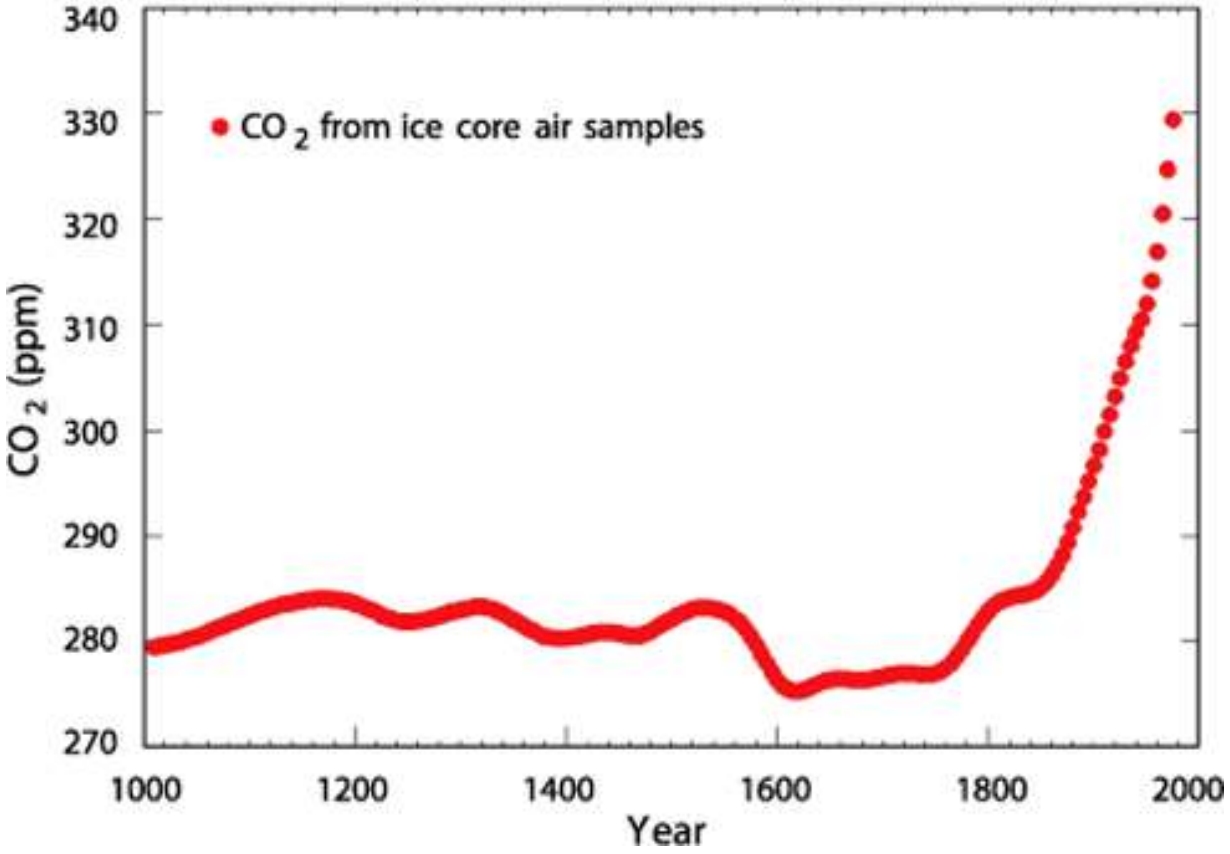
H_2O

CO_2 

CH_4

NO_2

O_3



(CSIRO Atmospheric Research)

The keywords of climate change

- The **effects** : what is predicted, expected

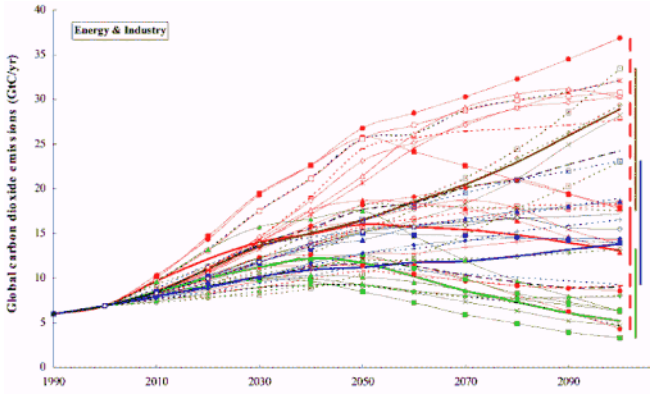
- The **impacts** : what is observed, proved, demonstrated

- The **consequences and risks** resulting from climate change

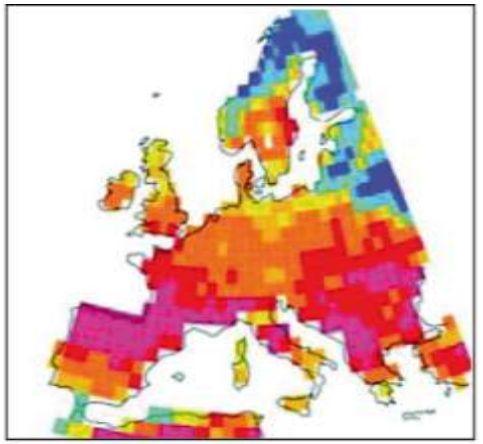
- The **adaptation** : means to adapt a situation to the climate change

- The **mitigation** : means to reduce greenhouse gases emission

The effects of climate change

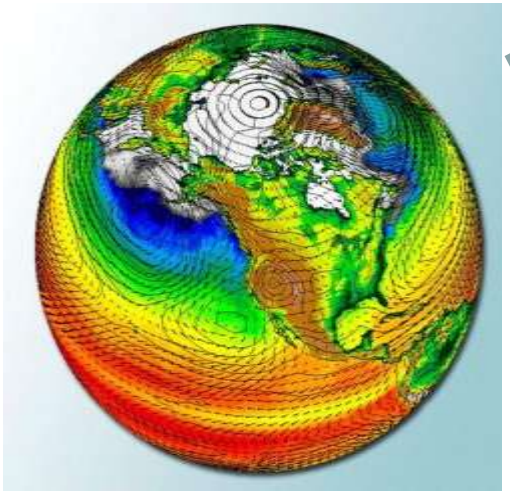


greenhouse gases emission scenarios

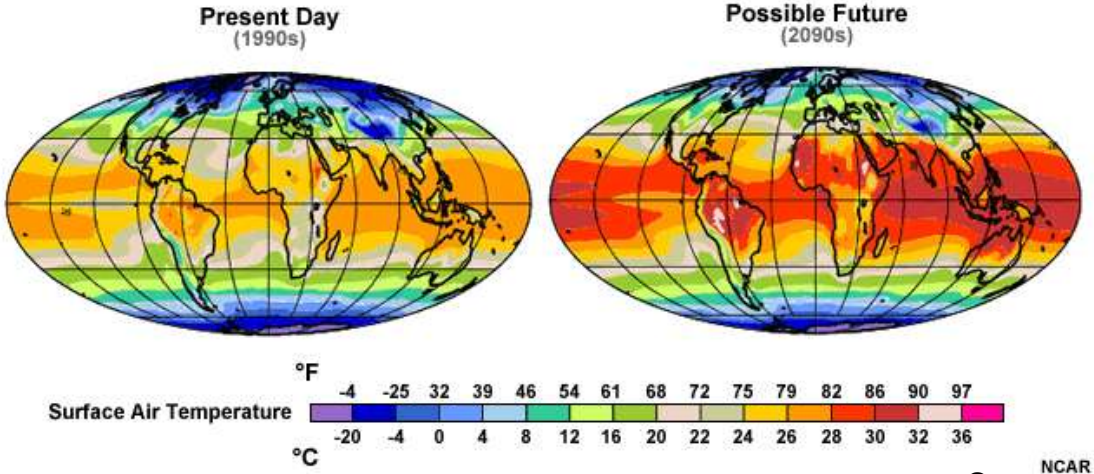


Predicted regional climate change

Regional Climate Models (RCM)



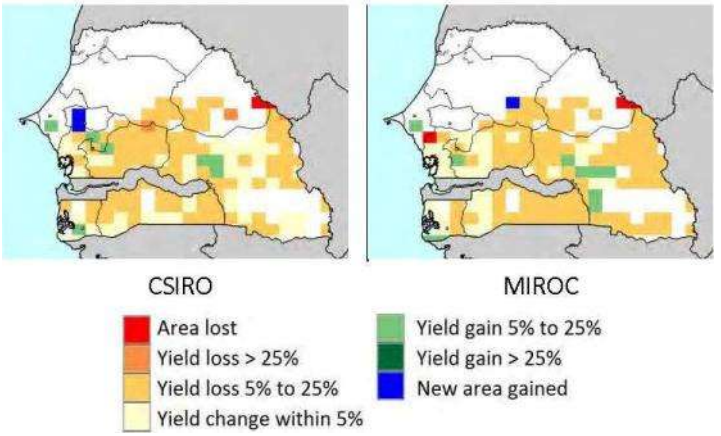
Global Climate Models (GCM)



Predicted global climate change

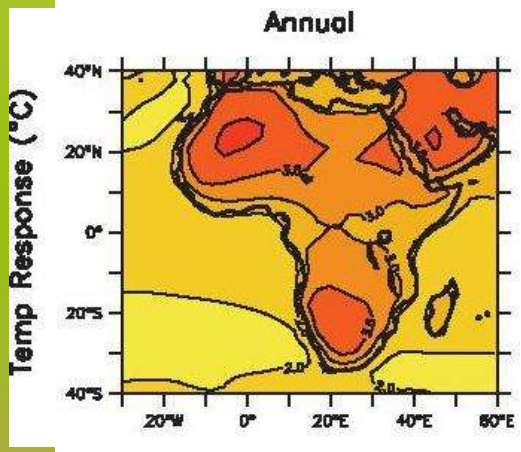
The effects of climate change

Predicted changes of groundnut yield in Senegal



(Khouma et al 2012 IFPRI)

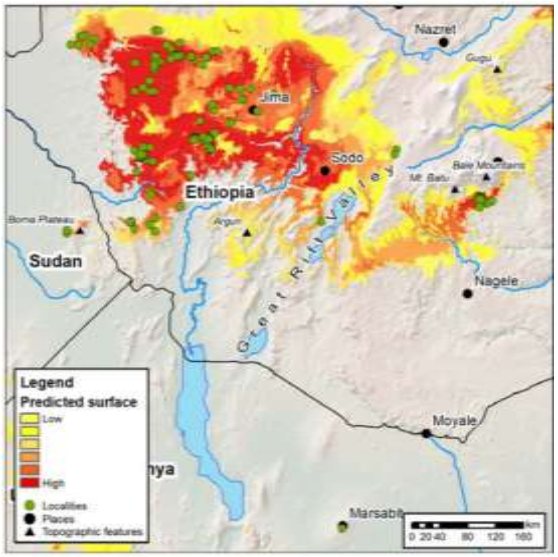
Crop models



Predicted regional climate change

(IPCC 2007)

Bioclimatic models



Predicted changes of suitable areas for Arabica coffee in Ethiopia

(Davis et al 2012 Plos One)

The impacts of climate change

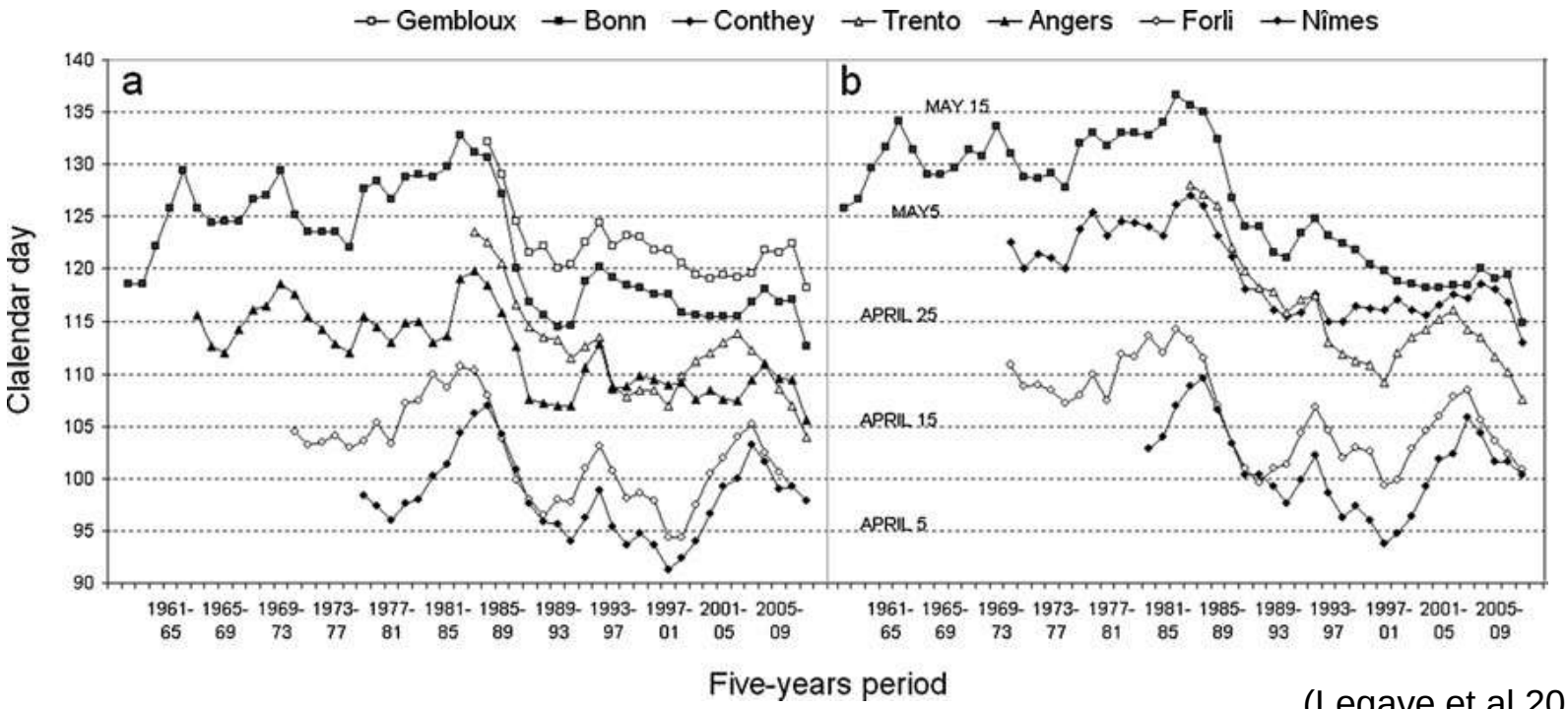
Different kinds of indicators: physical, biological, social

Ex: set of 24 indicators in France (ONERC, 2010):

- **Atmosphere and climate**
- **Cryosphere**
- **Biodiversity and marine ecosystems**
- **Biodiversity and terrestrial ecosystems**
- **Water**
- **Agriculture and forest**
- **Health and society**

The impacts of climate change

Agriculture and forest

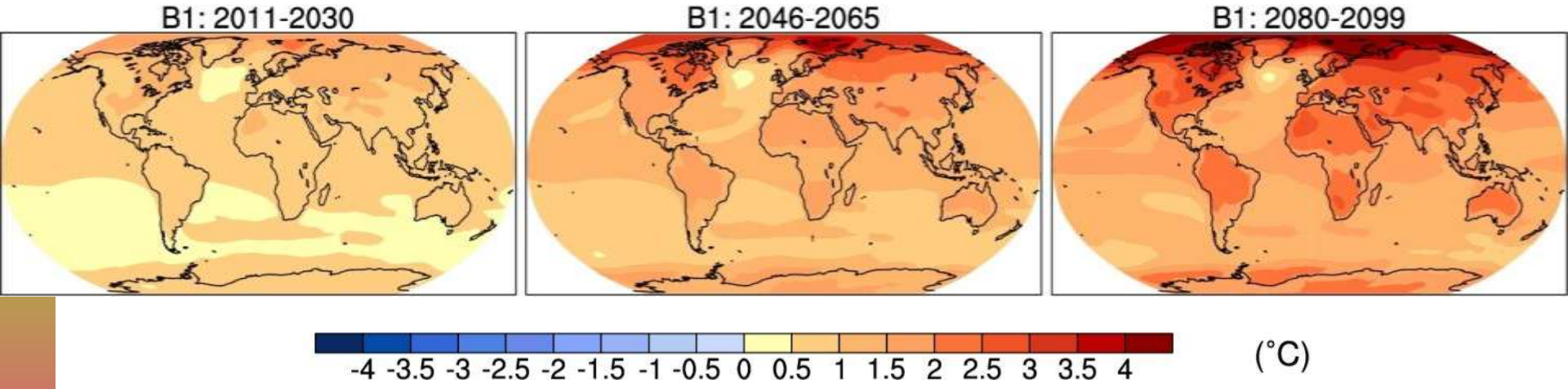


(Legave et al 2013)

Annual dates of two blooming stages (Fig a and b) in Golden Delicious apple at six sites in Europe

Expected changes are global, with a regional and seasonal variability

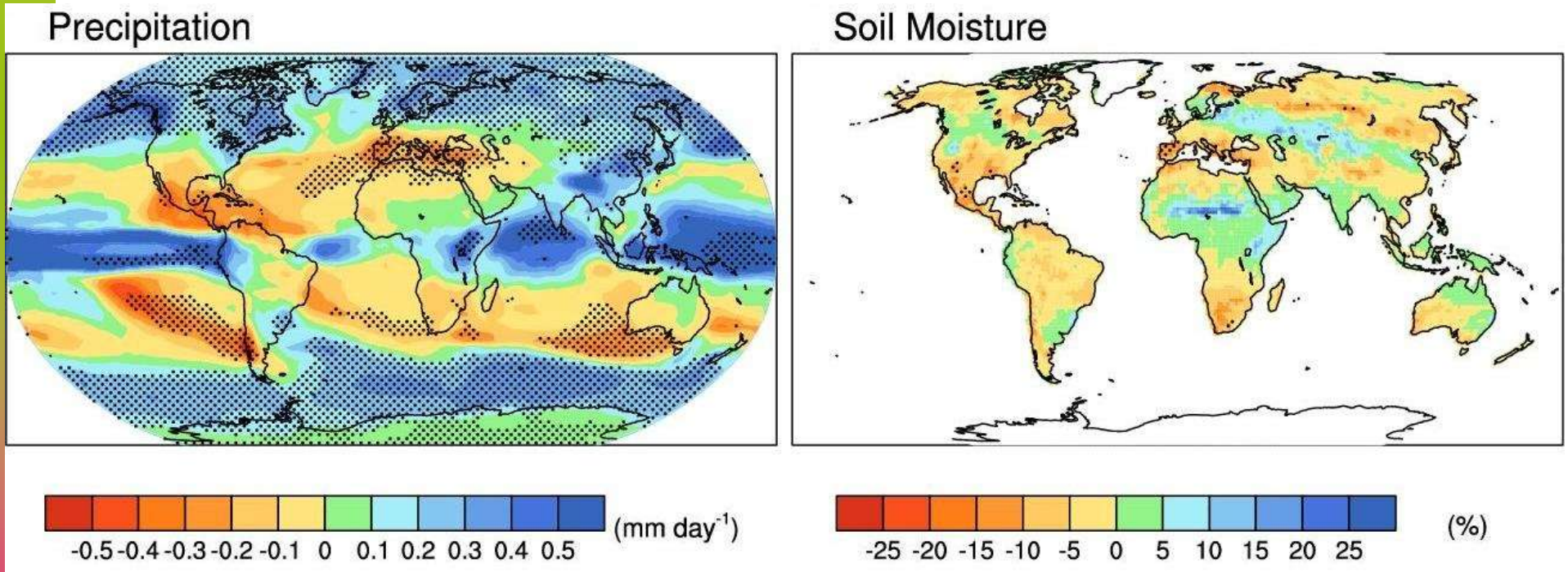
- ↗ temperature (+2 C → +4 C)



(IPCC 2007)

Expected changes are global, with a regional and seasonal variability

- ↗ **drought**



(IPCC 2007)

Expected changes impacting agriculture in the tropics

- ↗ temperature (+2 C → +4 C)
- ↗ drought
  - ↗ vapor pressure deficit (VPD)
- ↗ sea level
  - loss of arable land
  - ↗ soil and water salinity
- ↗ frequency of extreme events
- ↗ [CO_2]

Can we predict the effects of climate change on mango?

- **partial models are available:**
  - **photosynthesis** (Urban et al., 2003)
  - **stomatal conductance** (Damour et al., 2010)
  - **fruit growth and quality build-up**

    (Léchaudel et al., 2005, 2007)
  - **thermal time models: relationships between temperature and development**

    (Mosqueda-Vazquez et al., 1993; Dambreville et al., 2013)

- **but lack of a complete crop model for mango**

Can we predict the effects of climate change on mango?

- **partial models are not sufficient to predict the effects of climate change on mango**

- **need for a complete mango crop model,**

- **or better: a model of the cropping system including soil and pests**

- **what is possible : to assess the response of the mango tree to the predicted future climate, based on our current knowledge**

Assessing the response of the mango tree

- **photosynthesis**

- **vegetative development**

- **flowering**

- **fruit growth and quality**

Effect of climatic variables on photosynthesis

Variable	Expected change	Expected effect on photosynthesis
Temperature	increase	+
Light	increase	+ / -
$[CO_2]$	increase	+
VPD	increase	-
Drought	increase	-
Flooding	increase/decrease	-

Effect of climatic variables on photosynthesis

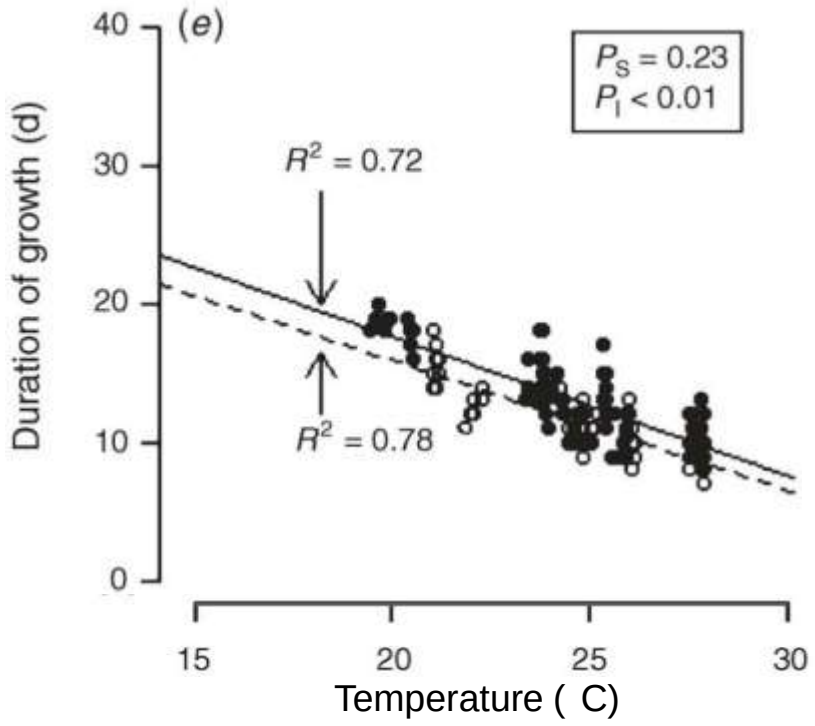
- **but**
  - **damaging effects on the photosynthesis machinery by :**
    - extreme temperatures (> 45 C)
    - high levels of light intensity
  - **counterbalanced effects of higher temperature and [CO_2]:**
    - increased photosynthetic assimilation
    - increased respiratory losses

Effect of climatic variables on vegetative development

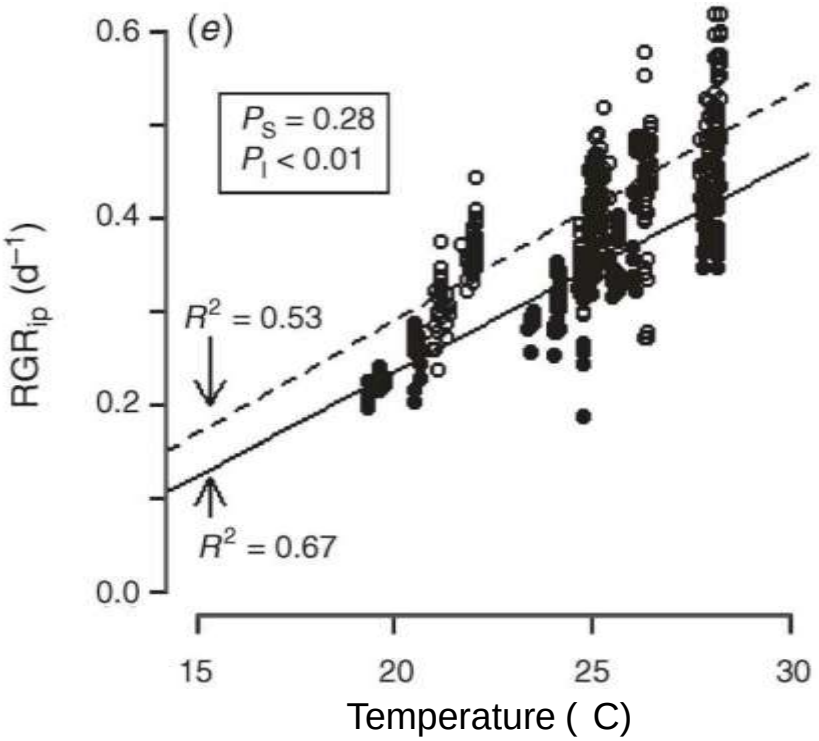
Variable	Expected change	Expected effect on vegetative development
Temperature	increase	More rapid growth rythm, no growth cessation, (larger GUs and leaves)
[CO_2]	increase	DM allocated to the roots
Drought	increase	- (reduced tree growth)
Flooding	increase/decrease	- (reduced tree growth, death)

Effect of temperature on the duration of growth and on the relative growth rate of leaves of two mango cultivars

Duration of growth



Relative growth rate



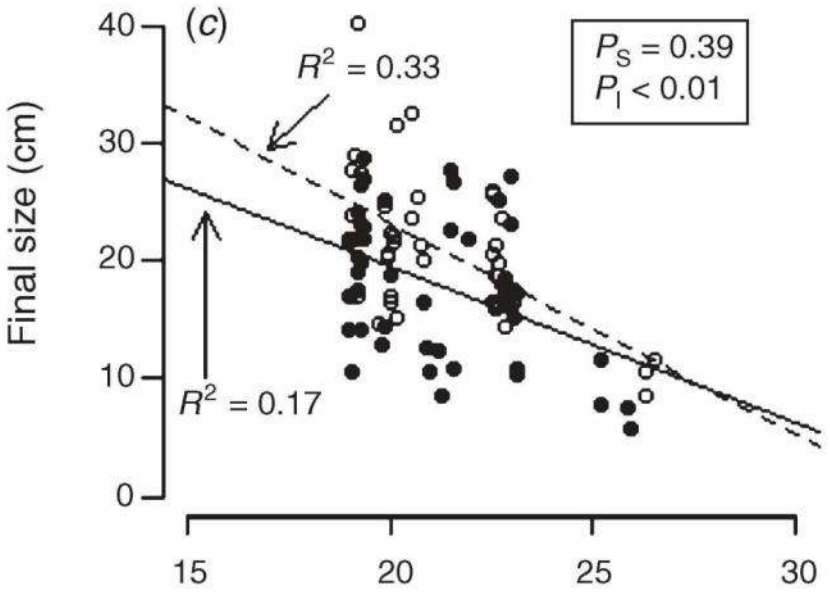
(Dambreville et al 2013 Functional Plant Biology)

Effect of climatic variables on flowering and fruit set

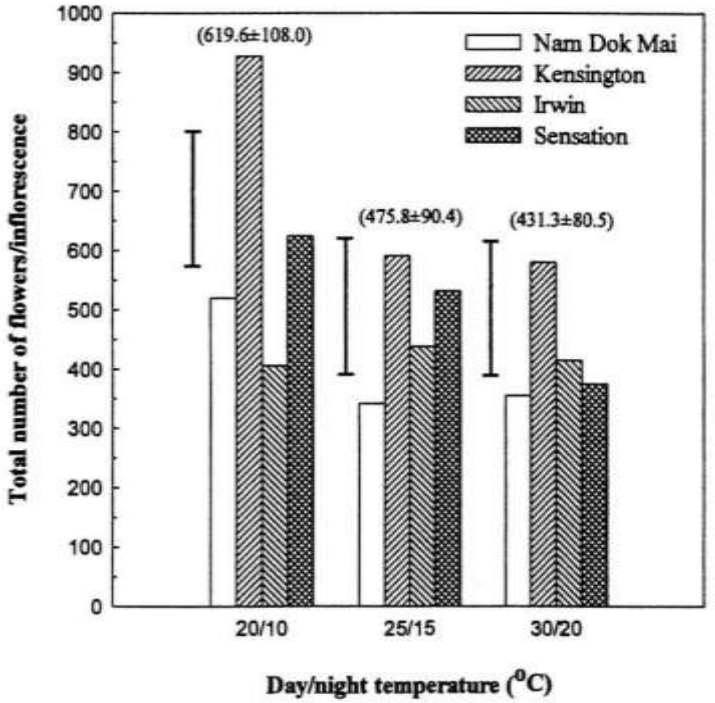
Variable	Expected change	Expected effect on flowering and fruit set
Temperature	increase	- (floral induction) + (pollen viability, fruit set)
Light	increase	+
VPD	increase	-
Drought	increase	+ (floral induction indirectly) - (fruit set and retention)

3- The effect of climatic variables on key processes for mango production

Negative effect of temperature on inflorescence size and number of flowers per inflorescence



(Dambreville et al 2013
Functional Plant Biology)



(Sukhvibul et al 1999
J. Hort. Sci. & Biotech)

Effect of climatic variables on fruit growth and quality

Variable	Expected change	Expected effect on fruit growth and quality
Temperature	increase	+ (more rapid growth) + / - (quality)
Light	increase	+ (skin color, quality, possibly size)
[CO_2]	increase	+
Drought	increase	- (size), + (quality)

Effect of the light on fruit color

Shaded fruit

gap fraction:0.09 0.01

Sunny fruit

gap fraction:0.66 0.03

(Léchaudel et al 2013
Journal Plant Physiology)

Conclusion

- difficult to draw clear conclusions on the response of the mango tree to each climatic variable

- interactions between variables
- effect of the tree phenological stage
- cultivar effect
- unknown optimal threshold value of these variables

-the current equation:

high temperature
+ low soil moisture
+ high evaporative demand

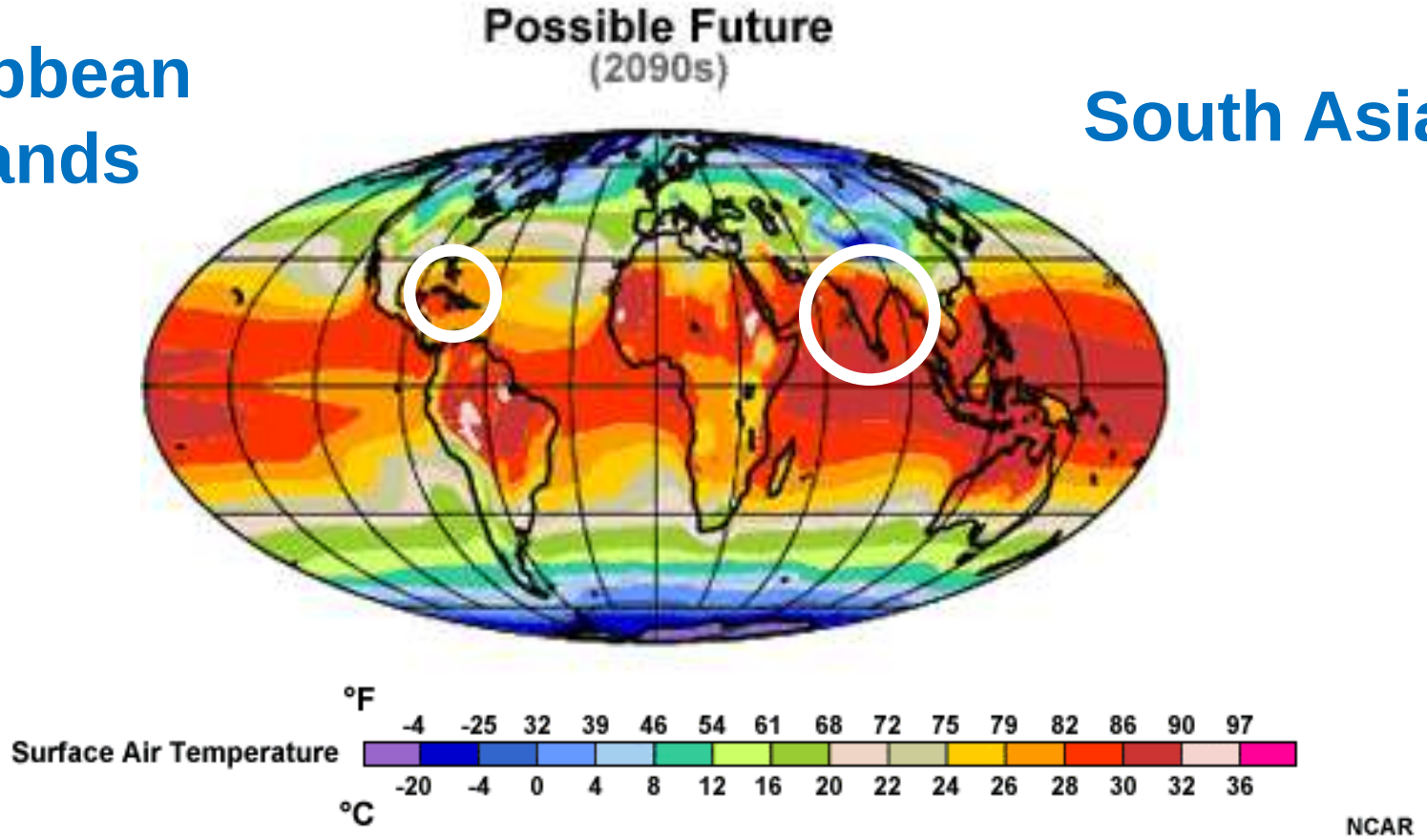
→ low yield

(Schaffer et al 2009 The Mango)

Two contrasted examples:

Caribbean islands

South Asia



South Asia

Months	Mango phenological stage	Changes in temperature (°C)	Changes in precipitation (%)
DJF	Flowering	+ 3.6	- 5
MAM	Fruit growth	+ 3.5	+ 9
JJA	Harvest / veg growth	+ 2.7	+ 11
SON	Veg growth / rest	+ 3.5	+ 15
annual	**-**	**+ 3.3**	**+ 11**

Regional median of temperature and precipitation projections in 2080-2099 from a set of 21 global models in the MMD for the A1B scenario. Reference: 1980-1999. (IPCC 2007)

- warmer winter
- wetter climate
- more extremely warm seasons
- more extremely wet seasons
- ↗ frequency and intensity of tropical cyclones

South Asia : expected effects on mango production

- **lower floral induction**
  - warmer winter
  - wetter climate during vegetative rest

- **good fruit growth but fruit quality reduced and probable pests and diseases problems**
  - hot and wet season

- **important vegetative growth**

- **increased damages by cyclones and flooding**

South Asia : probable consequences for mango cultivation

- **shift of mango cultivation areas toward the North or in altitude**

- **mango orchards established on slopes and not in the valleys or lowlands**

- **facultative irrigation**

- **intensive pruning**

Caribbean islands

Months	Mango phenological stage	Changes in temperature (°C)	Changes in precipitation (%)
DJF	Flowering	+ 2.1	- 6
MAM	Fruit growth	+ 2.2	- 13
JJA	Harvest / veg growth	+ 2.0	- 20
SON	Veg growth / rest	+ 2.0	- 6
annual	**-**	**+ 2.0**	**- 12**

- mean increase of temperature, regular along the year
- dryer climate (summer)
- more extremely warm seasons
- more extremely dry seasons
- no reliable data on frequency and intensity of hurricanes

Caribbean islands: expected effects on mango production

- **lower floral induction**
  - warmer winter

- **reduced fruit growth**

- **increased fruit quality**

- **reduced vegetative growth**

- **lower yields**

Caribbean islands: probable consequences for mango cultivation

- **shift of mango cultivation areas to the windward coast or in altitude**

- **less problems with pests and diseases**

- **irrigation needed**

- **reduced pruning**

- **high density orchards**

Some research ways to adapt mango cultivation to climate change

- **cultivar selection**
  - tolerance to drought, high temperature
  - floral induction at higher temperature

- **rootstock selection**
  - tolerance to drought, salinity
  - low vigor, but with strong root system

- **orchard management**
  - irrigation
  - favorable microclimate

Need for more knowledge

- **Stress physiology**
  - high temperature
  - drought
  - salinity

- **Early phenotyping methods for interesting selection criteria**

Need for international collaboration

- **References on climate and mango behavior**
  - international network
  - 1-2 common cultivars

- **Cultivar and rootstock selection**

- **Development of a mango crop model**

- **Climate change will have consequences on mango cultivation**

- **Not possible to draw a general scenario**
  - regional and seasonal variability
  - different cultivar responses

- **Be confident in the future of mango production**
  - species with ecological plasticity
  - mechanisms to cope with stressfull environment
  - large variability among genetic resources
  - global climate changes fit with mango requirements