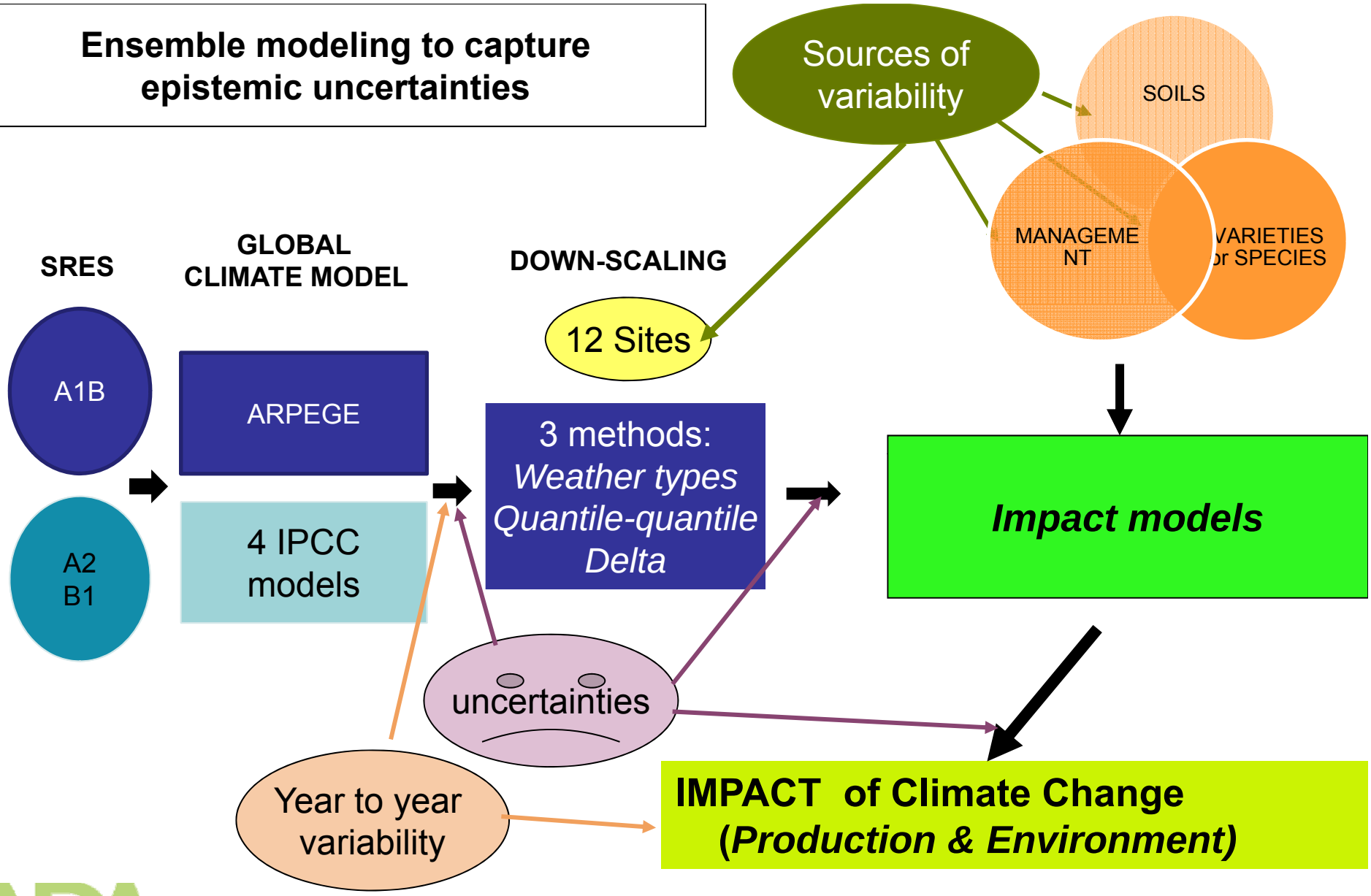
# Ensemble modeling to capture epistemic uncertainties




Baseline 1970-1999

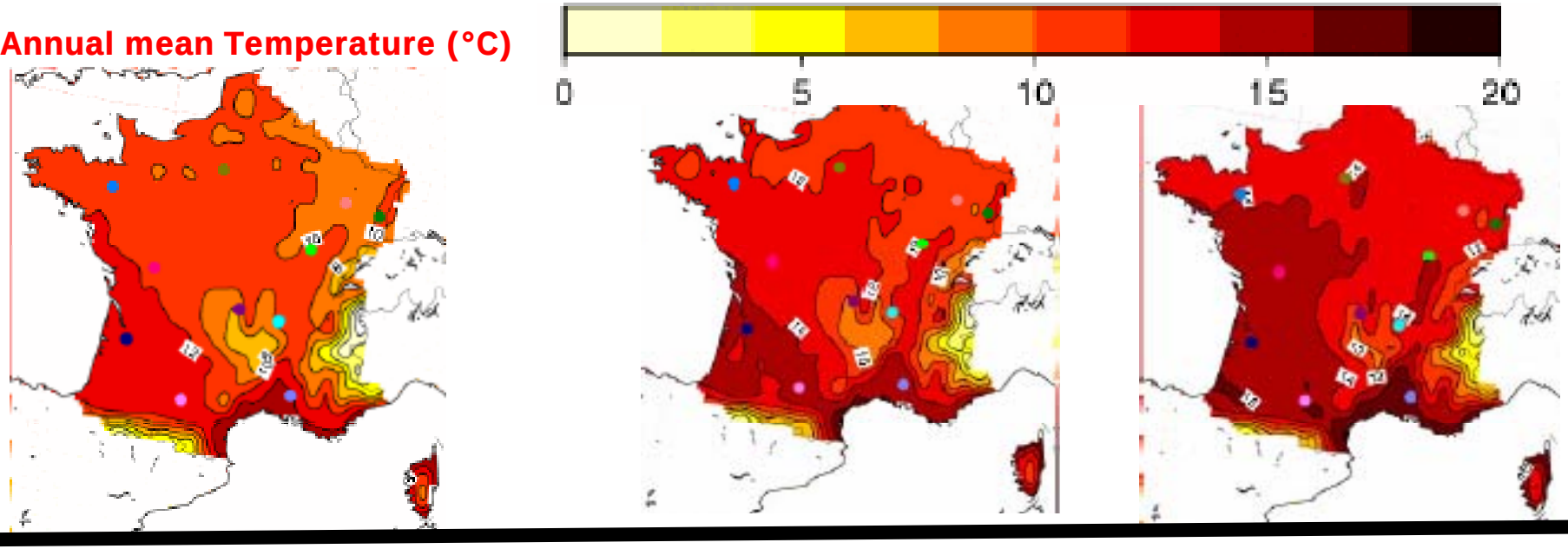
Near future 2020-2049

Distant future 2070-2099

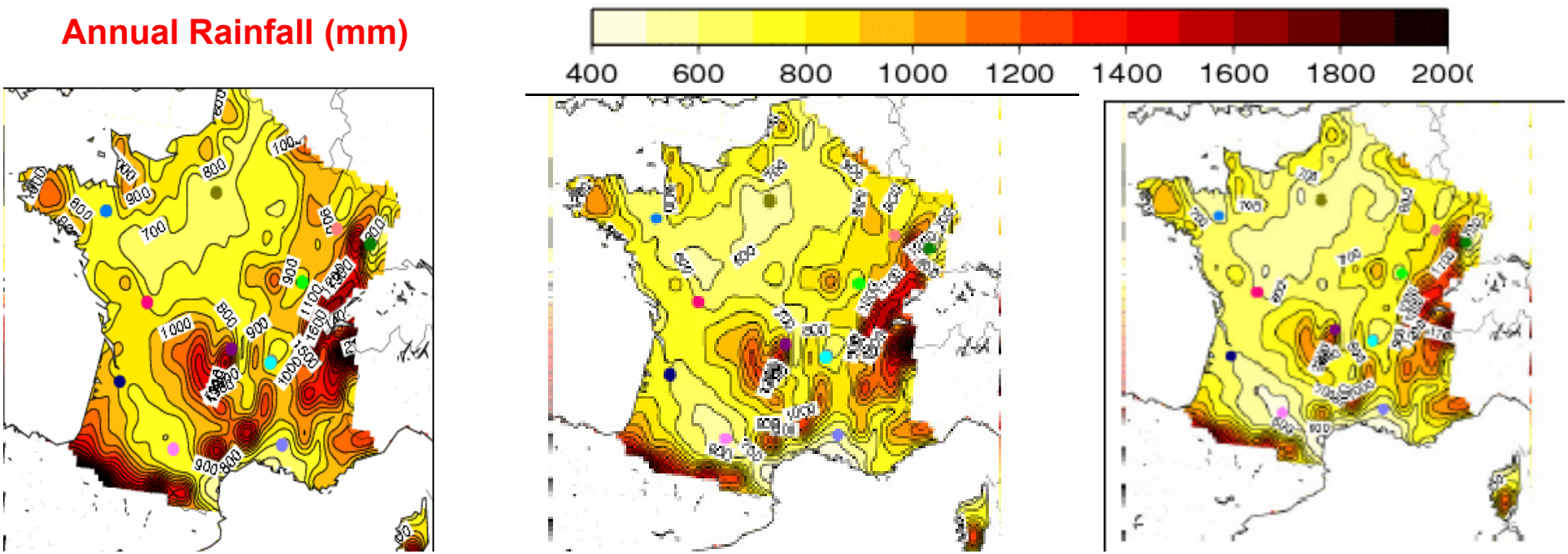
21st century climate (A1B, Arpège GCM, weather types)

**1971-1999** **2021-2049** **2071-2099**

**Annual mean Temperature (°C)**




**Annual Rainfall (mm)**



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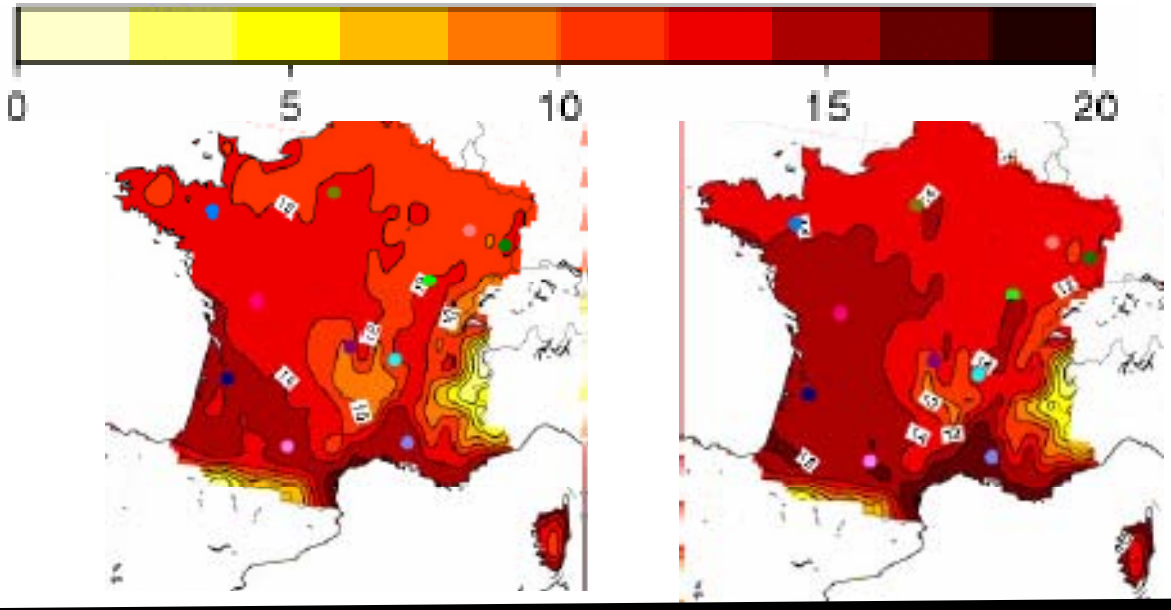
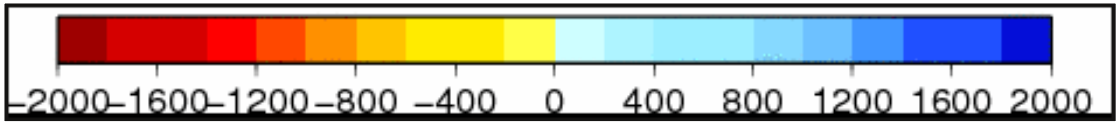
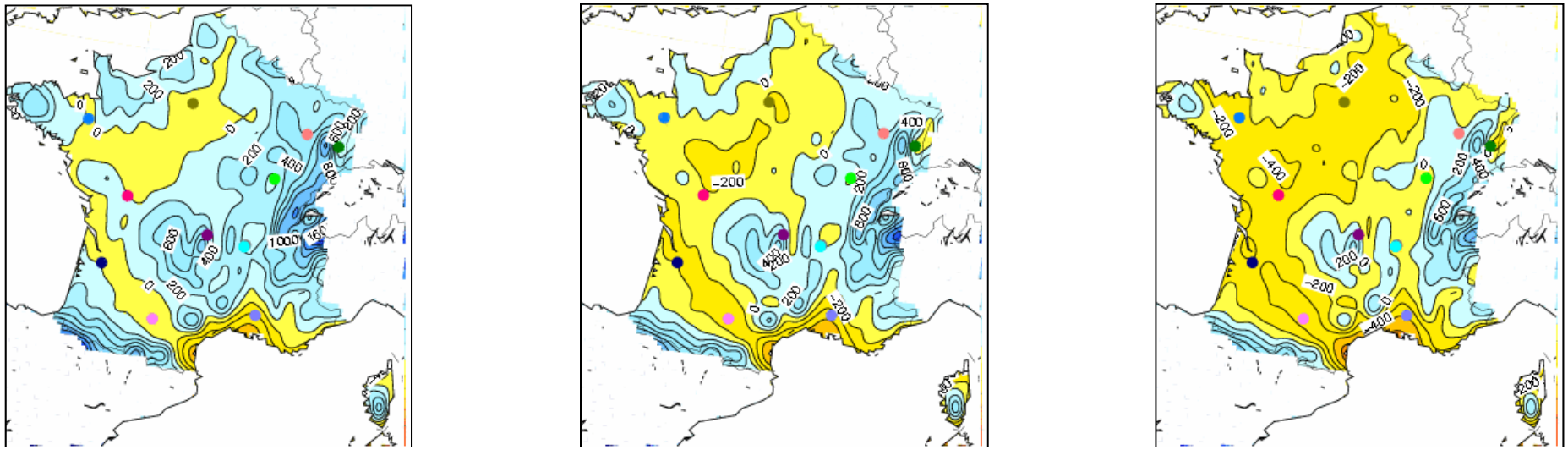



**Potential Water Balance: R-ETo (mm)**



# *Consequences of increasing temperatures on **dates** and **duration** of phenological stages*

- Development = *ƒ* (T) *{linear function of (T-To)}*

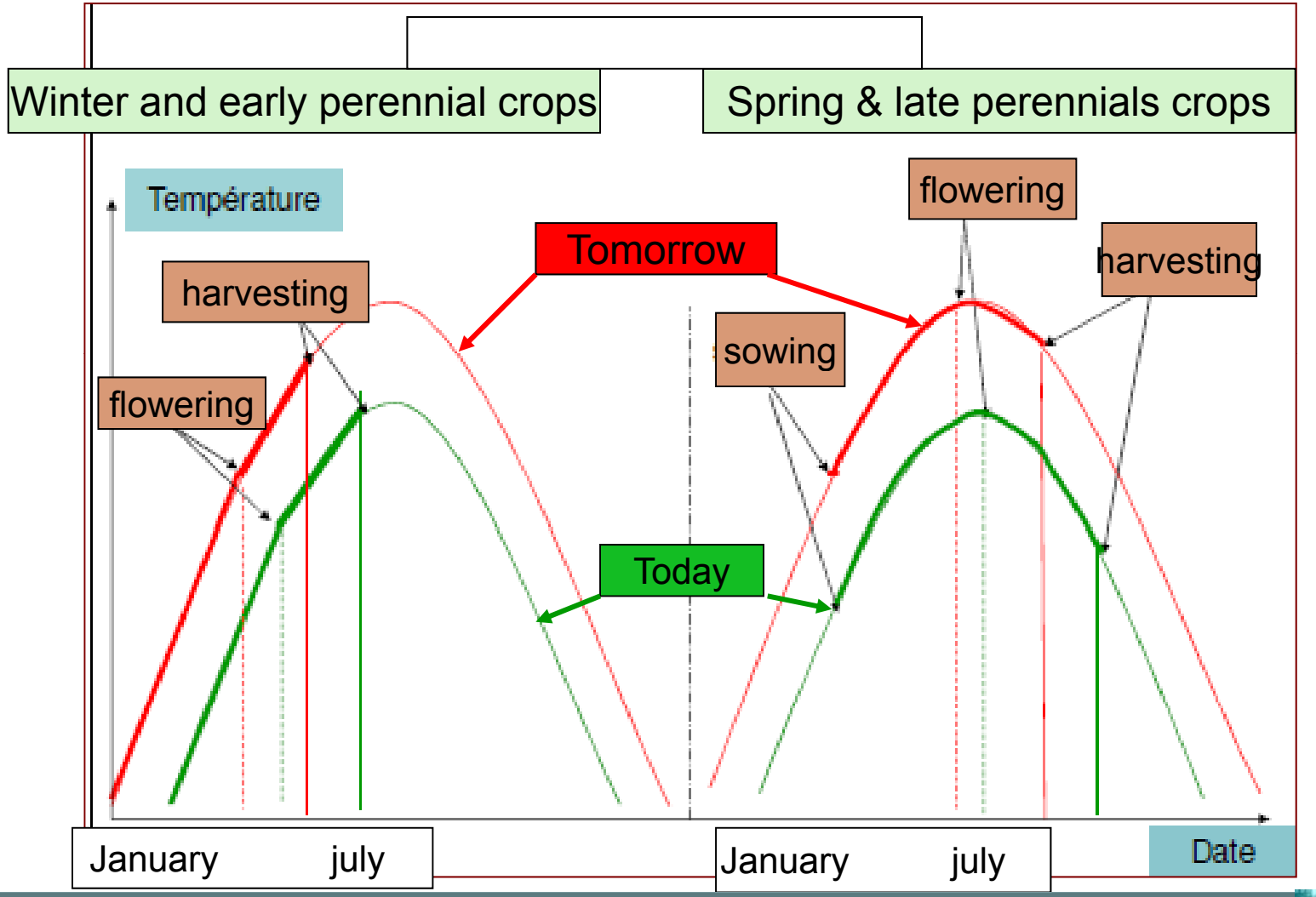
  *T* ↗ *:* → 1: earlier stages

  : → 2 : shorter phases

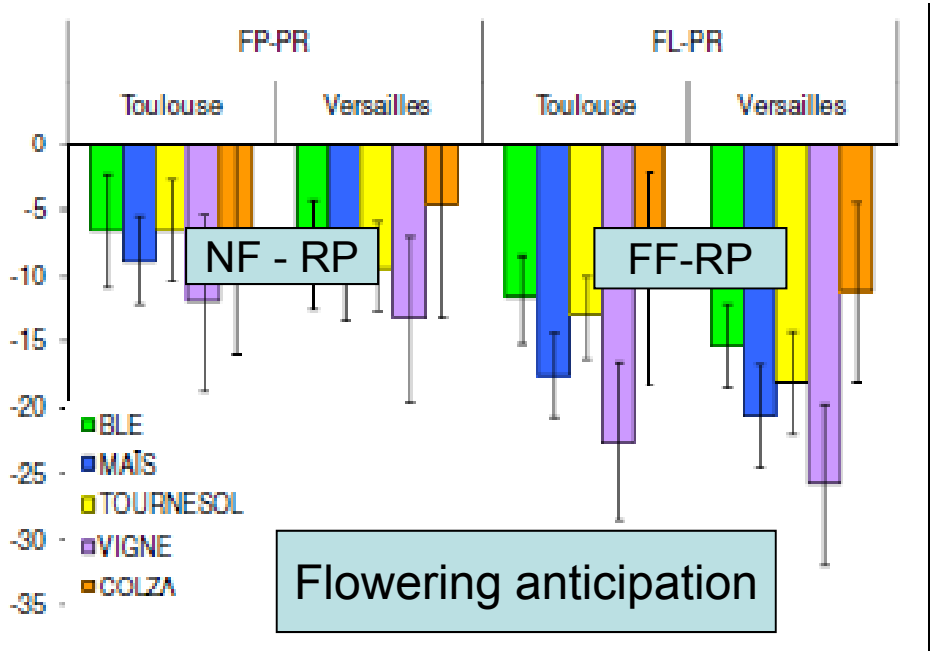
***Winter crops**: mean anticipation and small shortening of grain filling phase*

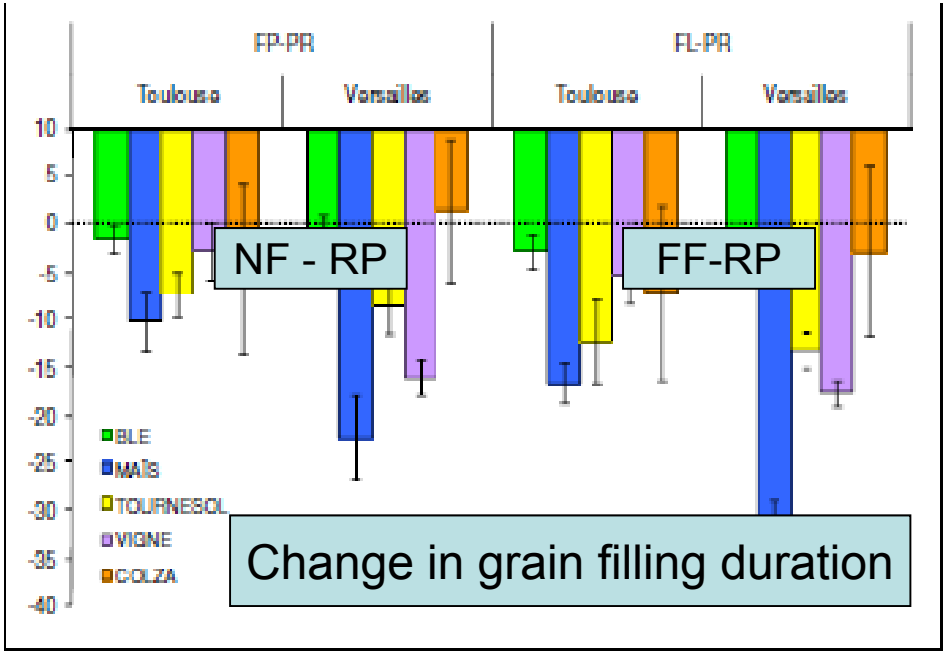
**Spring crops** (and late perennial crops): **Strong anticipation et strong shortening of grain filling phase** (inducing a decreasing yield if no change in variety)

# *Consequences of increasing temperatures on **dates** and **duration** of phenological stages*



# Stages anticipation and duration of phases



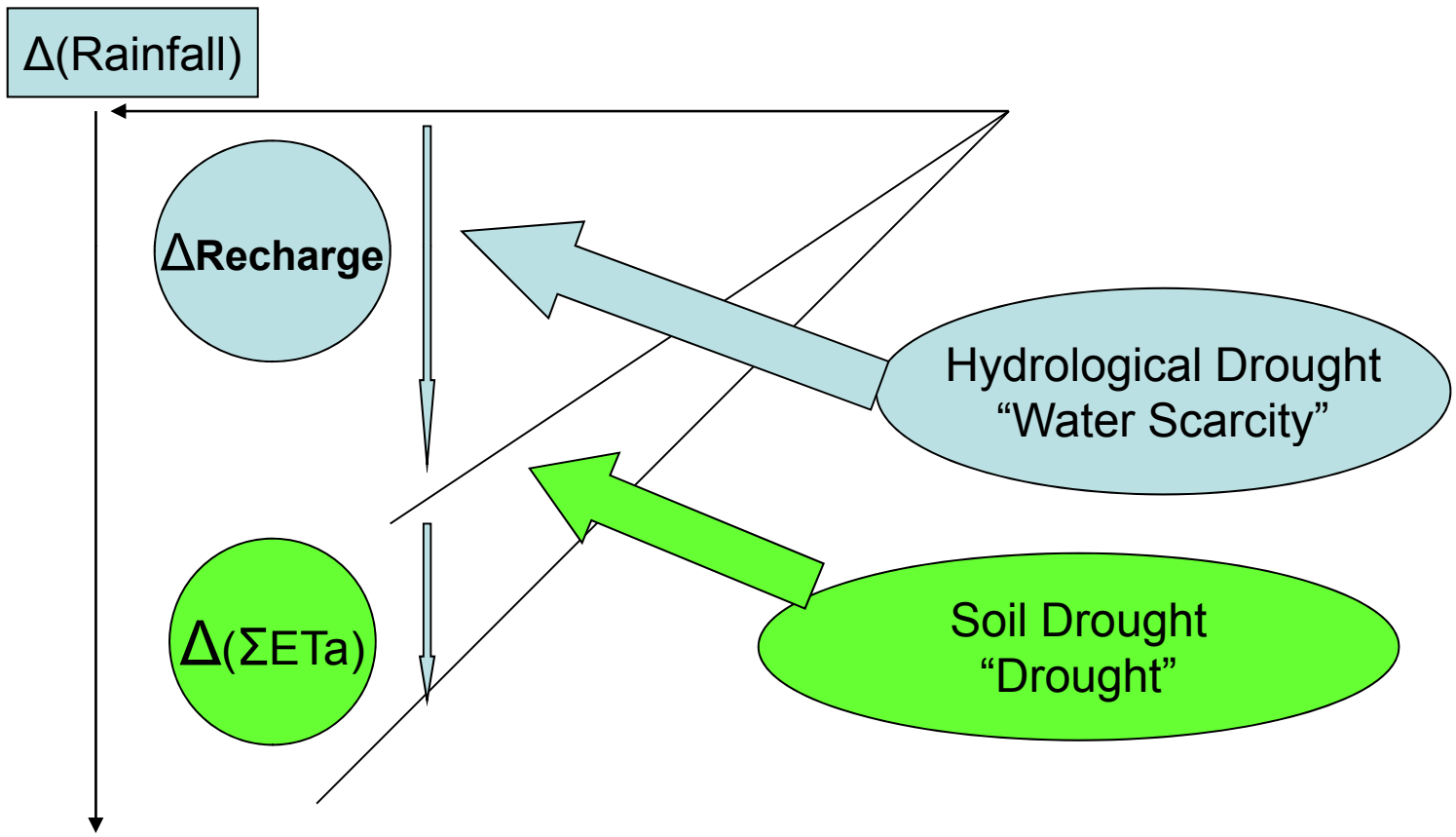

**Wheat, Corn, Sunflower, Vine, Rapeseed**

| Crop | ***Synthesis for 12 sites*** | |
|---|---|---|
| | Δ Flowering in d/°C | Δ Harvesting in d/°C |
| **Wheat, Corn, Sunflower, Vine** | 5 | 6 |
| | 5 | 15 |
| | 4 | 9 |
| | 8 | 10 |

## *2: Change in water comfort (W. Stress) of plants and recharge of aquifers*

*Agriculture depends on water availabilty & acts on water availability*

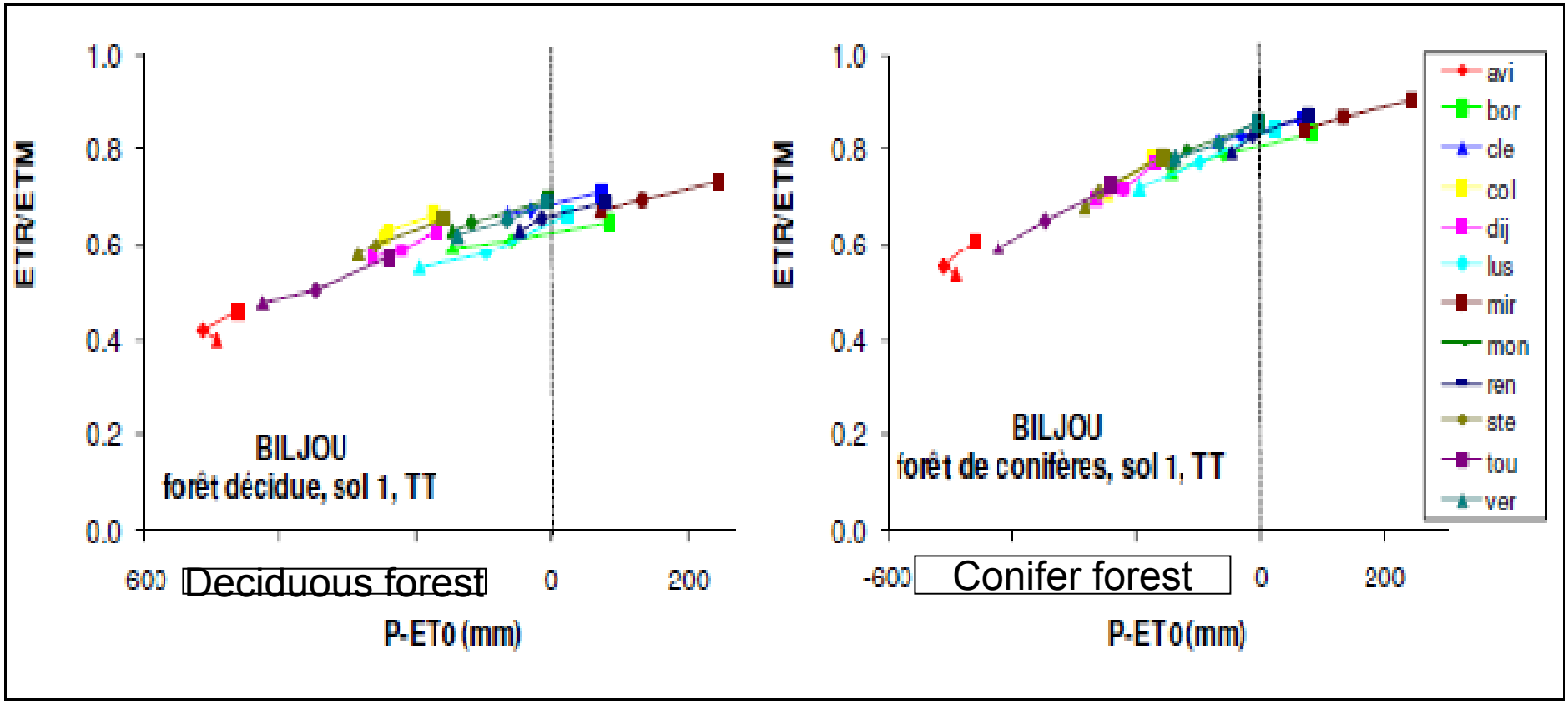
***How will be shared the decrease in annual rainfall?***



# ETa/ETM vs (R-ETo)

ETa/ETM
Conifers:
All over the year

**▲: Far Future ← ♦: Near Future ← ■: Recent Past**

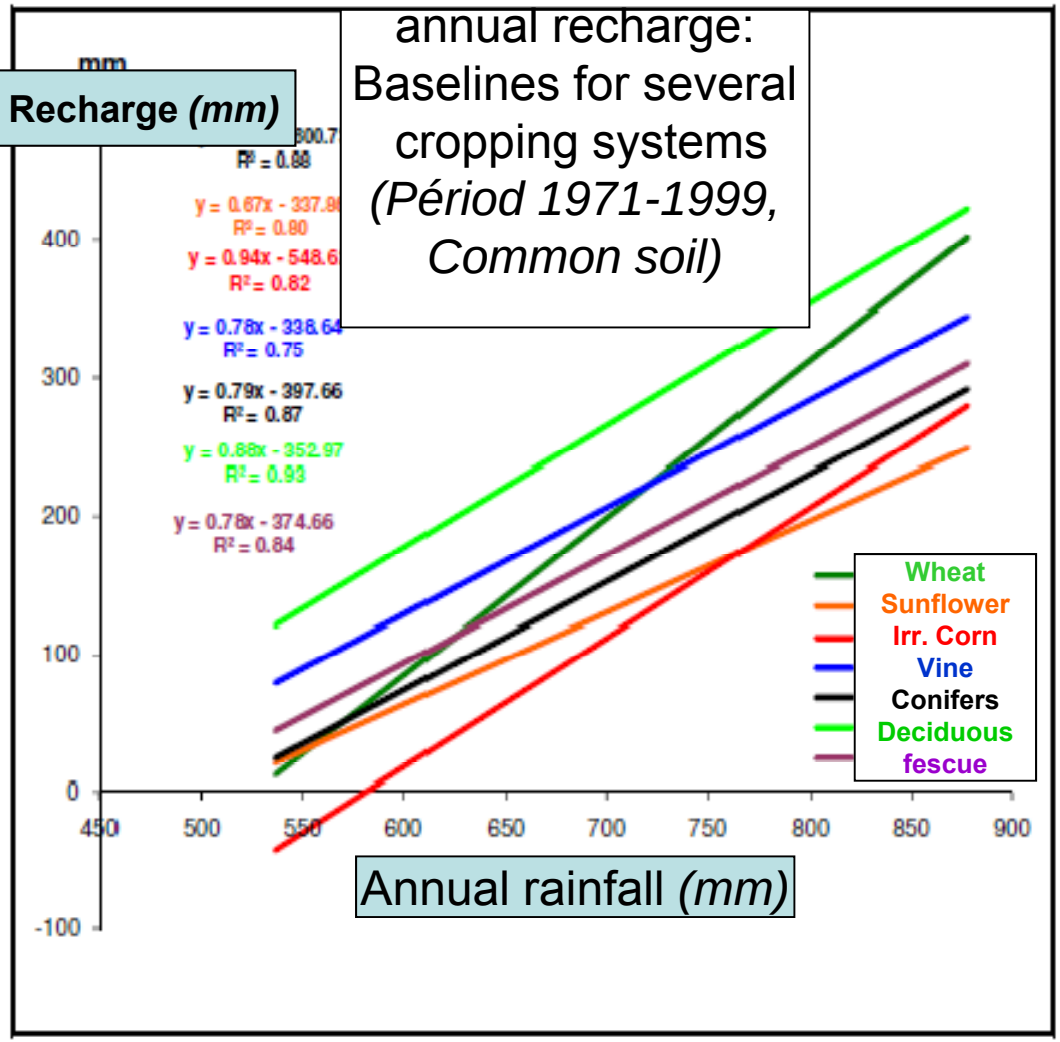



(R – ETo) ↘ → ETR/ETM ↘

# Is there any heriarchy of environmental behaviour??

## *Where do we start from??*

Deciduous
↓
Vine
↓
Winter crops
↓
Grass
↓
Conifers
↓
Spring crops.
↓
Irrigated crops




***Decicuous > Conifers***

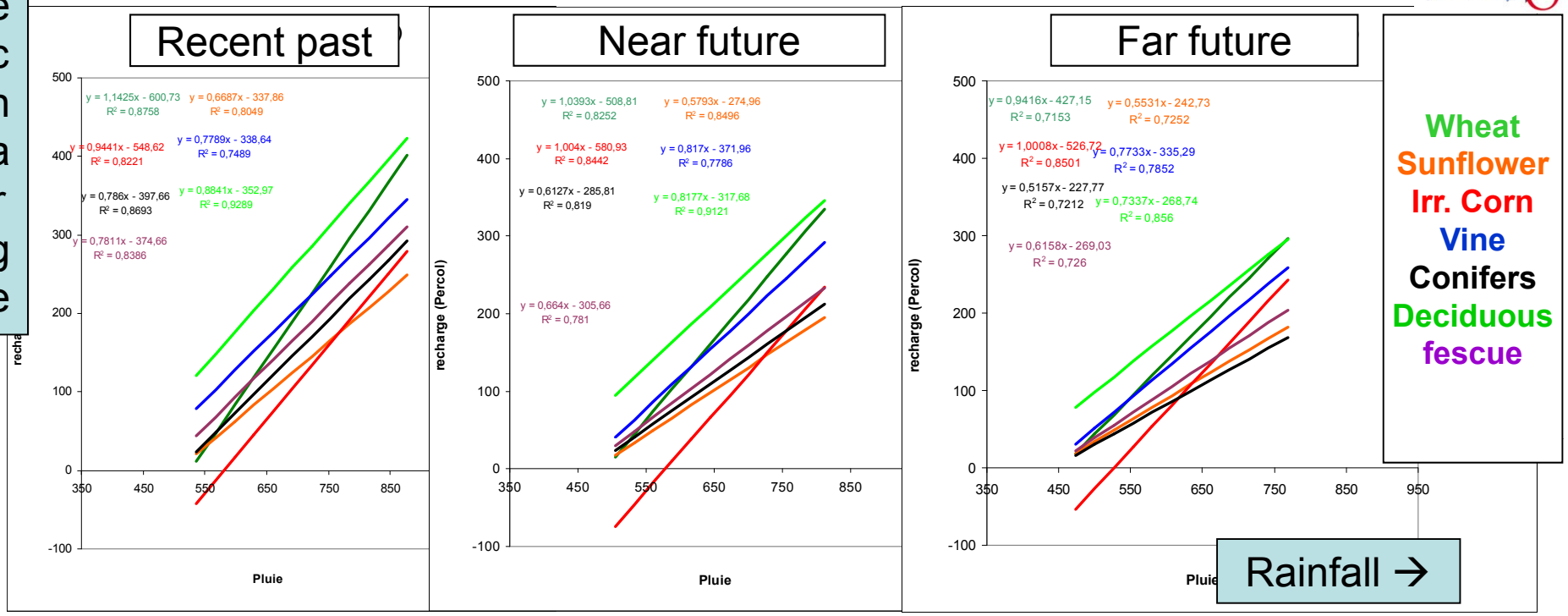
***Vine > Grass***

***Winter C. > Spring C.***

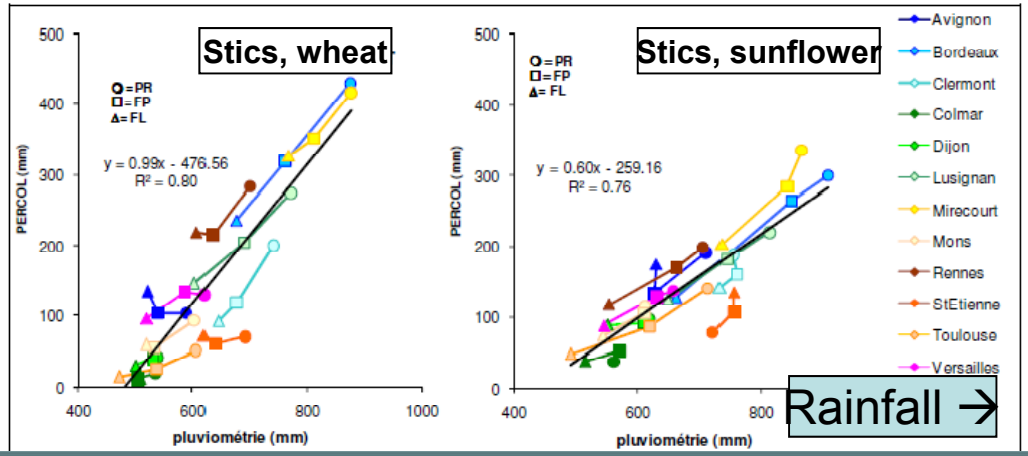
***Rainfed > Irrigated***

# Recharge versus rainfall in time ans space

Recharge

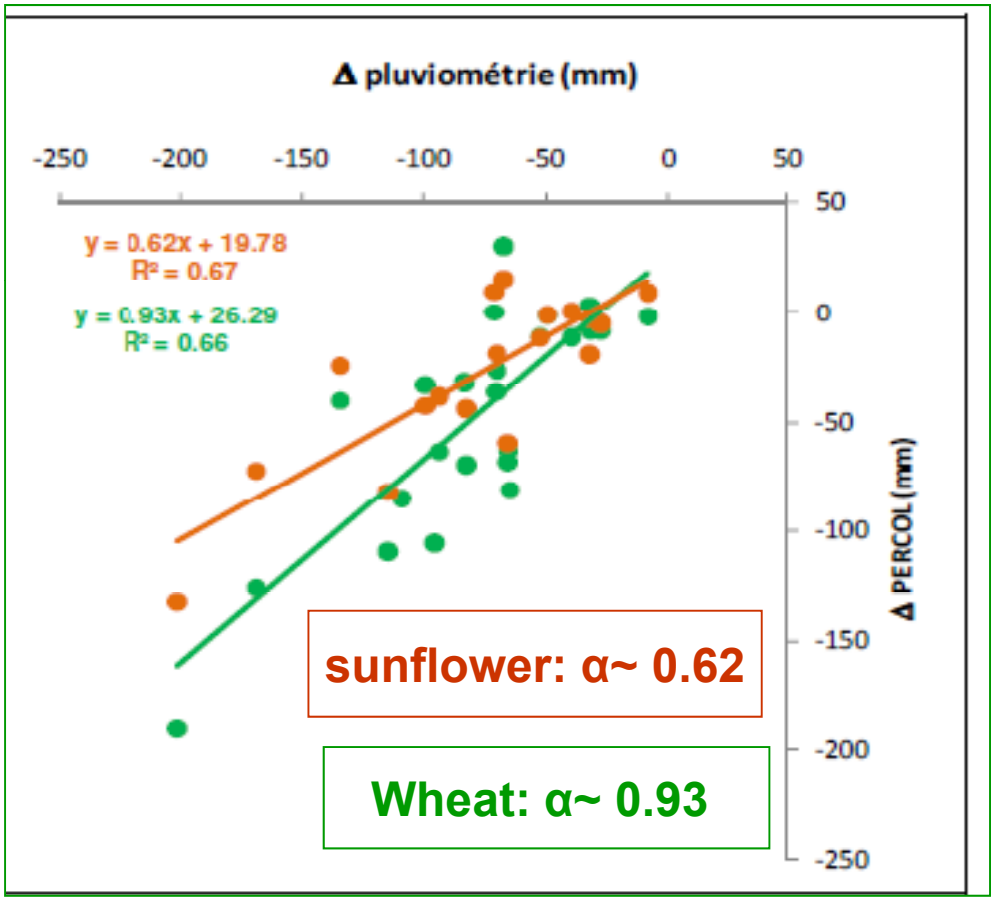


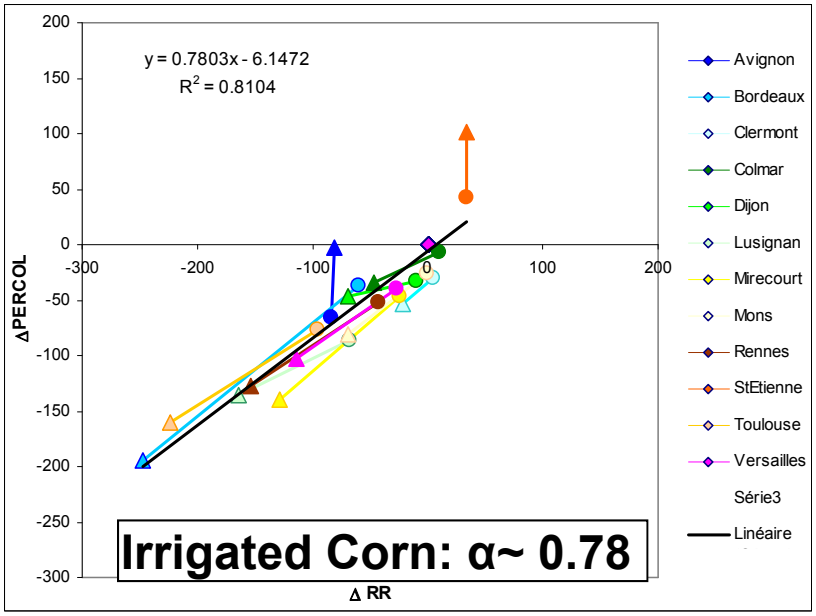

- ● recent past
- ■ near future
- ▲ far future

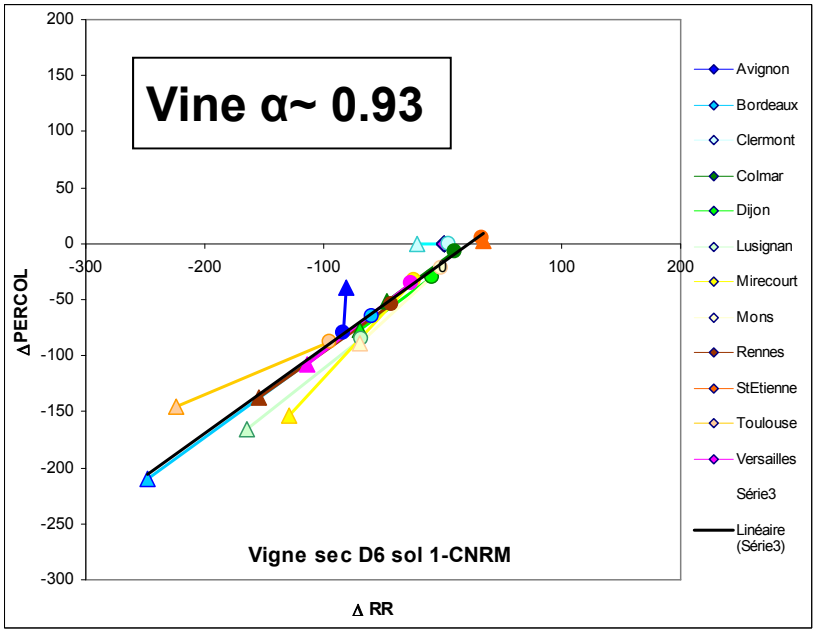


## *How will be shared the decrease in annual rainfall?*

**ΔRecharge/ΔRainfall close to ¾ !!!!**



# Then, tomorrow, water availability will be less:

- Not only

because rainfall will be less and atmospheric water demand (ETo) will be higher

*[Cf Evolution of (P-ETo)]*

- But also

because the **ratio « Efficient Rainfall/ Rainfall » will be less** for all agricultural systems, including rainfed agricultural Systems!!!

# *Spring crops yield:*
# *a decrease in the south or a change of variety ??*

- Decrease is the result of diminishing radiation interception due to shortening of stages duration (Fig 2) and no increase in water efficiency (C4),
- Meanwhile, decrease (or, at least, no increase) in water consumption (Fig 3)

**Fig 1 Yield**

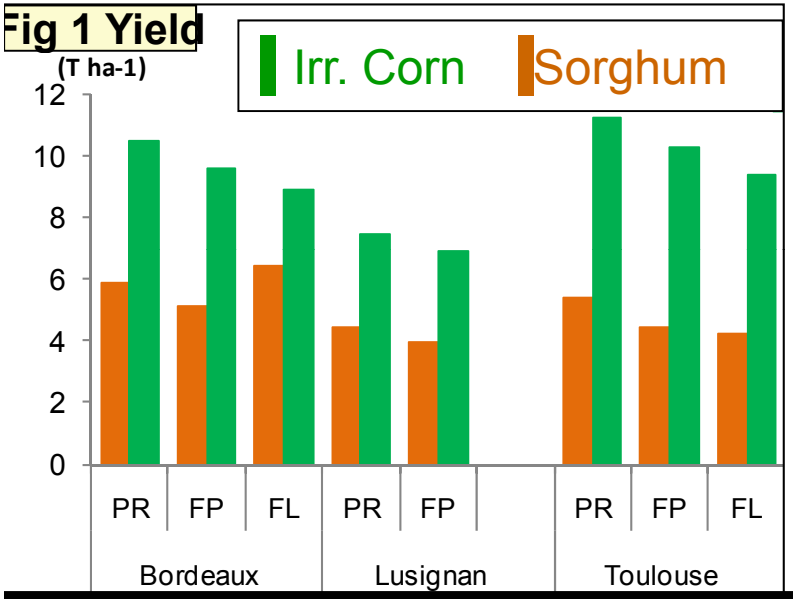



Fig 2: Shortening of grain filling duration in the far future at Toulouse for wheat, corn, sorghum, vine and colza

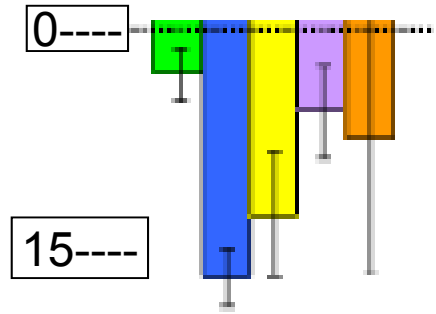
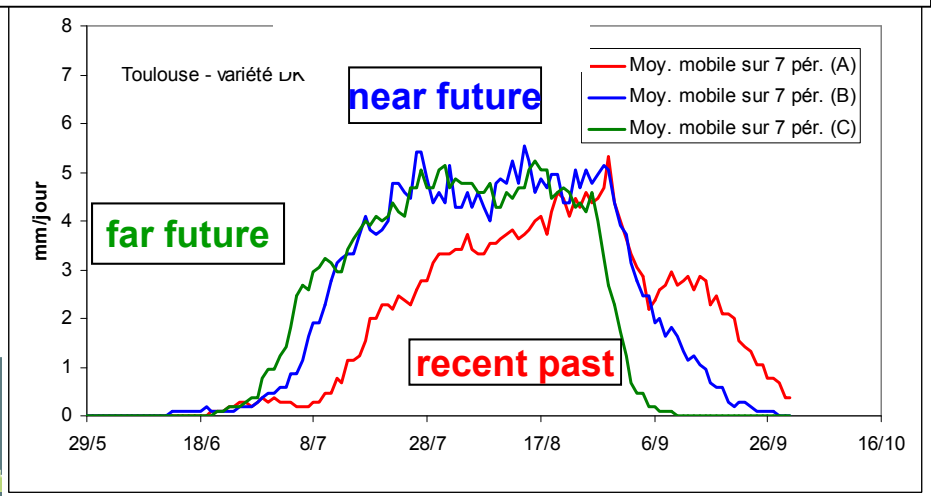



Fig3 Mean daily irrigation of corn at Toulouse




- **Dilemma**: changing variety

→ increase in production

**AND**

increase in water consumption

AgMIP The Agricultural Model Intercomparison and Improvement Project

Similar objectives as CLIMATOR
- At a global scale (required upscaling)
- Connection with economy

Modeling exercise at regional and global scales in view of estimating the uncertainty of yield estimates and improving assessment of the CC impact on future food security

US leadership : C Rosenzweig - NASA, J. Jones – U. Florida, J Hatfield – USDA

Extended steering group :Australia, France, Netherlands, Denmark, Germany, UK, Brazil, Kenya…

Participants : 200 scientists

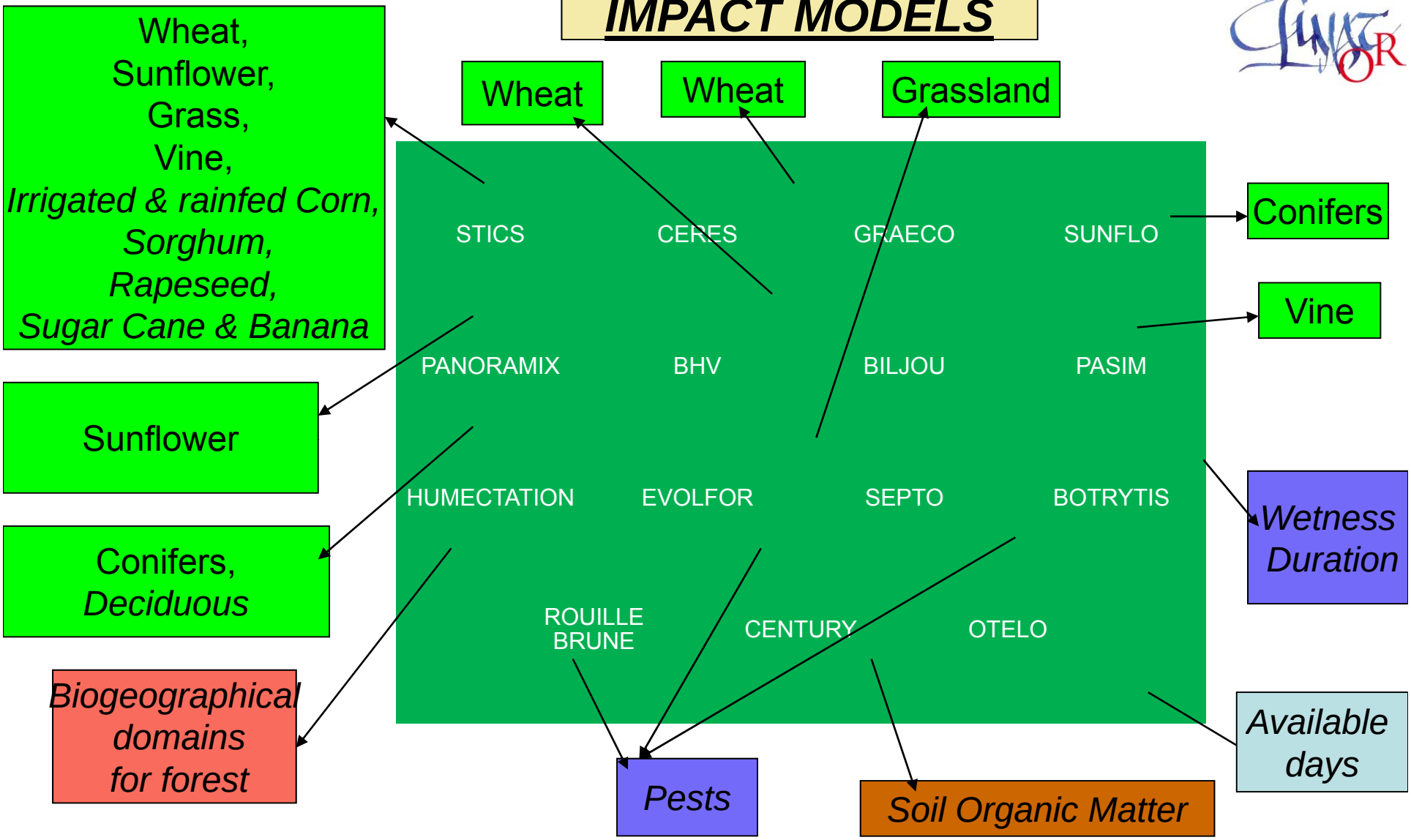
Self-funded project for developed countries –

Support by DFID (UK) for Africa and Asia

Ag MIP

# Thank’s for your attention

# IMPACT MODELS



# Multi-sites approach at the field scale

The spatial approach relies on 13 sites standing for French climate variability for which 30-year climatic series are available (1970-1999)

All the systems where simulated in all the sites (except for the tropical one)

# Topics

- *What will induce changes in temperature and rainfall on agriculture?*

-1: change in phenology (stages duration, dates of harvesting)

-2: change in water comfort (W. Stress) and recharge of aquifers

-3: change in production (yield & quality)

*(+ change in plant health, + possible change in carbone storage)*

# Is the impact of climate change homogeneous throughout cropping systems and French locations ?

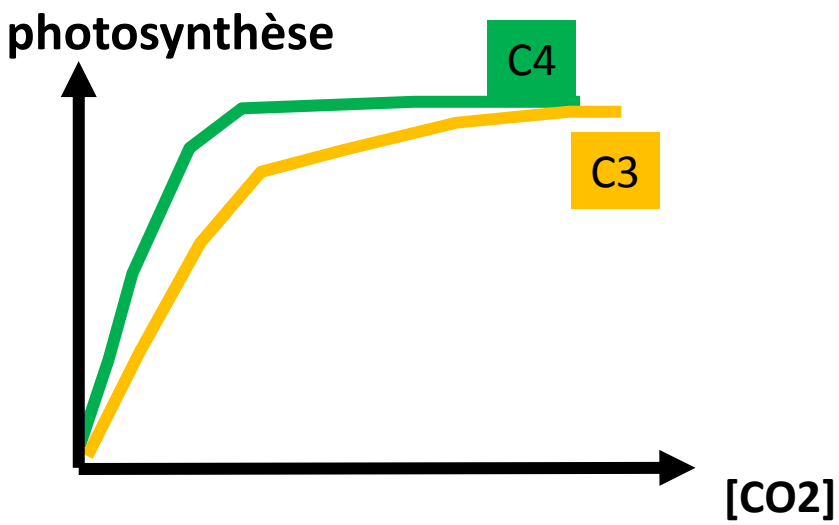
•Yield projections : Delta (Near future –Recent Past) (t/ha)

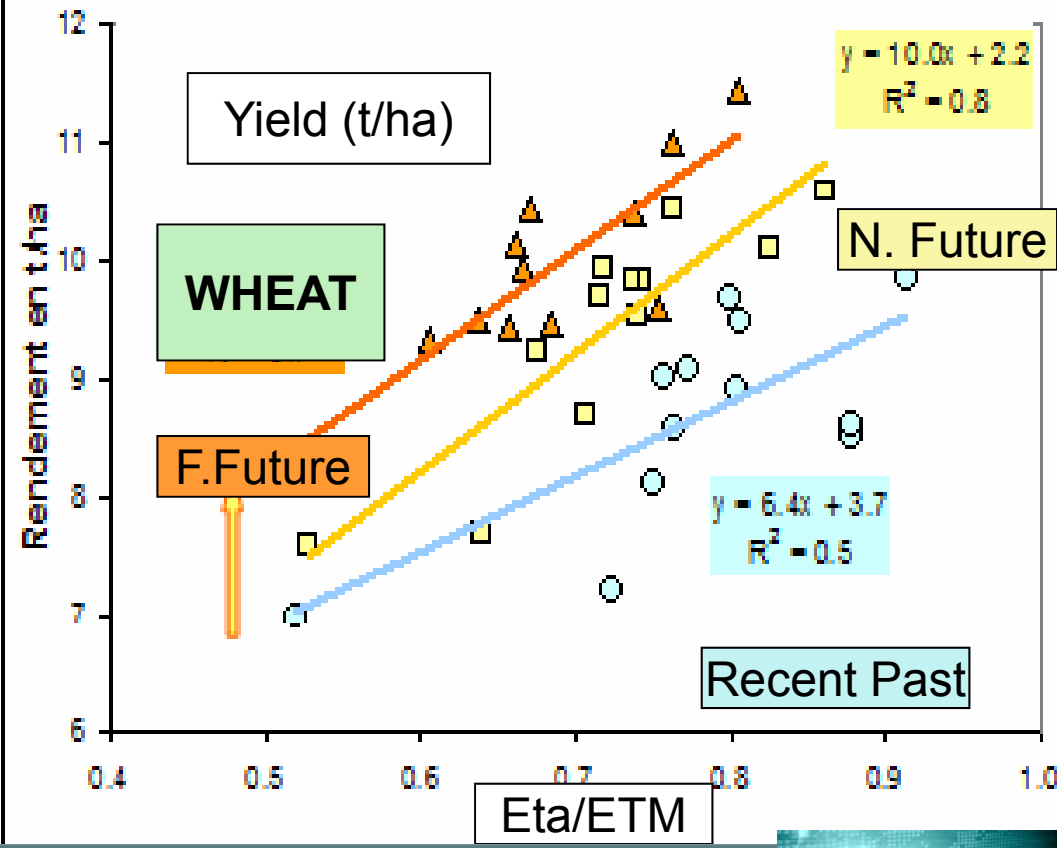
| | Blé | Maïs | Colza | Tournesol | Sorgho | Vigne | Pin | Fétuque |
|---|---|---|---|---|---|---|---|---|
| Avignon | ~~0,05~~ | **-1,00** | ~~-0,36~~ | ~~0,25~~ | ~~0,14~~ | **-0,33** | **-0,19** | ~~-0,64~~ |
| Bordeaux | ~~0,66~~ | **-0,90** | ~~0,03~~ | ~~0,08~~ | **-0,77** | *0,15* | **-0,18** | ~~-0,25~~ |
| Clermont-Theix | ~~0,11~~ | **2,32** | **1,44** | *0,59* | ~~0,21~~ | ~~0,13~~ | **-0,14** | **0,88** |
| Colmar | *1,06* | **-0,81** | **0,67** | ~~-0,31~~ | ~~-0,29~~ | **0,56** | **-0,34** | -0,59 |
| Dijon | ~~0,85~~ | *-0,30* | *0,65* | ~~0,07~~ | ~~0,21~~ | **0,68** | **-0,26** | ~~-0,15~~ |
| Lusignan | ~~0,31~~ | **-0,64** | ~~0,23~~ | ~~0,11~~ | -0,64 | **0,44** | **-0,41** | **-0,81** |
| Mirecourt | **1,89** | **4,25** | **1,40** | **2,71** | **5,73** | **3,60** | **0,17** | *0,61* |
| Mons | *1,05* | **3,22** | ~~0,11~~ | **1,91** | **4,13** | **2,75** | **-0,23** | ~~-0,41~~ |
| Rennes | ~~-0,15~~ | ~~0,16~~ | ~~0,06~~ | **1,01** | **2,16** | **1,54** | **-0,11** | *-0,68* |
| St-Etienne | **2,43** | **-1,19** | **0,97** | ~~-0,16~~ | ~~-0,31~~ | 0,27 | **-0,38** | *-1,00* |
| Toulouse | 1,28 | **-0,97** | ~~0,00~~ | ~~0,05~~ | -0,73 | **-0,45** | **-0,42** | *-0,65* |
| Versailles | **0,88** | **1,30** | ~~0,35~~ | **1,37** | **2,56** | **1,85** | **-0,06** | ~~-0,22~~ |
| Tous | **0,87** | **0,45** | **0,46** | **0,64** | **1,03** | **0,93** | **-0,21** | **-0,330** |

Bold: p<0.01; italic: p< 0.05; normal: p< 0.10; crossed out: not significant

# Winter crops yield: the reasons of an increase

*1: drought escape (anticipation of stages)*
*2: better W.U.E (due to CO2 increase)*
*3: small reduction of grain filling duration*



# Is the impact of climate change homogeneous throughout cropping systems and French locations ?

***Climate change : Dangers & Opportunenesses***

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Bold: p<0.01; italic: p< 0.05; normal: p< 0.10; crossed out: not significant

# Improve and/or go further

## Benchmarking of « impact models »

- Increase the number od models on the same system
- Propose simple formalisms for missing modules

## RELATIONS « DIAGNOSTIC»

Check the robustness (Recharge= f(rainfall), Δ FLO= f(ΔT°C)…),

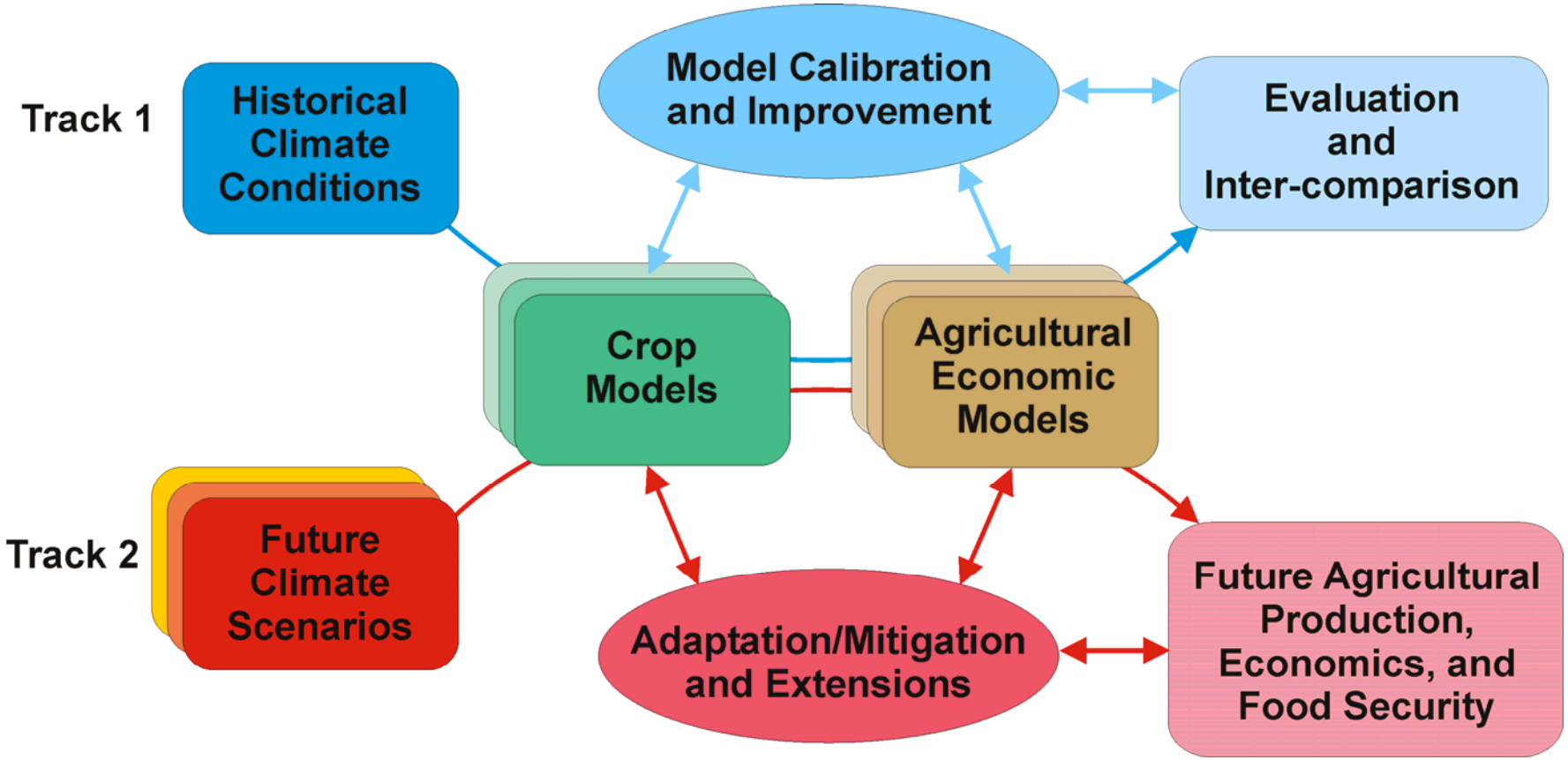
## QUANTIFY UNCERTAINTIES

Risk estimation through threshold values ( frost, shrivelling, pests)

Reduce epistemic uncertainties by improving impact models

*Ag MIP*

# Two-Track Science Approach




**Track 1: Model Inter-comparison and Improvement**
**Track 2: Coordinated Future Scenario Simulations**

*Ag MIP*

# Two relevant scales and appropriate methodologies

Crop model inter-comparison and benchmarking against experimental datasets

Regional yield estimates for today and tomorrow complemented with the appropriate uncertainties

From the field to the region: A key point!

**Ag MIP**

# Three drivers in the project

— *French leadership*

**Models** :
- ❑DSSAT (leaders),
- ❑APSIM,
- ❑ STICS,
- ❑ CropSyst,
- ❑ SUCROS…

Upscaling
Yield gap estimates
Regional level uncertainty
**Regional projections**

**Regions**
- ❑ North America
- ❑Europe
- ❑Australia
- ❑South America
- ❑ Africa
- ❑ Asia….

**Crops** :
- ❑Wheat,
- ❑maize,
- ❑rice,
- ❑sorghum….
- ❑grasslands

Field level data sets
Simulation frameworks
Sensitivity analysis
Field level uncertainty
Field level projections

Regional data sets
Crop management definitions at a sub-regional level
Genotype choices
Adaptation scenarios