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Bernard Itier, Nadine Brisson, Vincent Badeau, Nathalie Bréda, Alexandre Bosc, Michel Déqué, Jean Louis Durand, Lydie Guilioni, Christian Pagé, Romain Lardy, et al.

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# **Change in recharge of aquifers under several cropping systems due to climate change.**

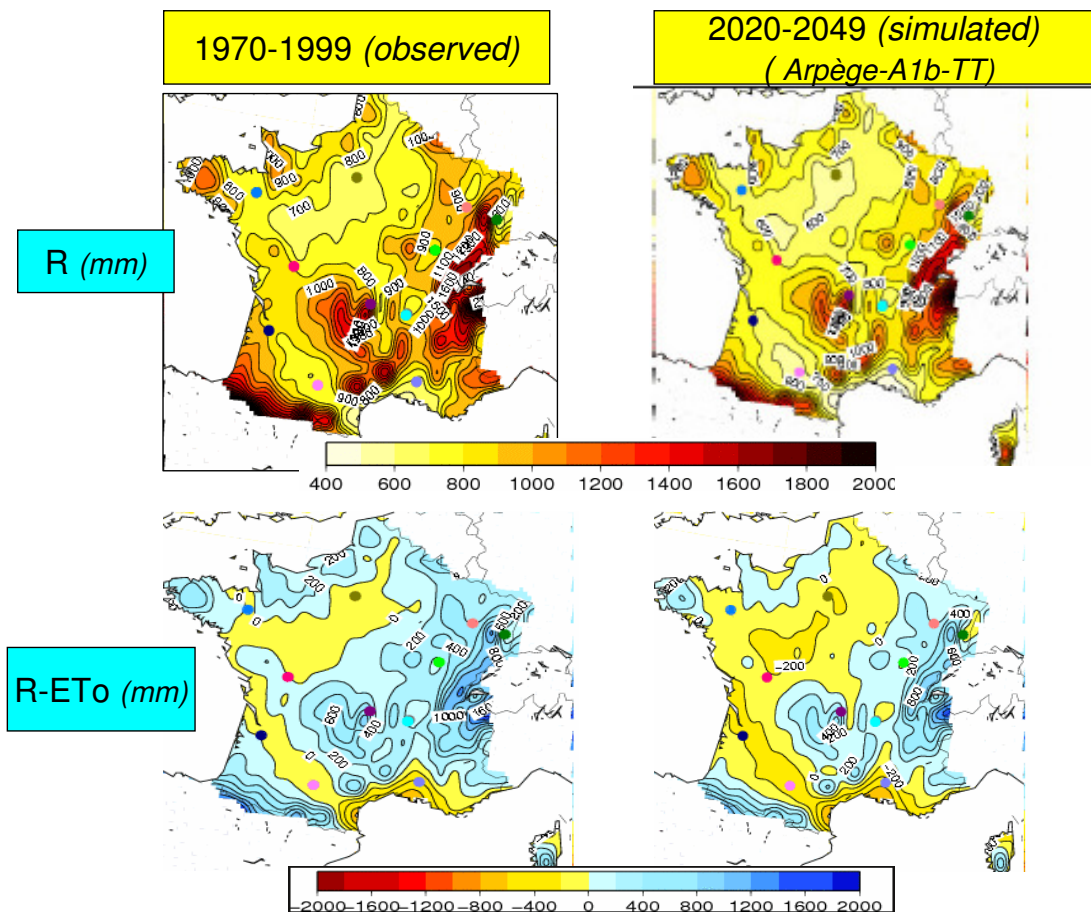
## **Consequences on land use at territorial level**

**Bernard Itier (INRA), Nadine Brisson (INRA), Vincent Badeau (INRA) Nathalie Breda (INRA), Alexandre Bosc (INRA), Michel Déqué (CNRM), Jean Louis Durand (INRA), Lydie Guillioni (SUPAGRO), Christian Pagé (CERFACS), Romain Lardy (INRA), Philippe Pieri (INRA), Romain Roche (INRA)**

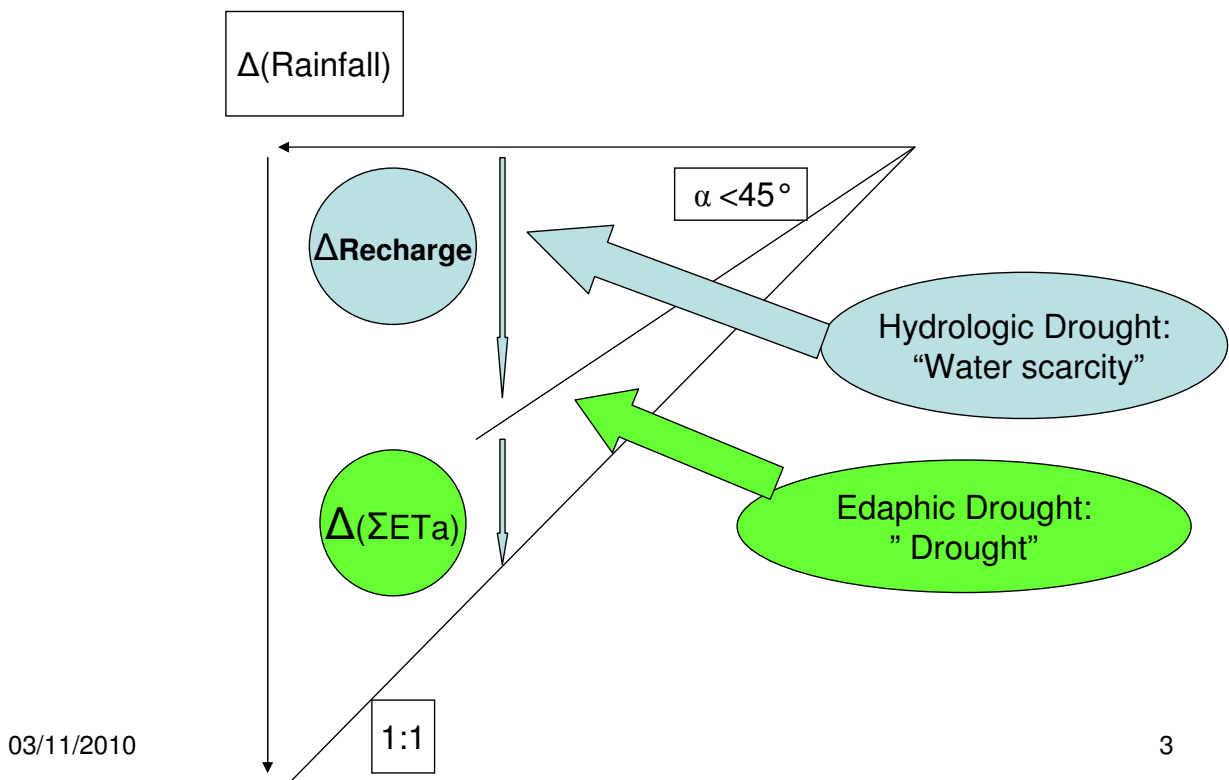


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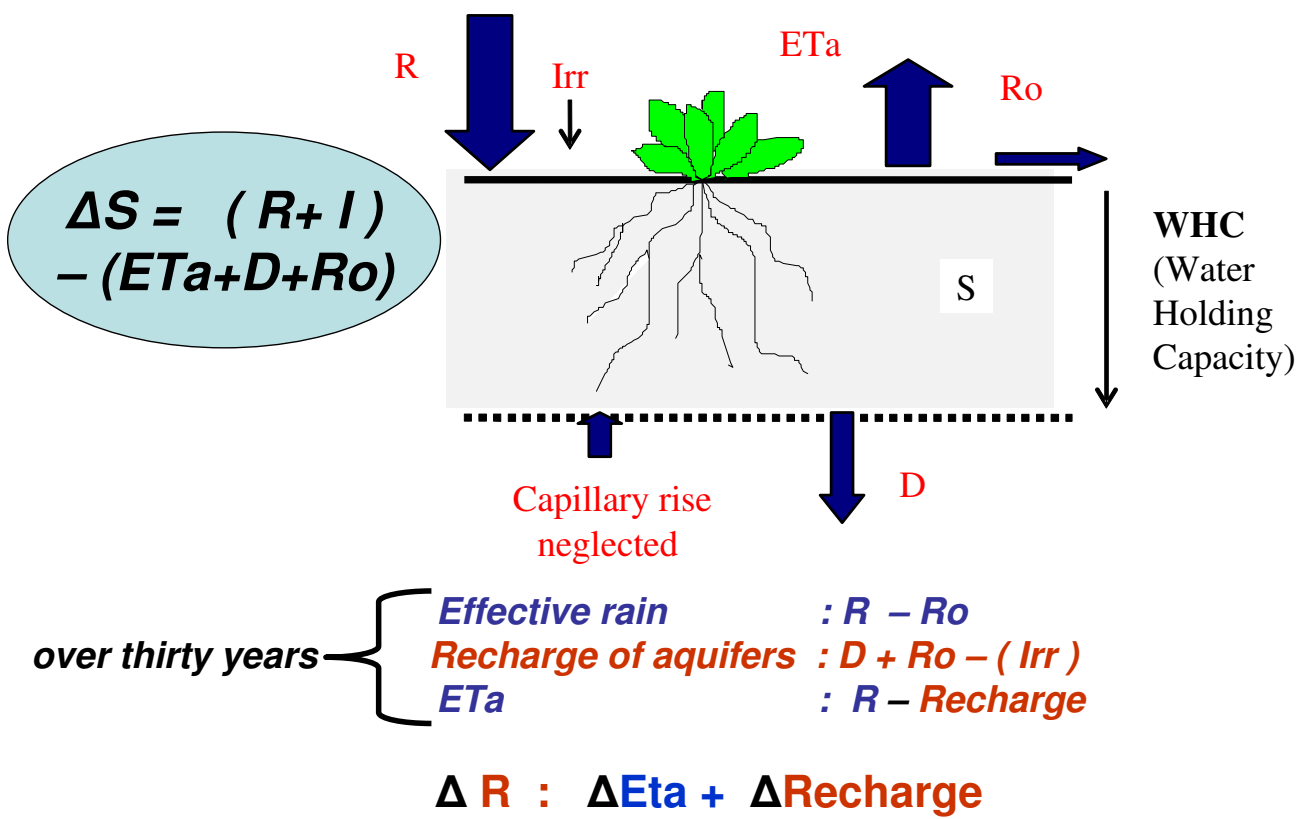
### Evolution of annual rainfall & potential water balance over France



# Decrease in water recharge ( $\Delta\text{Recharge}$ ) versus decrease in rainfall ( $\Delta\text{Rainfall}$ ) due to climate change



## Water balance at field level



At catchment level :

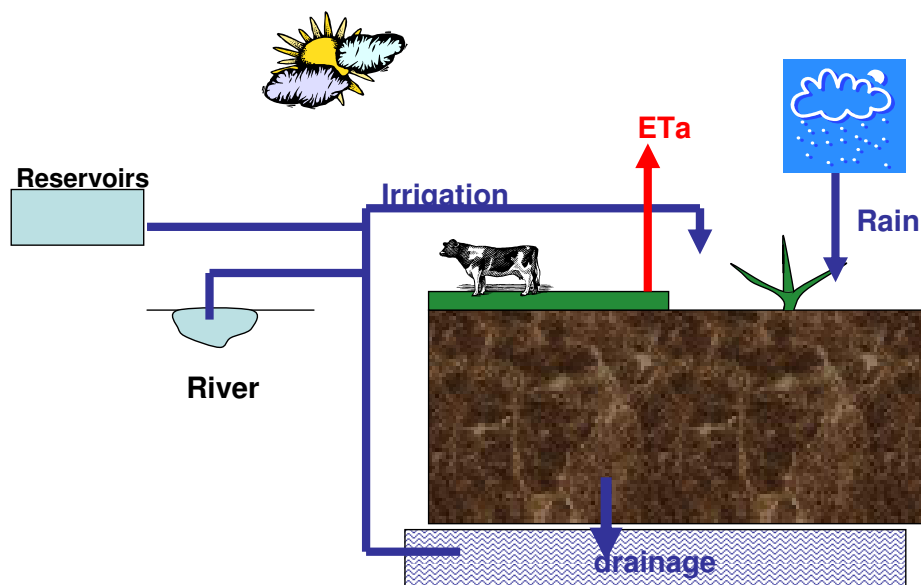
$$\text{Recharge} = \sum_{k=1,N} \alpha_k \cdot \text{Recharge}_k$$

- A catchment can be covered with several types of cropping system:
- Rainfed ,Fully irrigated, Deficit irrigated
- Winter crops, Spring crops
- Annual crops, Perennial crops

***Is there any characteristic of a particular cropping system regarding water recharge as a function of soil & climatic conditions?***

Irrigation is generally classified according to the way water is distributed within the field: ***{pivot, sprinkler, furrow,drip,...}***

To tackle the question of water resource management at catchment level, we need to classify irrigation system according to the **origin of irrigation water**



## *An attempt to tackle the question of irrigation through a typology of water resources*

To improve water management at catchment level, what is the relative importance of practices and cropping systems patterns?

depending on :

- *1/ Water comes from **large aquifers** belonging ( even partly) to the catchment*
- *2/ water comes from **rivers** ( fed or not by **canals**) or from **small aquifers** associated to these rivers*

### *What are the questions?*

- *A/ Large aquifers:  
What will enable the level of the water table to be maintained year after year?*
- *B/ Rivers:  
What will enable the flow above the threshold value necessary for other use and water quality purposes to be maintained?*

A/ Large aquifer-dependent irrigation systems  
( *Beauce (F), Castilla la Mancha (E),...* )

**Improving practices will not raise the annual water table level** (except by limitation of direct evaporation)

→ because drainage due to excess irrigation recharges the aquifer

→ so in simply quantitative terms, waste water is not lost water

**So how can we avoid a year after year lowering of the water table?**

→ By ensuring that the water conservation equation works correctly at catchment level:

**Global recharge must compensate losses**

**Global recharge must compensate losses**

**Recharge =  $D + Ru - Irr = F$ (annual rainfall, climate( $ET_o$ ), {Cropping Systems} )**

**=  $\beta$  . (annual rainfall)**

**$\beta \ll 1$  ( in the long term,  $(1 - \beta) \sim \Sigma ET_a / \Sigma R$  )**

**$\beta \gg 0$  (because aquifers feed springs )**

**Tools for estimating  
water recharge versus rainfall  
for a cropping system  
under several soil & climate conditions**

→ « **Crop models** » providing  
« environmental outputs »:

***A systematic approach in the frame of a project***

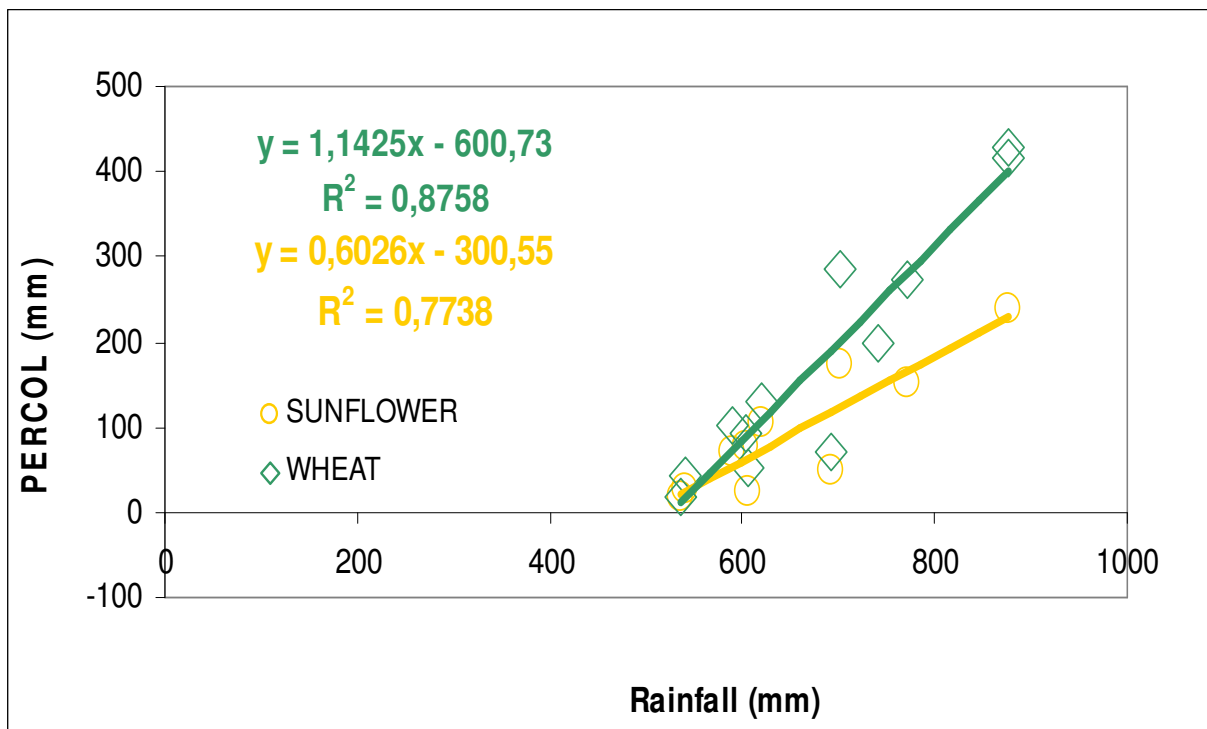
***(CLIMATOR 2007-2010)***

*devoted to*

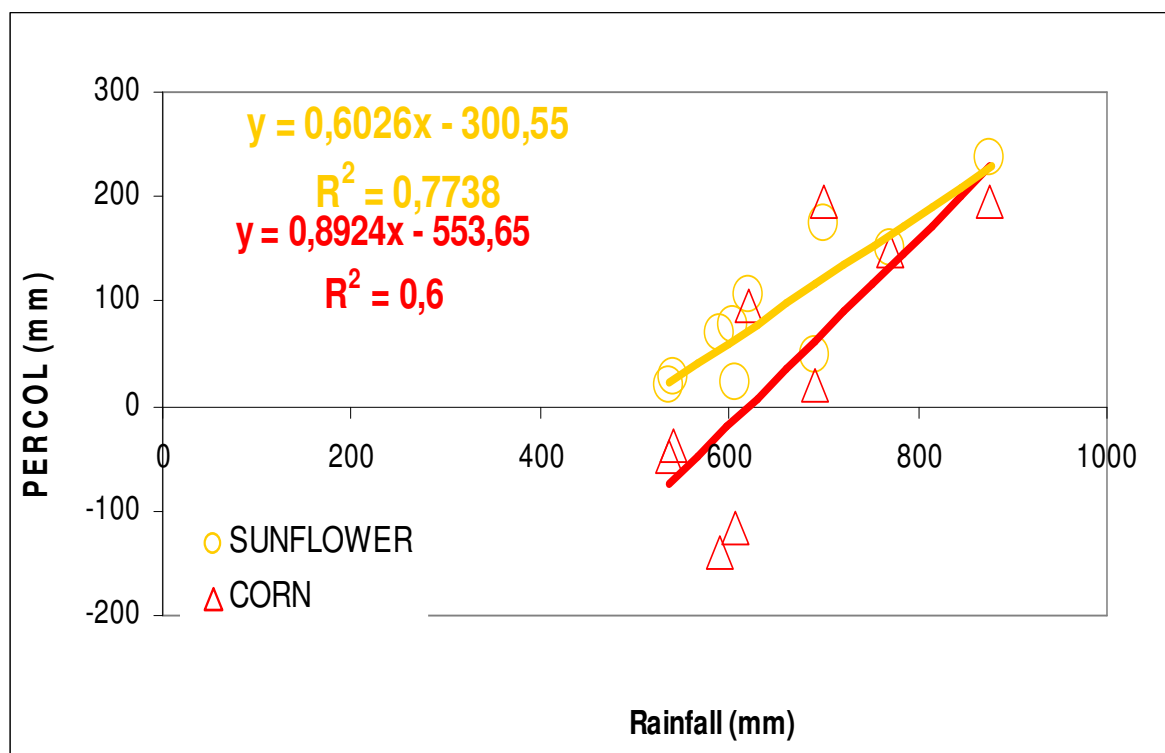
**« the impact of Climate Change on agriculture  
(Production and Environment) »:**

- 
- **8 cropping systems**
  - **On 12 locations** in France
  - **Over 3 soils**
  - By using **at least two models** for each crop
  - By means of **climatic data for 3 periods** of 30 years:  
1970-2000 « recent Past » ( *observed*);  
2020-2050 & 2070-2100, «near & far Future » (*simulated*).

**Relationship between Recharge and annual Rainfall for  
Wheat (◇) and Sunflower (○)  
in 12 locations in France**  
*(from STICS model with observed climatic data from 1970-1999)*

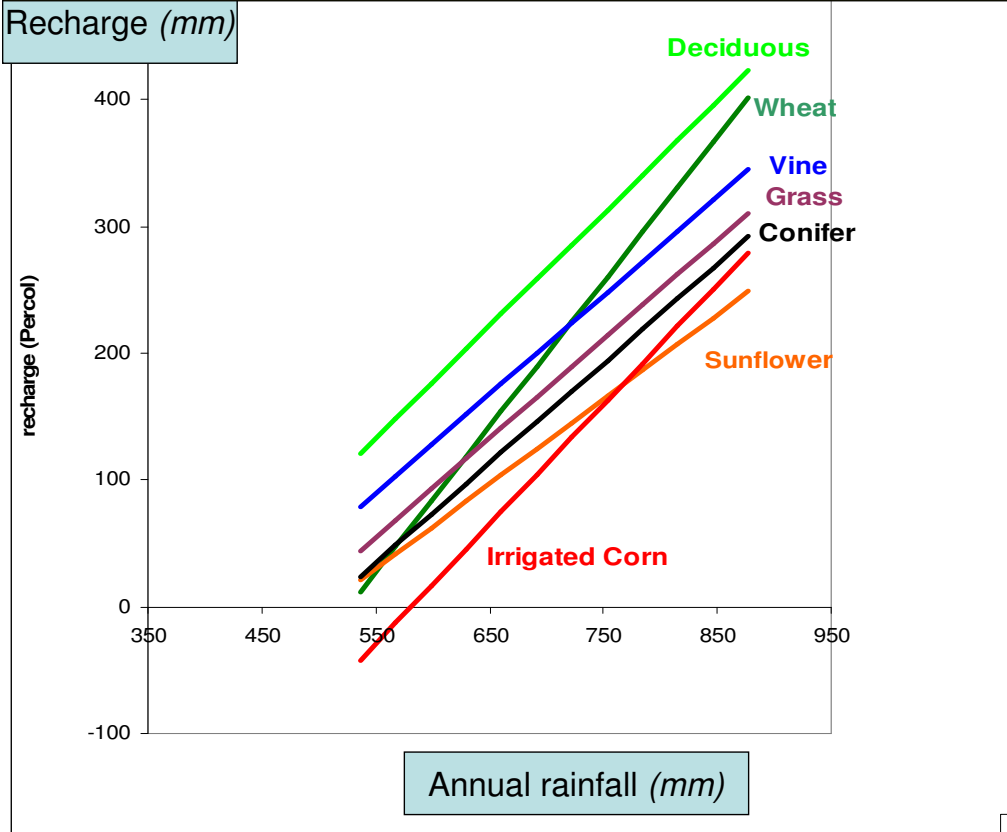


**Relationship between Recharge and annual Rainfall for  
Sunflower (○) and irrigated Corn (△)  
for 12 locations in France**  
*(from STICS model with observed climatic data from 1970-1999)*



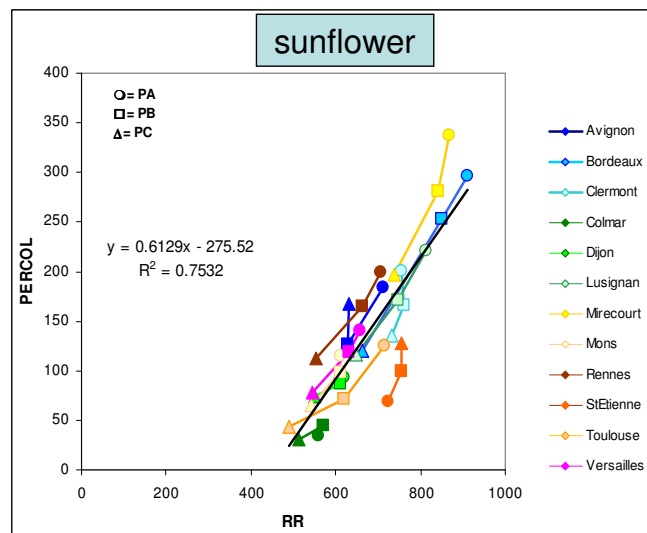
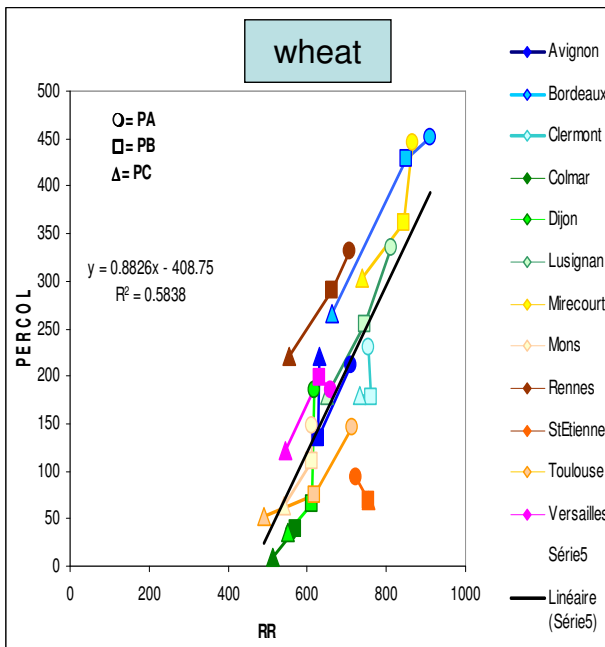


Annual recharge below some cropping systems  
 Stics & Biljou (forest)  
 using observed climatological data (1970-1999)

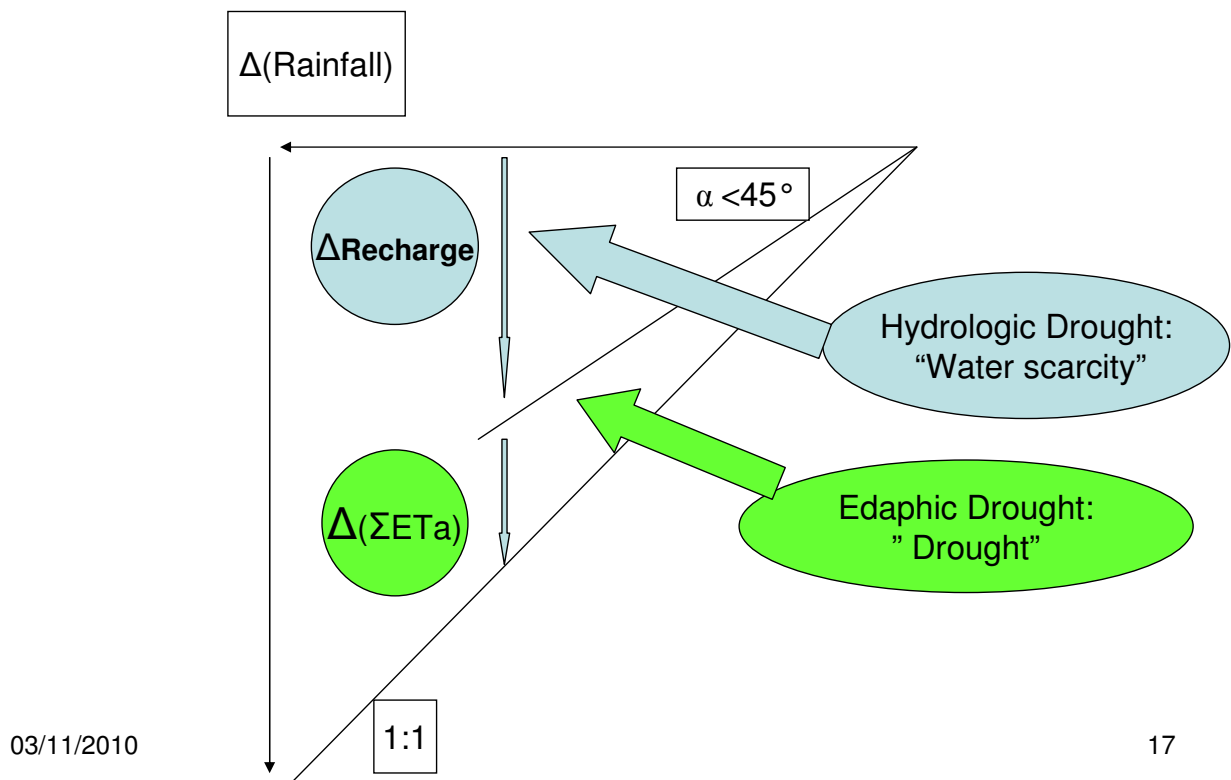


Evolution of Recharge (PERCOL) with annual Rainfall for wheat and sunflower at several locations in France

- PA: 1970-1999 → (observed climatic data)
  - PB: 2020-2049
  - ▲ PC: 2070-2099
- (simulated c. data - Arpège, TT, Stics).

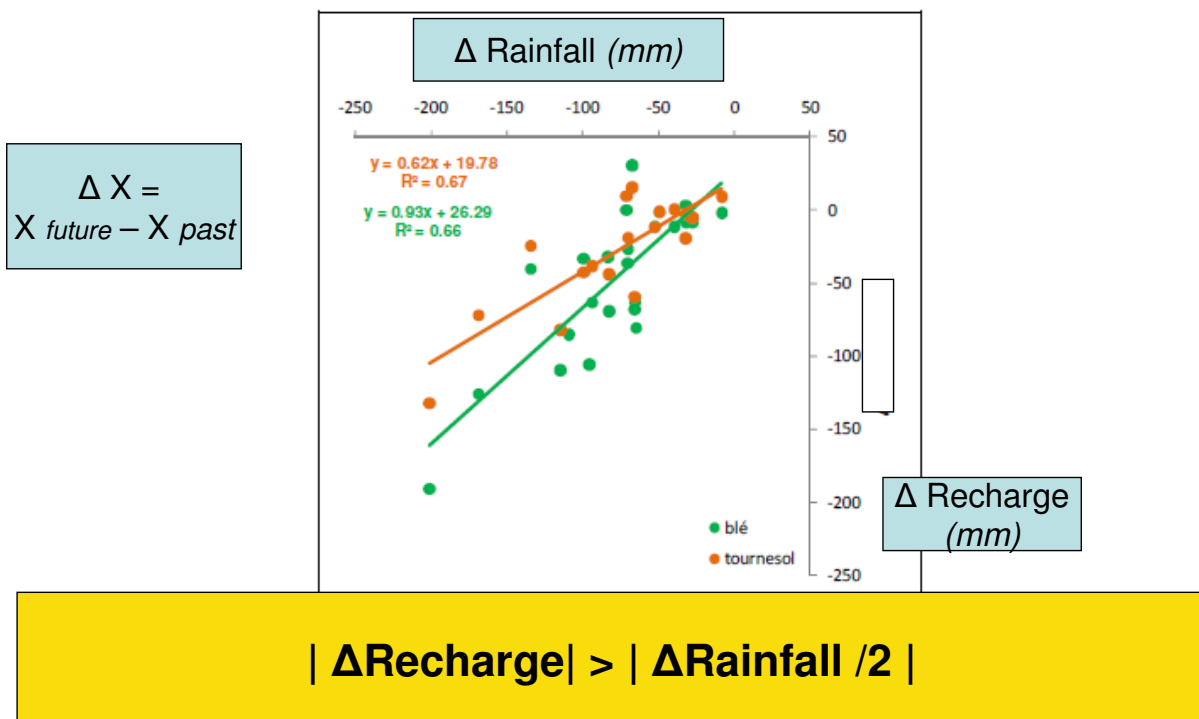


# Decrease in water recharge ( $\Delta\text{Recharge}$ ) versus decrease in rainfall ( $\Delta\text{Rainfall}$ ) due to climate change

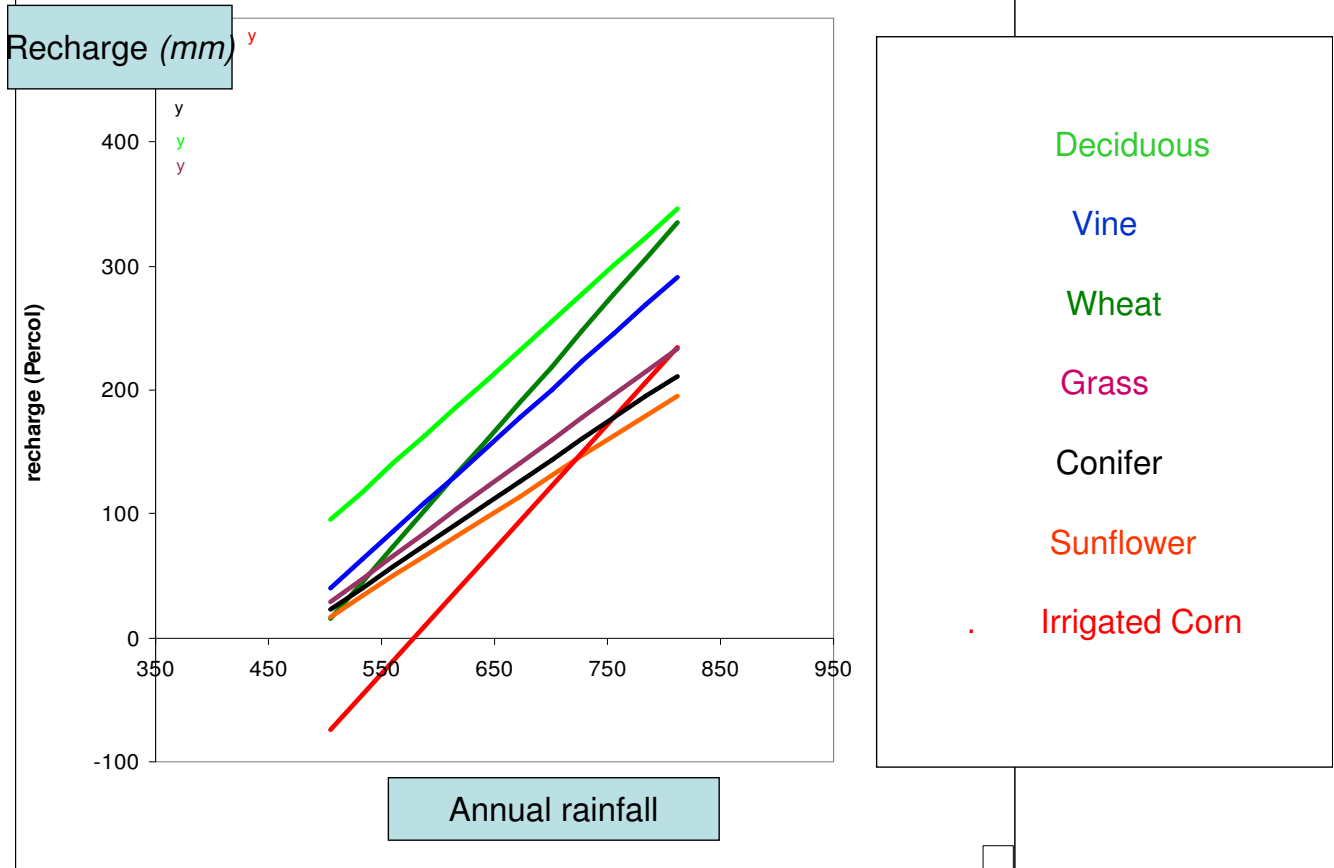


## Decrease in water recharge ( $\Delta\text{Recharge}$ ) versus decrease in rainfall ( $\Delta\text{Rainfall}$ ) (*Arpège, TT, Stics*)

Wheat – Sunflower



Annual recharge below some cropping systems  
(2020-2049) Stics & Biljou using simulated data



**Conclusions for**

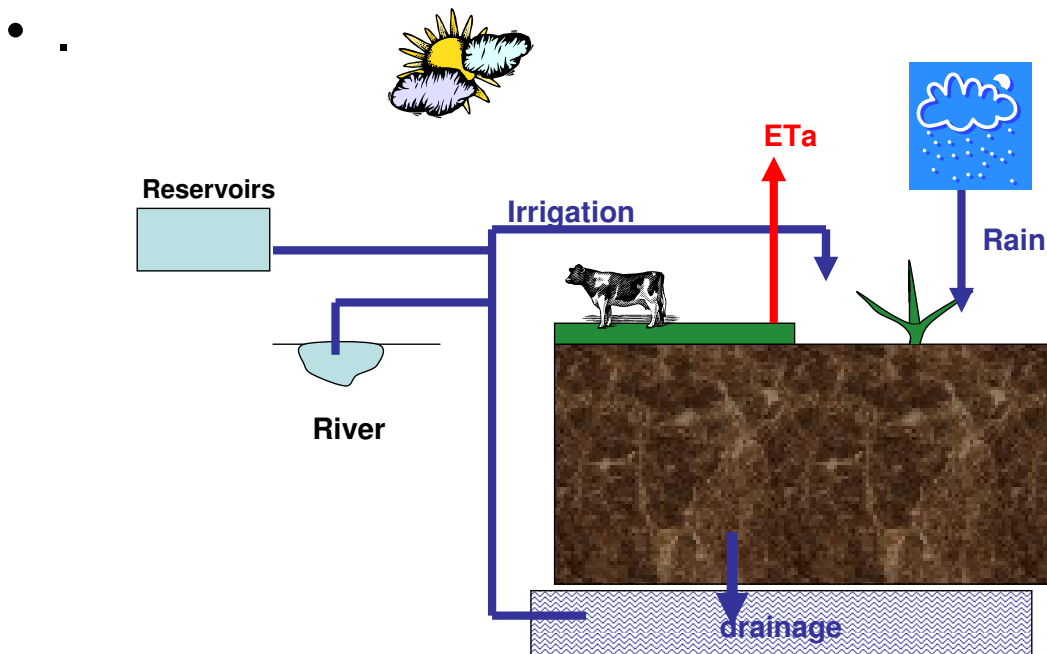
**« Large aquifer-dependent irrigation systems »**

- At catchment level, recharge depends on the combination of rainfed and irrigated systems
- The amount of water necessary to maintain the water table level will determine the capability of irrigation in terms of % of irrigated crops (acreage)

## Some ideas to improve the recharge capacity

- **Increase the % area cultivated with rainfed crops (obvious!!!)**
- Within irrigated crops,
  - **increase the % area cultivated with deficit irrigated crops (well known!!)**
- Within rainfed crops,
  - **increase the % area cultivated with winter crops**

## River(\*)-dependent Irrigation systems \* (or associated aquifers)



## *Rivers or water tables associated with rivers*

We are and we will be facing the question of « time of irrigation »: ***Water demand is high while water supply is at a minimum!***

***How can we improve water management at catchment basin level?***

Two ways:

- Improving practices
- Changing cropping patterns

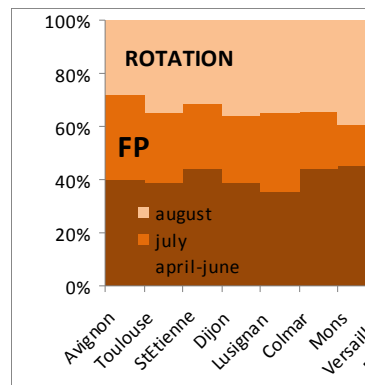
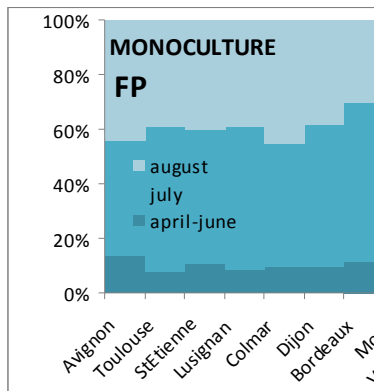
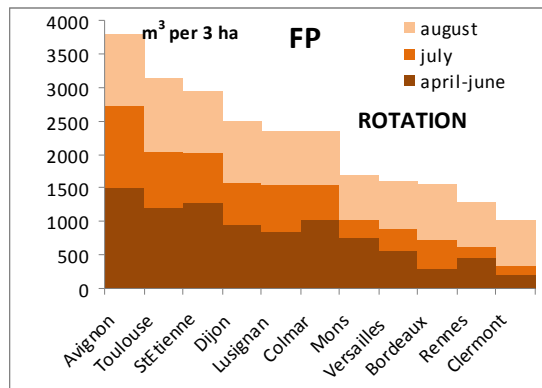
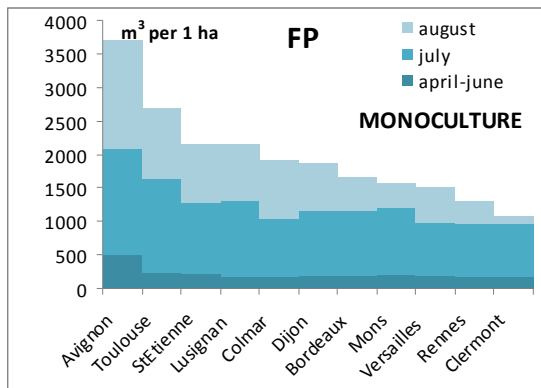
## *Rivers or water tables associated with rivers*

**Two reasons why a diversified cropping system pattern improves water management at catchment basin level:**

***1: The total amount of water demand decreases***

***2: Water demand is distributed throughout the irrigation season***

Irrigation water demand (**total amount and time of occurrence**) for irrigated Corn monoculture and a rotation ( *iC, dW,rR,dW*) at 12 locations in France,(2020 – 2049, ARPEGE,TT,STICS )



## Conclusion

Whatever the irrigation system,  
In addition to improving practices

***It is worthwhile to improve the matching of cropping systems to water supply at catchment level***

**Diversifying cropping systems will help:**

- to **equilibrate** the annual water balance of large aquifers
- to better **distribute** water demand throughout the year

# Thank you for your attention

**Climate change will produce a decrease in rainfall over French territory, especially in western France. Cropping systems pattern is a key factor in water resources management at catchment basin level.**

**In the frame of the ANR French project “Climator”, we have undertaken an analysis of the relationship between rainfall and the annual supply of water to the aquifers under several cropping systems and ecosystems.**

**This was performed through crop modelling using agroclimatic data provided either by measurements at 12 experimental sites in France (1971-2000) or by using regionalised outputs of the French climatological model Arpege (2021-2050 and 2071-2100). The simulations highlight the important differences in aquifers recharge between cropping systems (rainfed vs irrigated but also winter vs spring crops and annual crops vs perennial vegetation). For the 12 sites, they also give an estimate of the decrease with time of the annual recharge under each cropping system (at least 2/3 of rain decrease). In the driest locations, that decrease may lead to a partial change in cropping systems pattern in order to match the total water demand at catchment level.**

**Such change could be devoted either to increase annual recharge when irrigation water is pumped from large aquifers or to reduce summer water demand when irrigation water comes from rivers. Both cases are illustrated.**

***Matching supply to irrigation demand?  
or .....irrigation demand to supply?***

**1- Matching supply to demand**

**(when it is possible: dams, ...)**

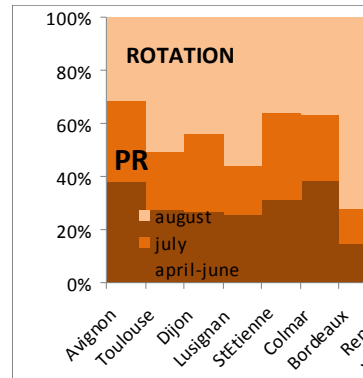
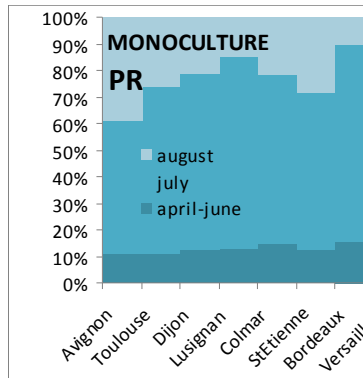
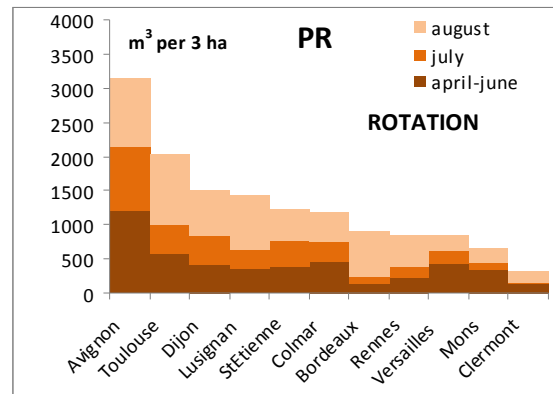
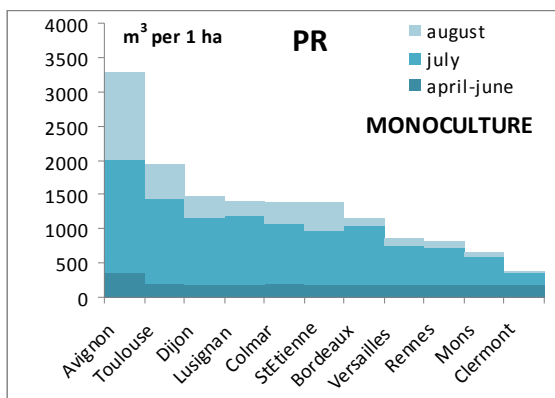
**2- Matching demand to supply**

**- *either by reducing water provided to crops  
and improving cultural practices***

**- or by reducing the water demand at  
catchment level by changing the cropping  
system**



Irrigation water demand (**total amount and time of occurrence**)  
 for irrigated Corn monoculture and a rotation ( *iC, dW, rR, dW* )  
 at 12 locations in France, (1970 – 1999, STICS )



Irrigation water demand (**total amount and time of occurrence**)  
 for irrigated Corn monoculture and a rotation ( *iC, dW, rR, dW* )  
 at 12 locations in France, (2020 – 2049, ARPEGE, TT, STICS )

