Water use adaptations to climate change

Eduard Pla and Diana Pascual, CREAF

Workshop: Landscape and Climate Change

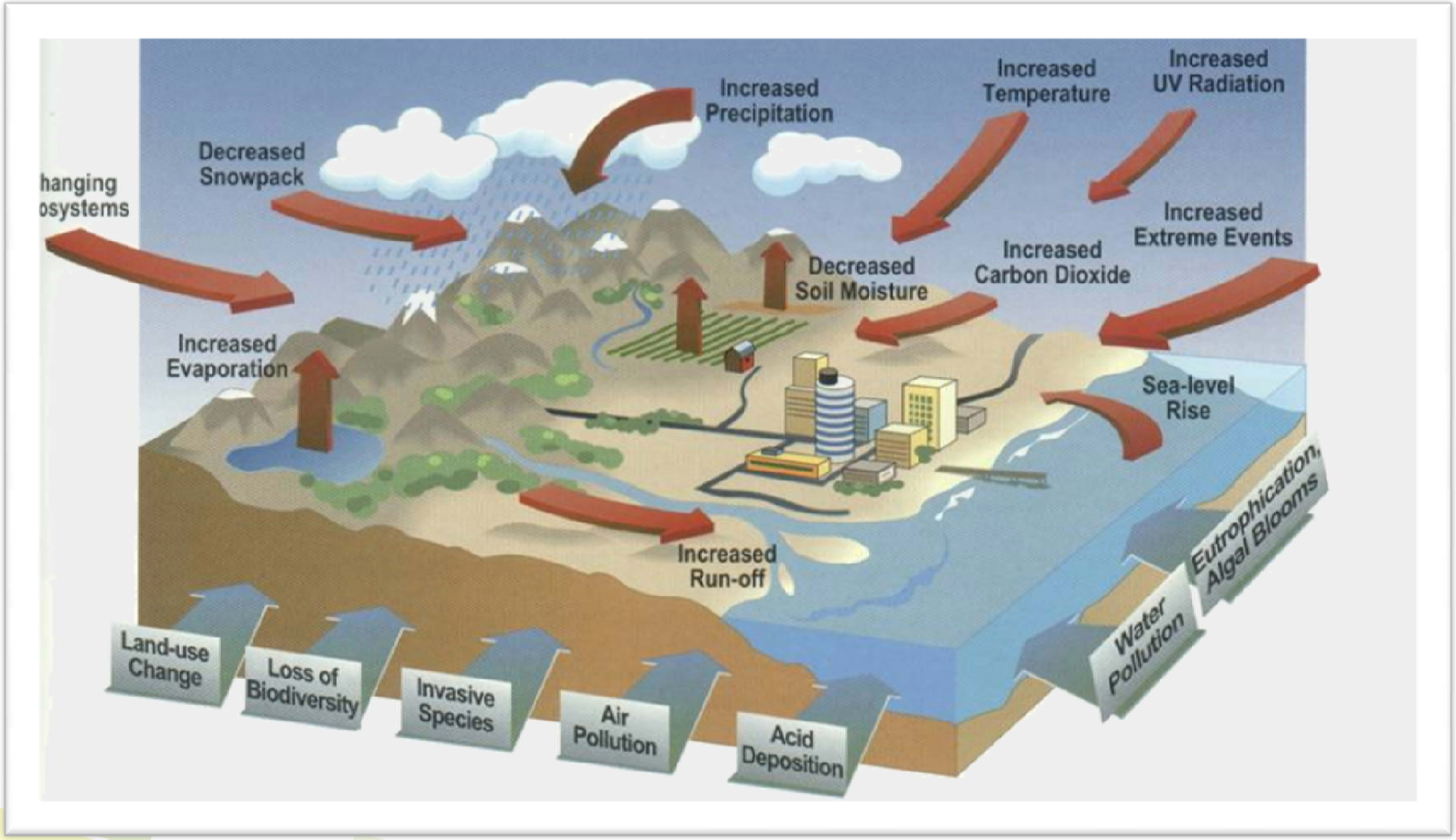
Olot, 10th July 2012

- Global Change Impacts
- Impacts in the Mediterranean basin
- ACCUA project

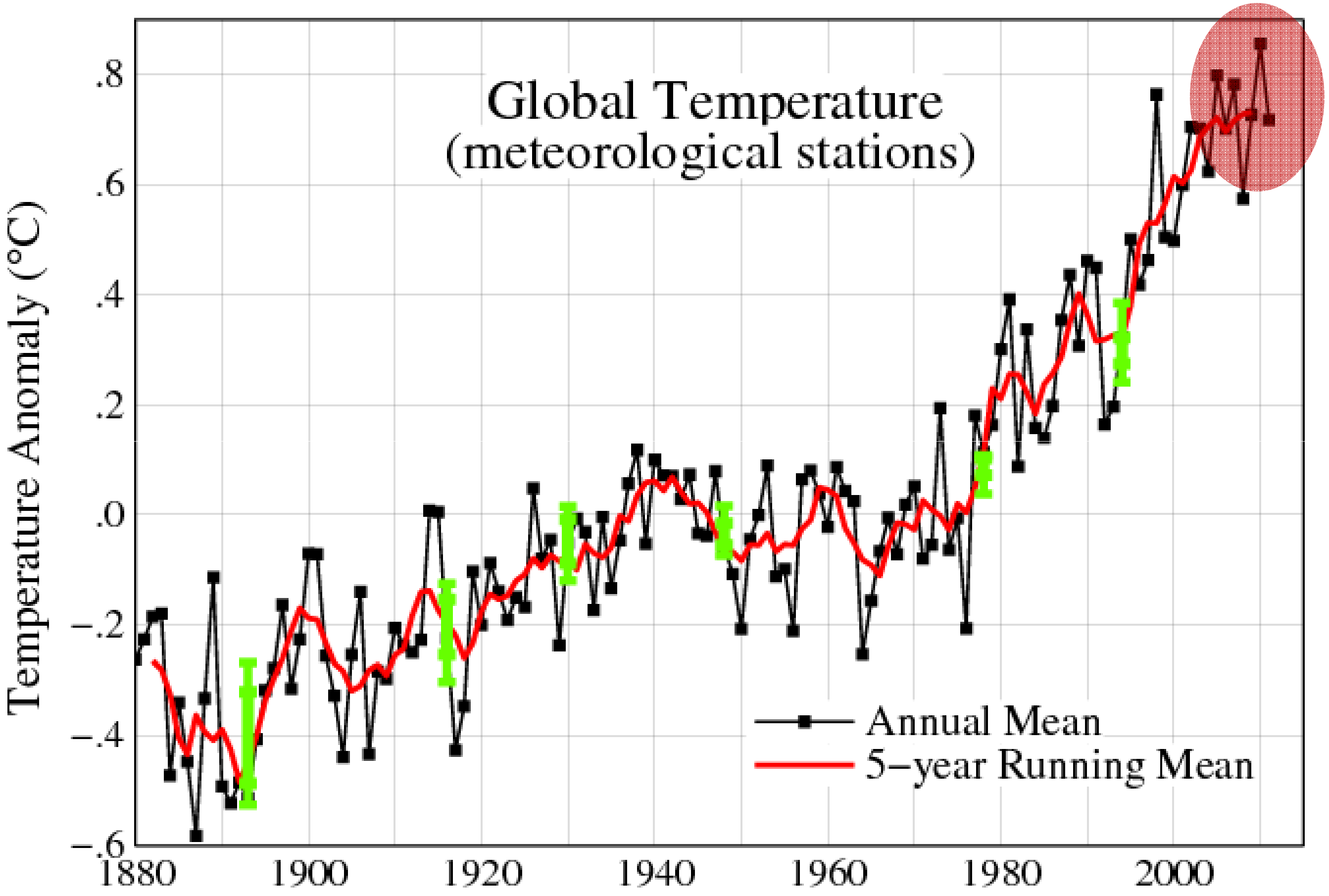
Global Change impacts

Global Change impacts

Main driving forces of Global Change



Global Change impacts
Temperature increase



Increase 0.74 ºC from1906 to 2005

5 warmest years:
1th. 2005
2nd. 2010
3rd. 1998
4th. 2003
5th. 2002

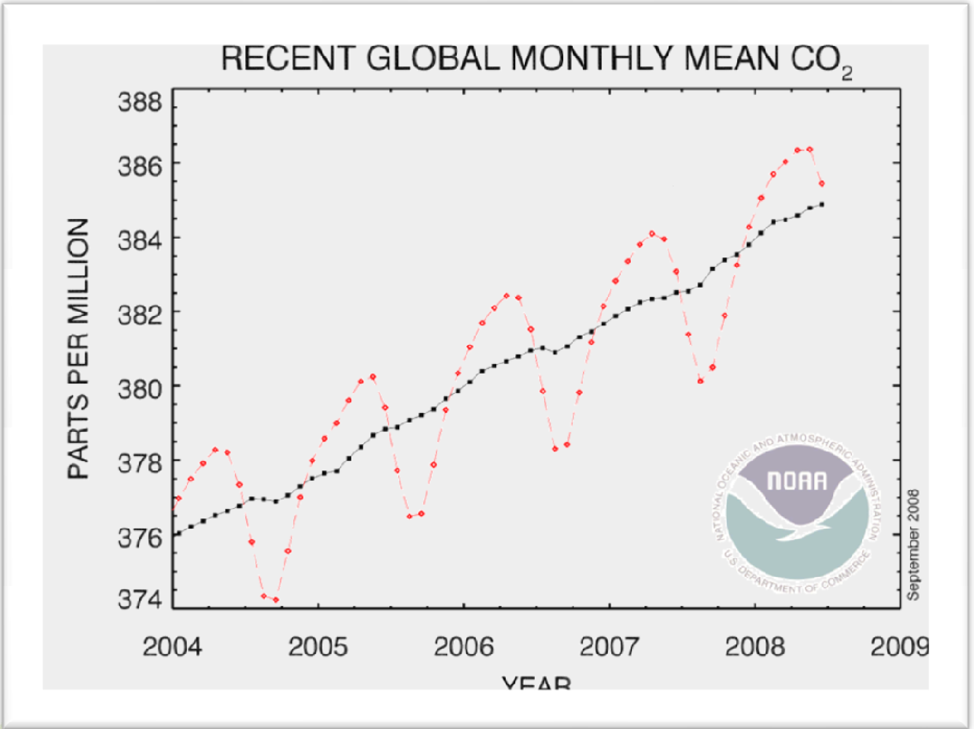
Source: GISS 2012

The **2001-2010 decade** has been the **warmest** one never registered

Global Change impacts
CO_2 concentration increase

2008 CO_2 atmospheric concentration: **389 ppm**

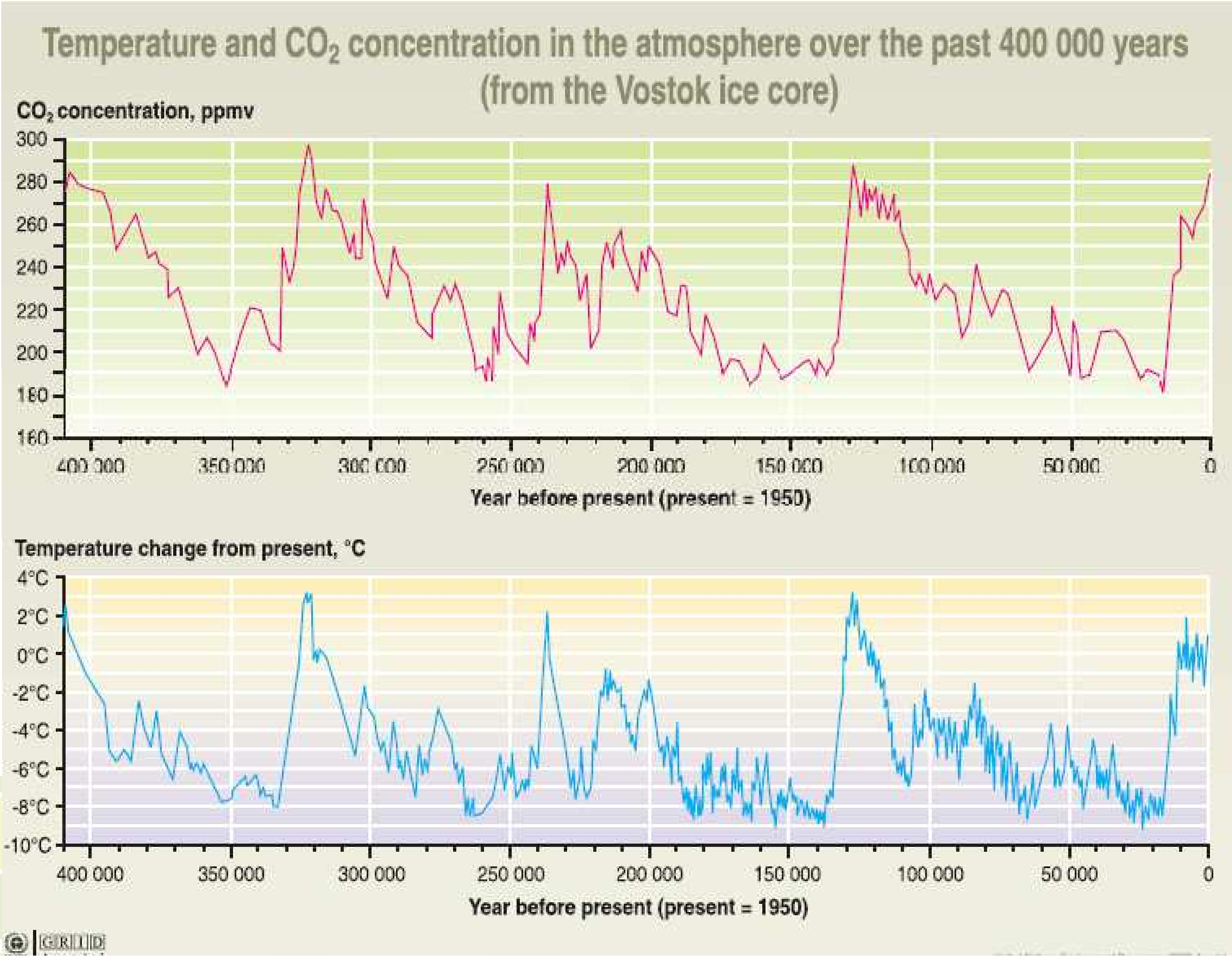
+36% over pre-industrial level
+28% over 1990 Kyoto baseline



1970 – 1979: 1.3 ppm yr^{-1}
1980 – 1989: 1.6 ppm yr^{-1}
1990 – 1999: 1.5 ppm yr^{-1}
2000 – 2006: 2.0 ppm yr^{-1}
2007 – 2008: 2.5 ppm yr^{-1}

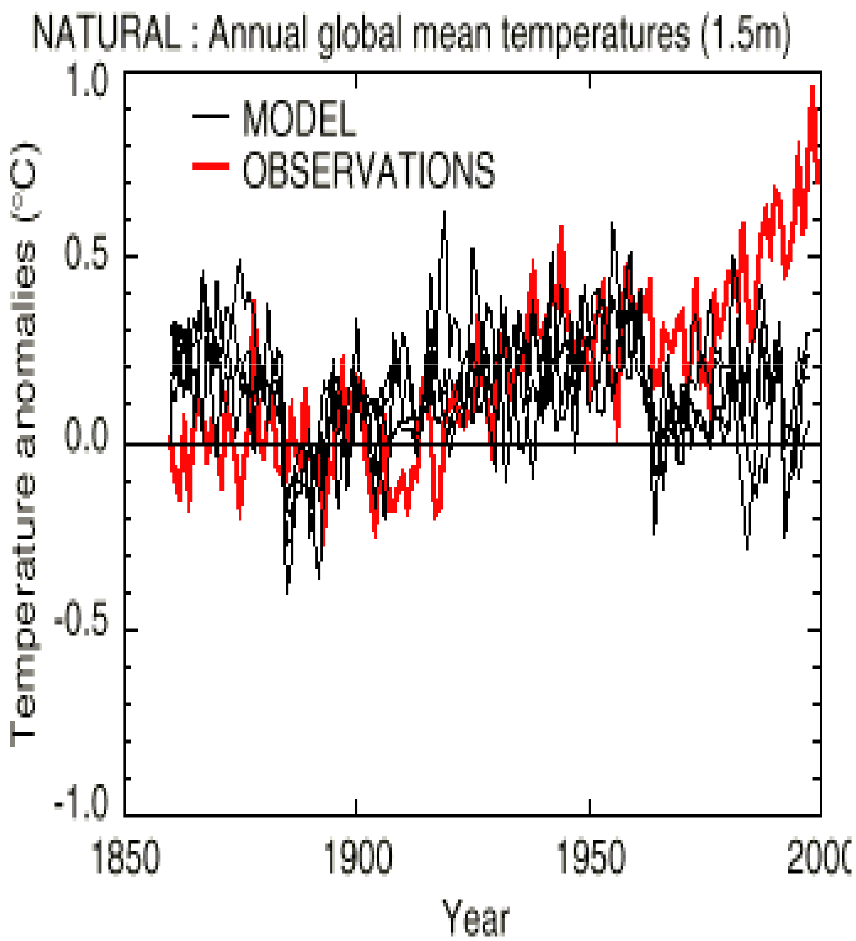
Global Change impacts

CO_2 concentration and temperature relationship



Global Change impacts

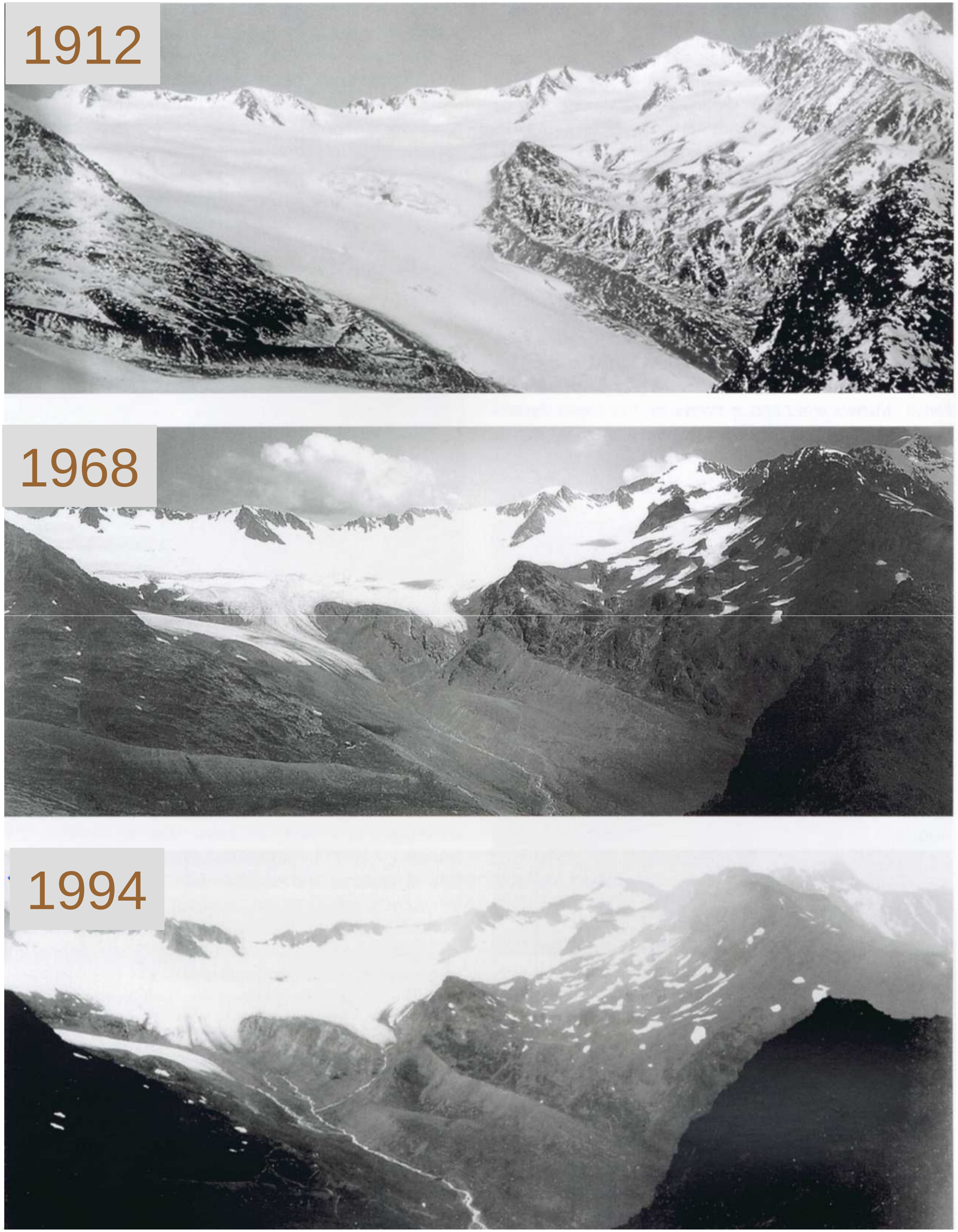
Temperatures: observed vs simulated



Source: Tett et al. 1999.

Global Change impacts

Glaciers retrait

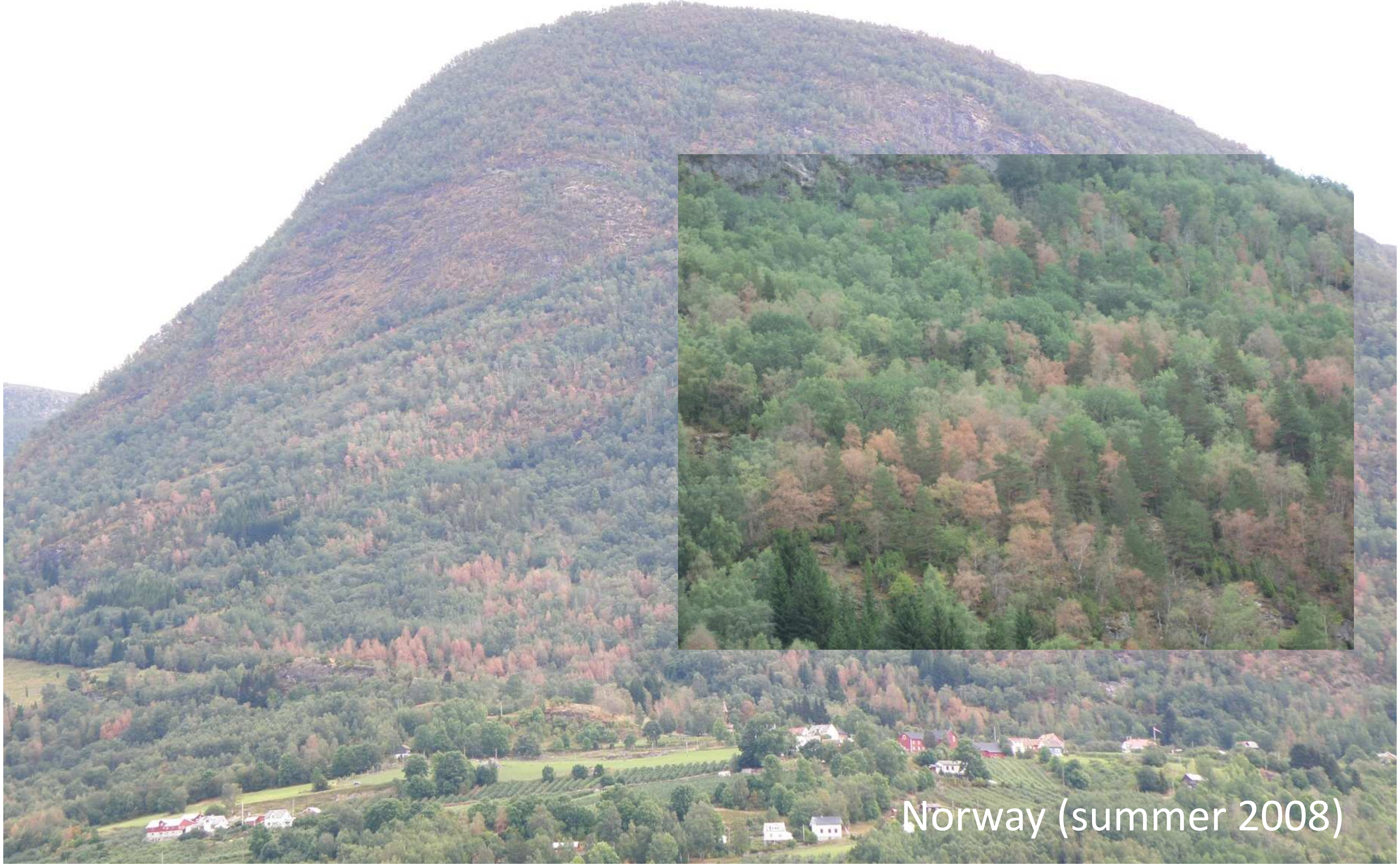


Vernagt Ferner glacier

(Tyrolean Alps)

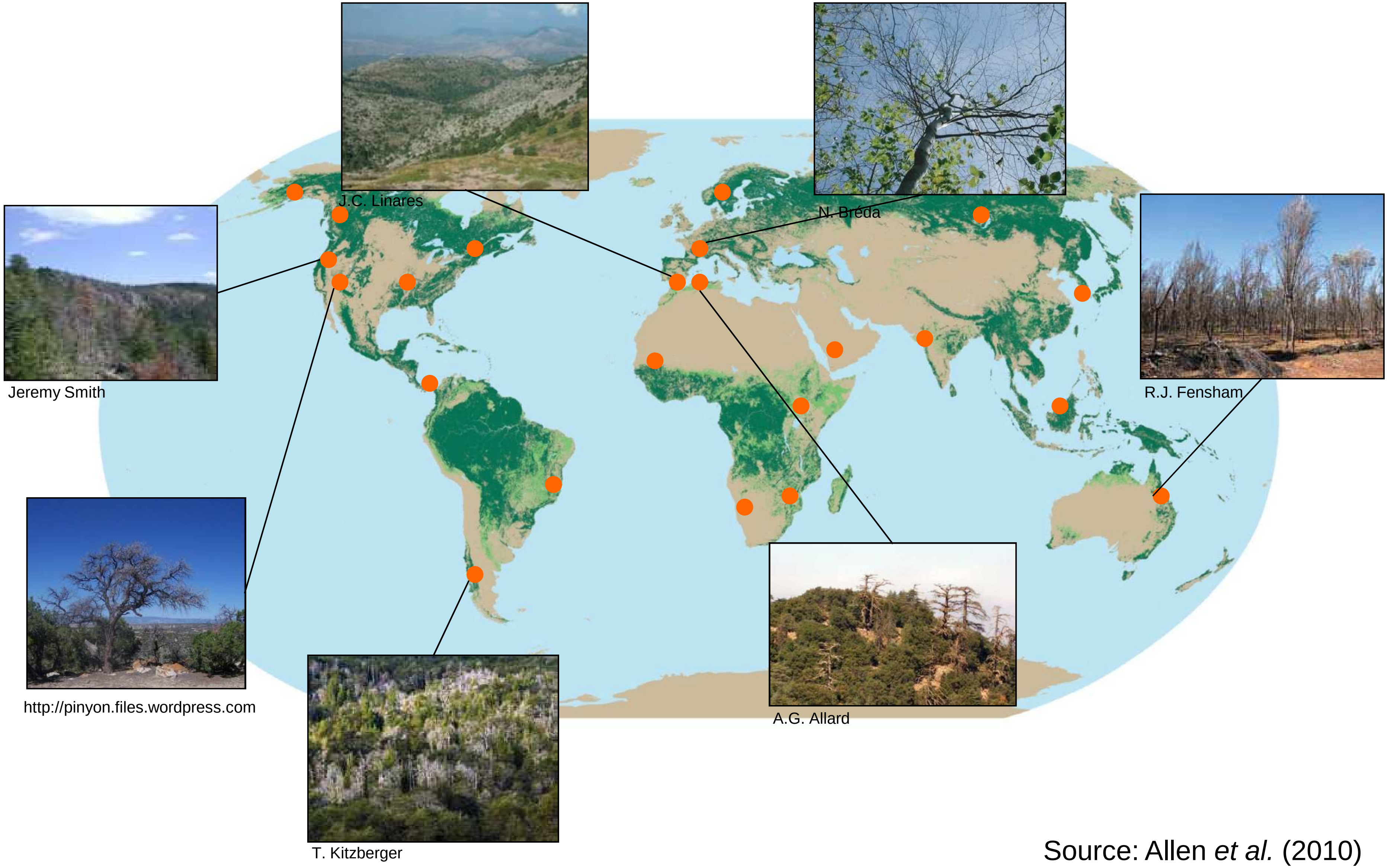
Global Change impacts

Droughts and tree mortality



Global Change impacts

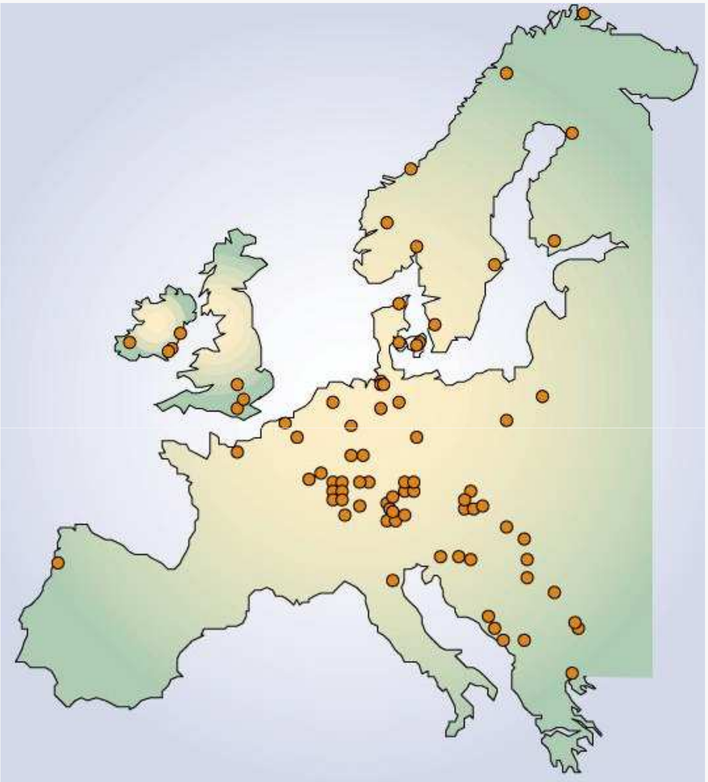
Droughts and tree mortality

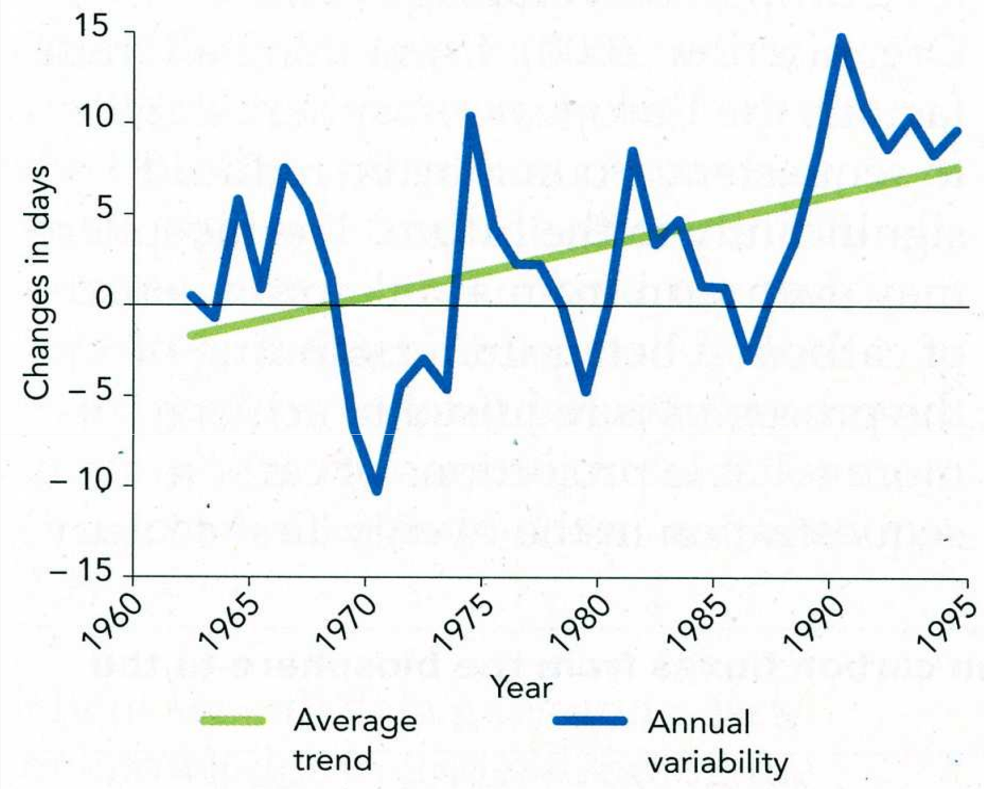


Source: Allen *et al.* (2010)

Global Change impacts

Changes in plant growth period





Note: Observed data from the International Phenological Gardens in Europe except France, the Iberian peninsula, mid and southern Italy, and Greece.
Source: Menzel, 2002; Menzel u. Fabian, 1999.

Disruptions in organism relationships

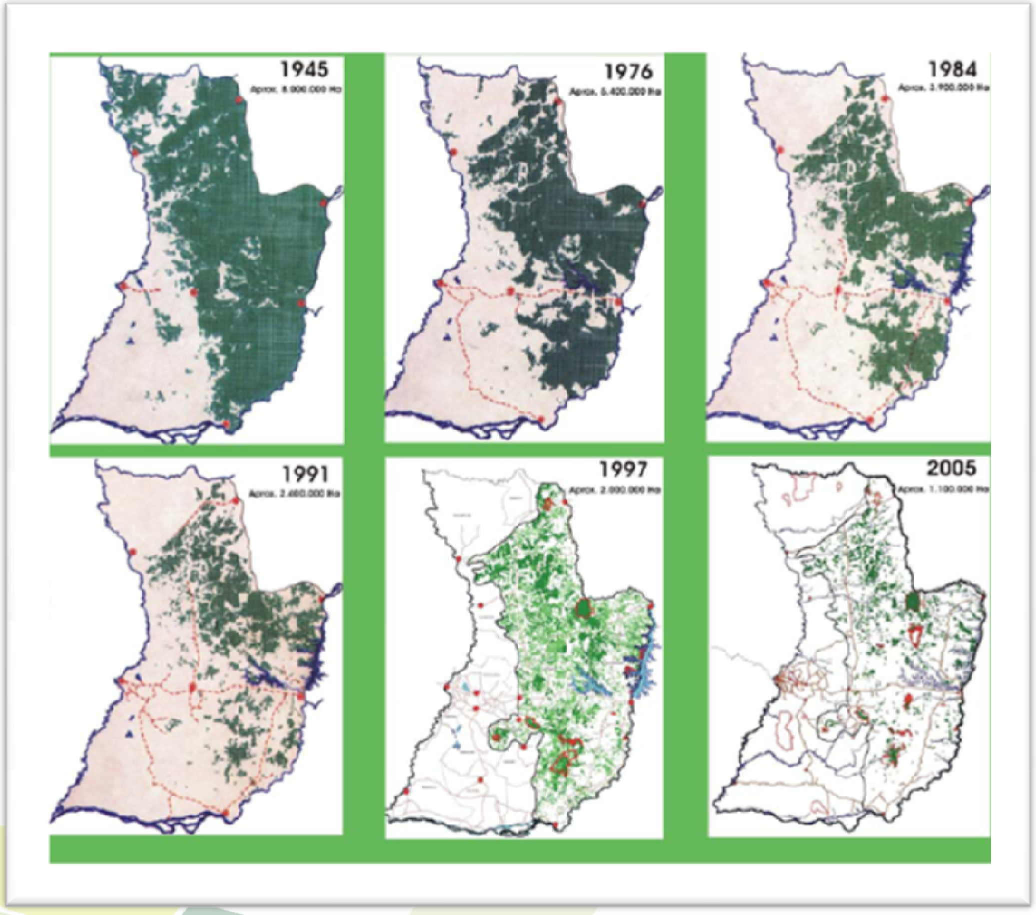
Global Change impacts

Deforestation in some Planet regions

Matto Grosso do Norte, Brasil. Y. Arthus-Bernard, 1999, *La Tierra desde el Cielo*.

Global Change impacts

Deforestation in some Planet regions



Paraguay, conserved forests:

1945 → 8 M ha

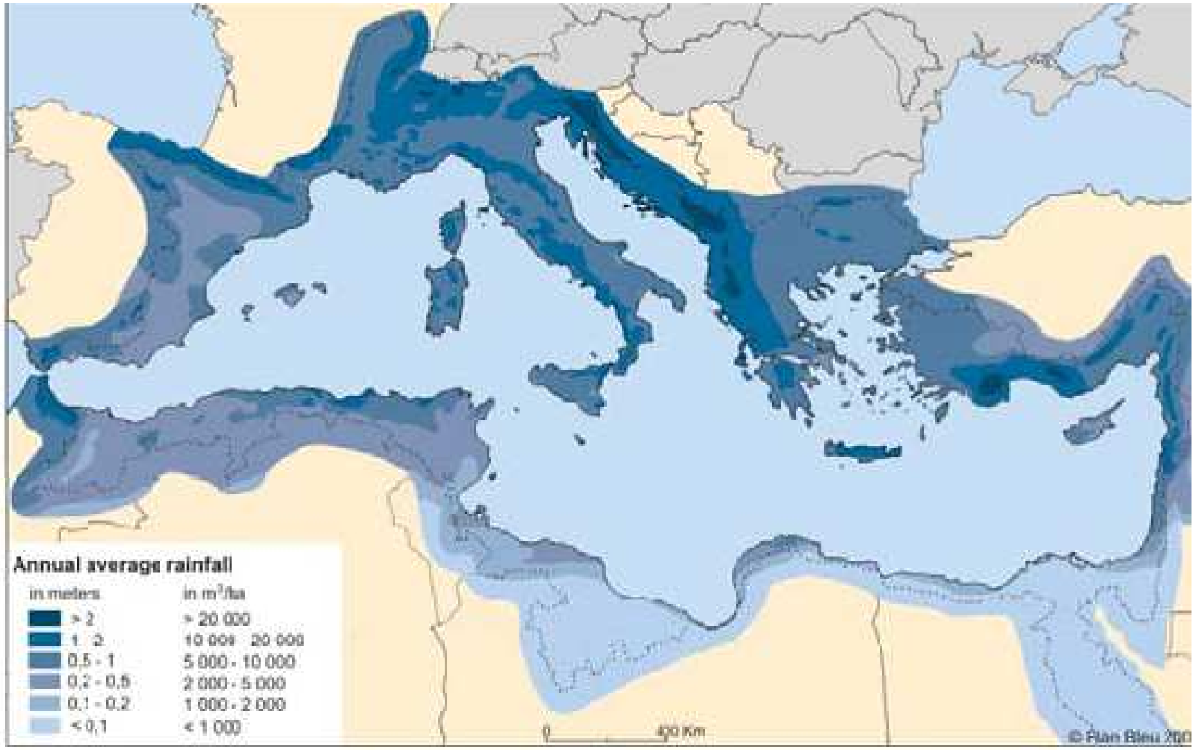
2005 → 0,8 M ha

Source: PNUD 2007

Impacts in the Mediterranean basin

Impacts in the Mediterranean basin

A region with high heterogeneity in space and time

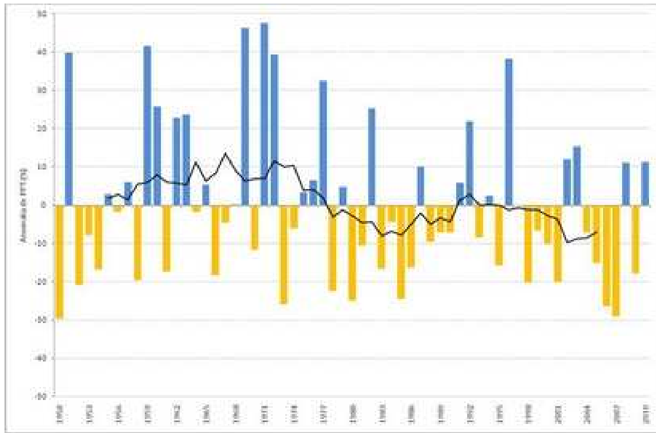


Source: Plan Bleu 2003

Rainfall distribution in a region with a **3% of World water resources** for a **7% of World population**.

Source:SMC 2011

Rainfall anomaly in Catalonia compared with the historical mean for the 1950-2010 period



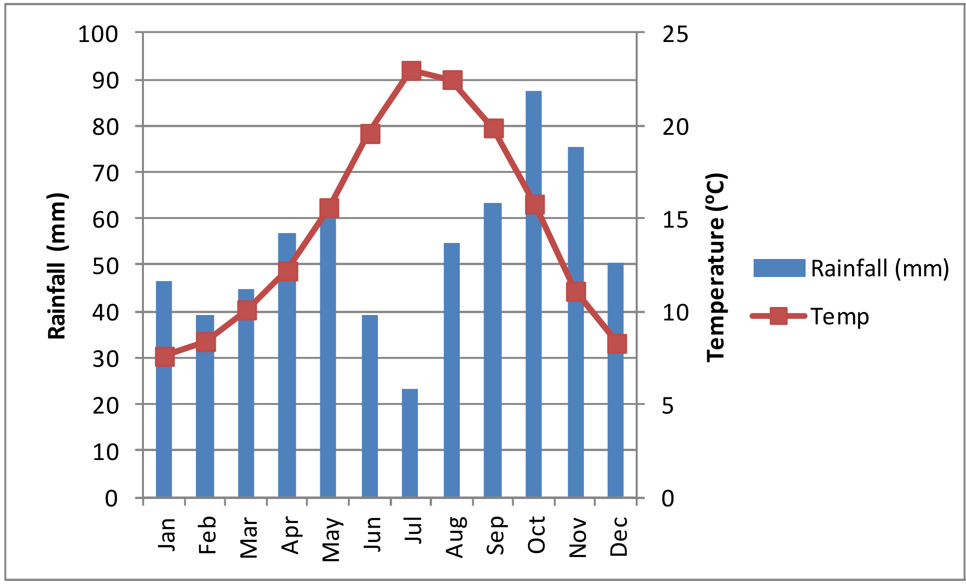
Impacts in the Mediterranean basin

A region with high heterogeneity in space and time

Al meu país la pluja no sap ploure:
o plou poc o plou massa. *Raimon (1983)*

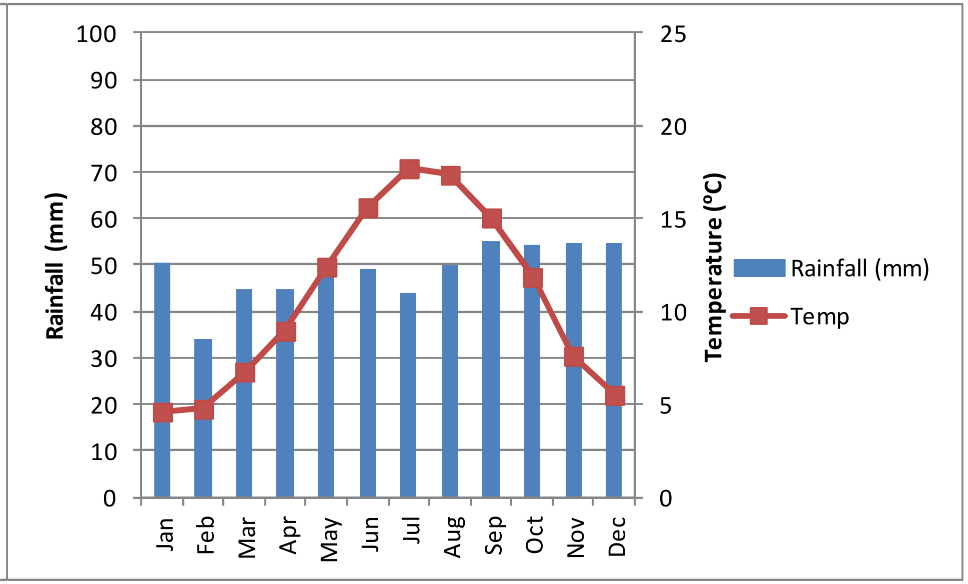
In my country the rain doesn't know how to rain,
it either rains too much or too little. *Raimon (1983)*

Barcelona (Fabra station)



Mean anual precipitation 1961-90: 641.8 mm

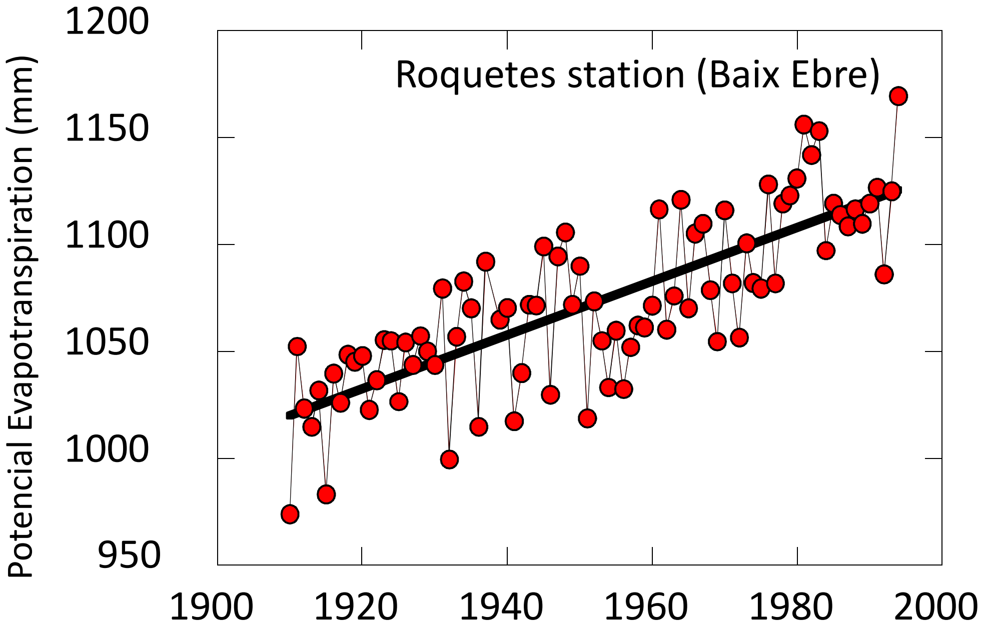
London (Greenwich)



Mean anual precipitation 1961-90: 585.5 mm

Impacts in the Mediterranean basin

Trends in Potential Evapotranspiration



Source: Piñol et al. 1998

Weather is becoming more **arid**...

Impacts in the Mediterranean basin

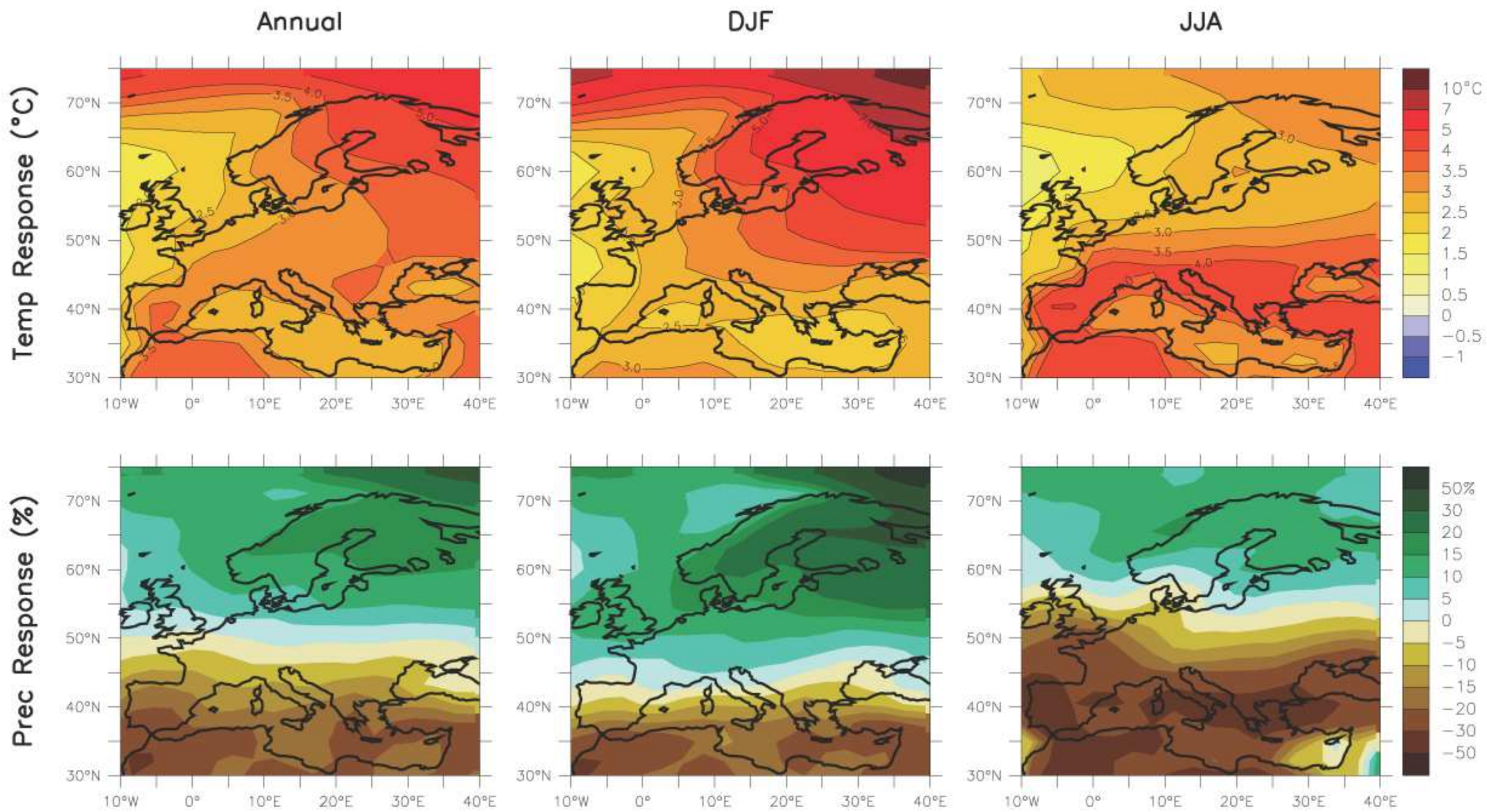
Impacts can vary among regions

Impacts in the Mediterranean basin

Future climate: temperature and rainfall projections

Annual mean, DJF and JJA temperature change between 1980 to 1999 and 2080 to 2099, averaged over 21 models (A1B scenario)

Annual mean, DJF and JJA fractional precipitation change between 1980 to 1999 and 2080 to 2099, averaged over 21 models (A1B scenario)



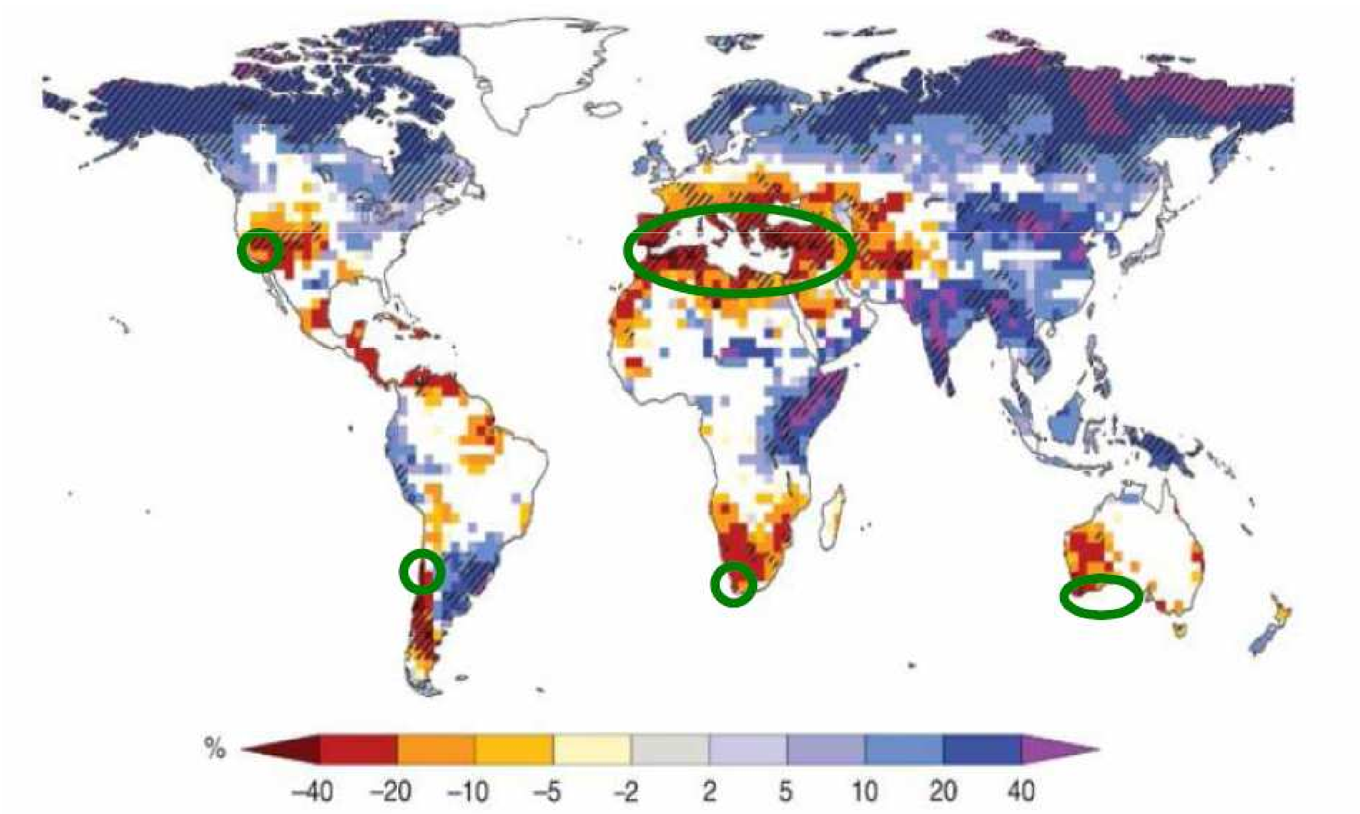
Mediterranean basin could become one of the **most vulnerable areas** to climate change in Europe

Source: Climate Change 2007
Fourth IPCC Assessment Report

Impacts in the Mediterranean basin

Changes in water resources

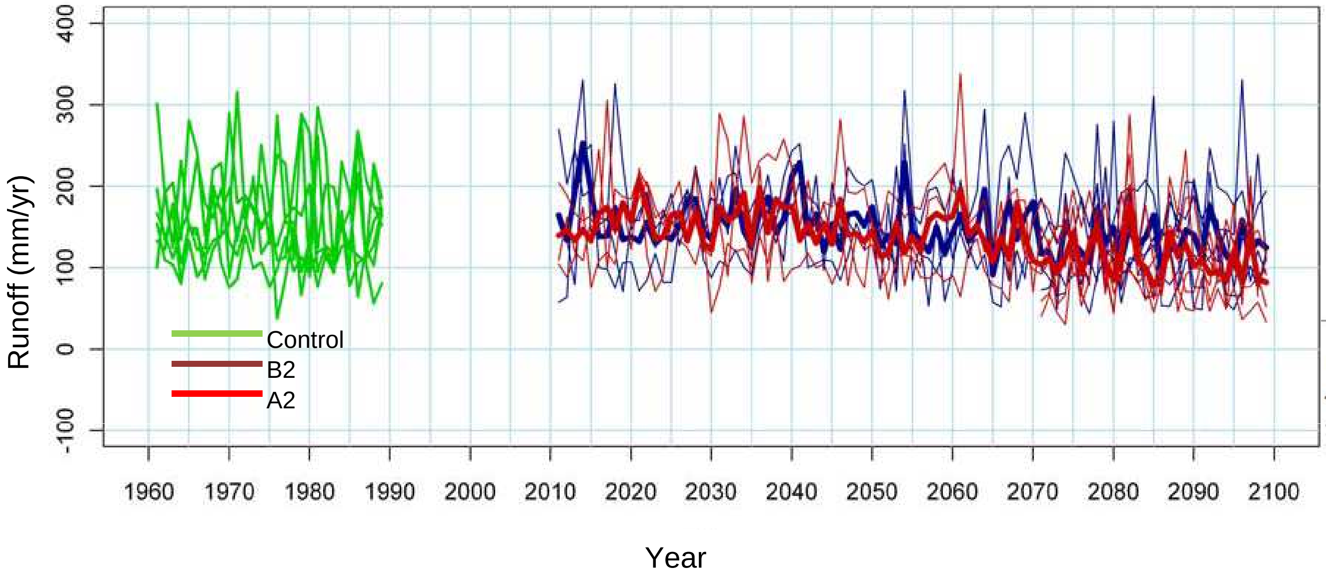
Changes in **annual runoff** for 2090-99 period, relative to 1980-99

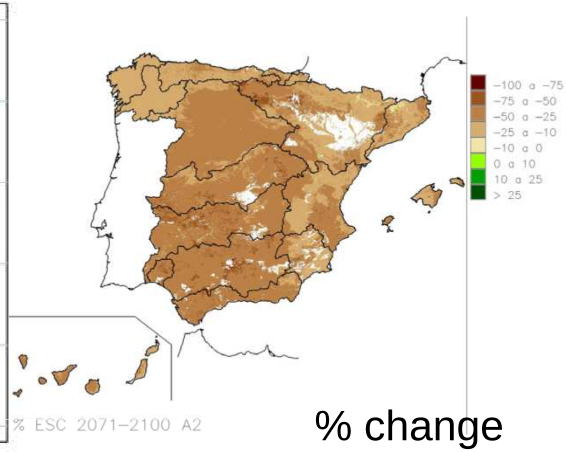


Source: Climate Change and Water 2008. IPCC Technical Paper VI

Impacts in the Mediterranean basin

Future trends on water resources in Spain





% change
A2 (2071-2100)

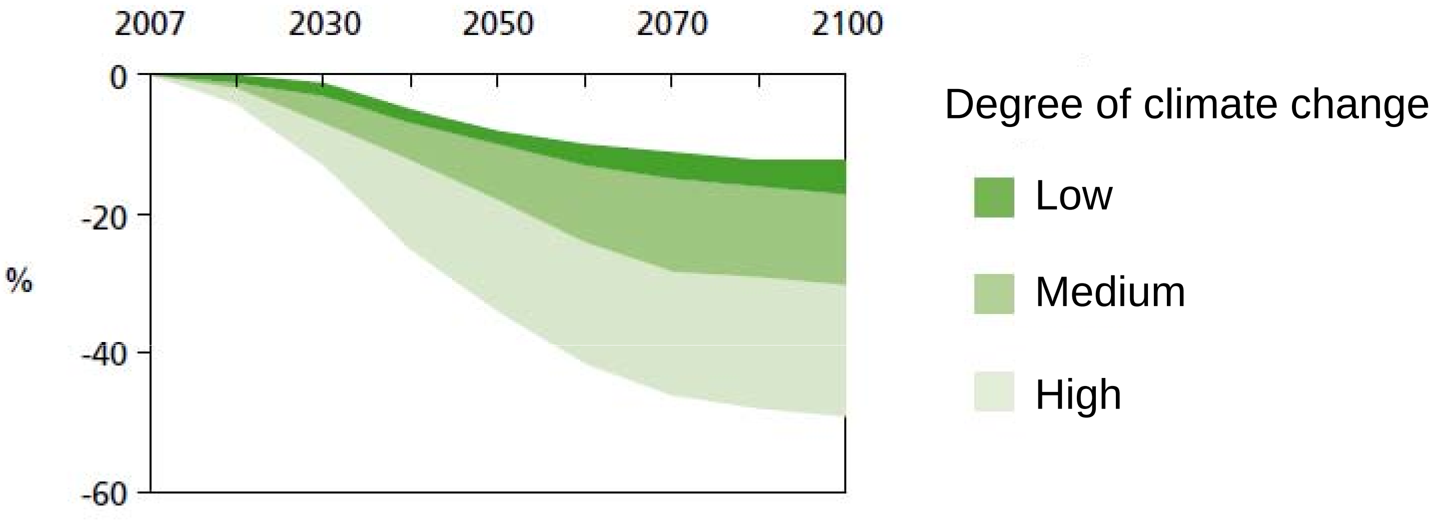
Runoff could decrease **-8%** for the 2011-2040 period, **-16%** for 2041-2070 and **-28%** for 2071-2100 (**A2** scenario)

Groundwater recharge: -8% for 2011-2040, **-15%** for 2041-2070 and **-27%** for 2071-2100 (**A2** scenario).

Source: CEDEX-MARM 2011

Impacts in the Mediterranean basin

Future trends on water resources in Catalonia

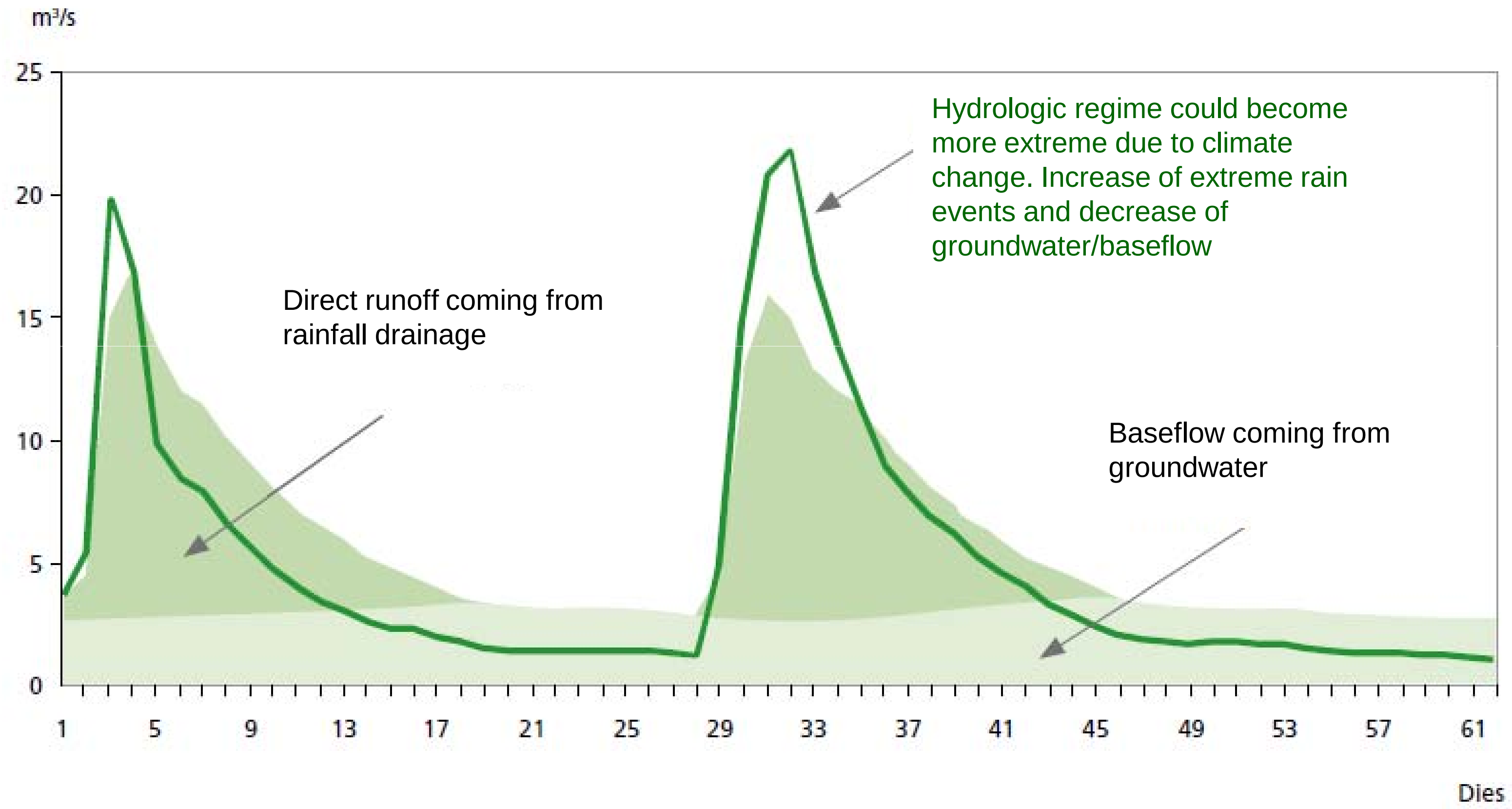


Source: ACA 2009

Compilation of previous studies focused on **Catalonia**: average decrease on annual stream flow contributions of **-5%** (2015-2030) and **-16 to -28%** (2070-2100)

Impacts in the Mediterranean basin

Expected changes in stream flow pattern

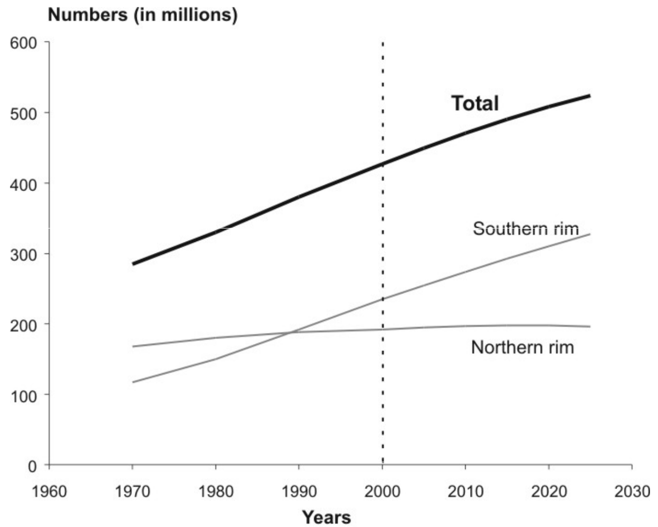


Source: ACA 2009

Impacts in the Mediterranean basin

Vulnerabilities of human populations

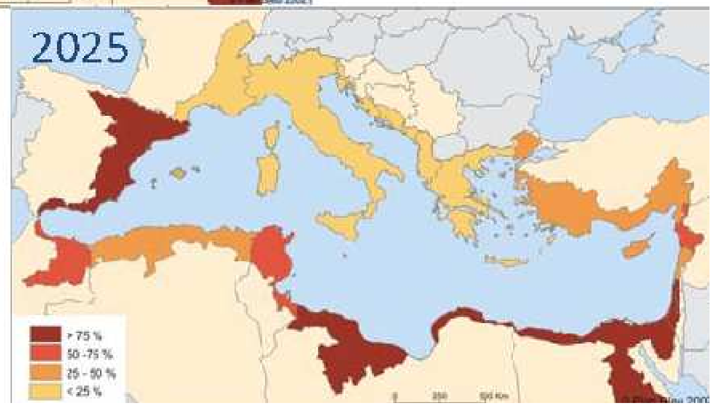
Mediterranean population



Source: Plan Bleu 2004

Water Exploitation Index (WEI)

WEI > 40% indicates severe stress over water resources



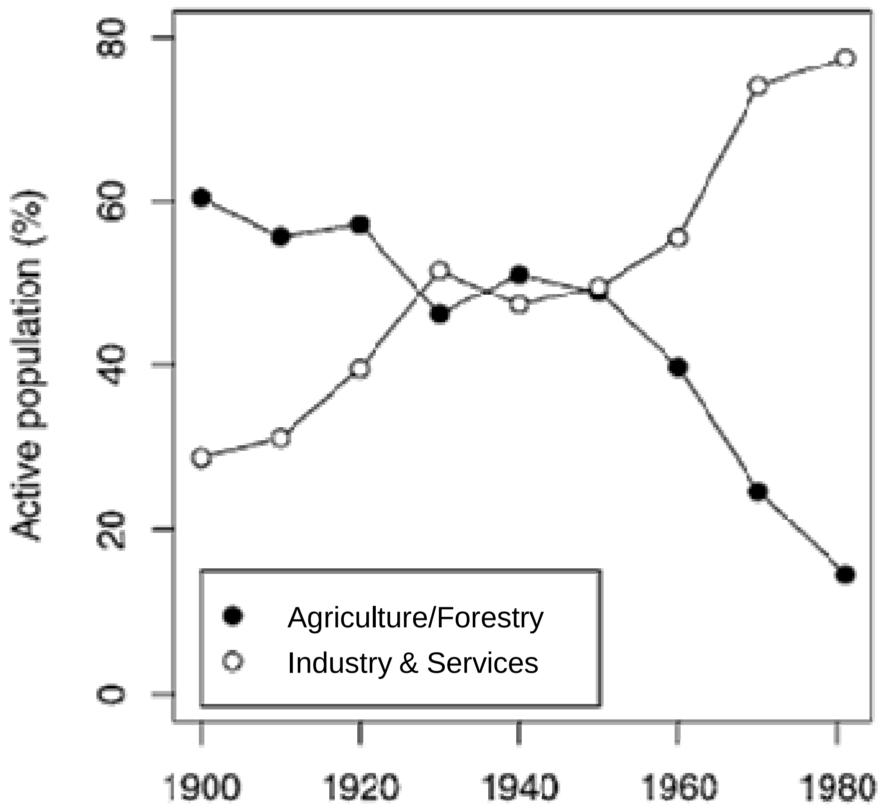
Source: Benoit i Comeau 2005

Impacts on Mediterranean basin

There are also important land use changes in the North rim

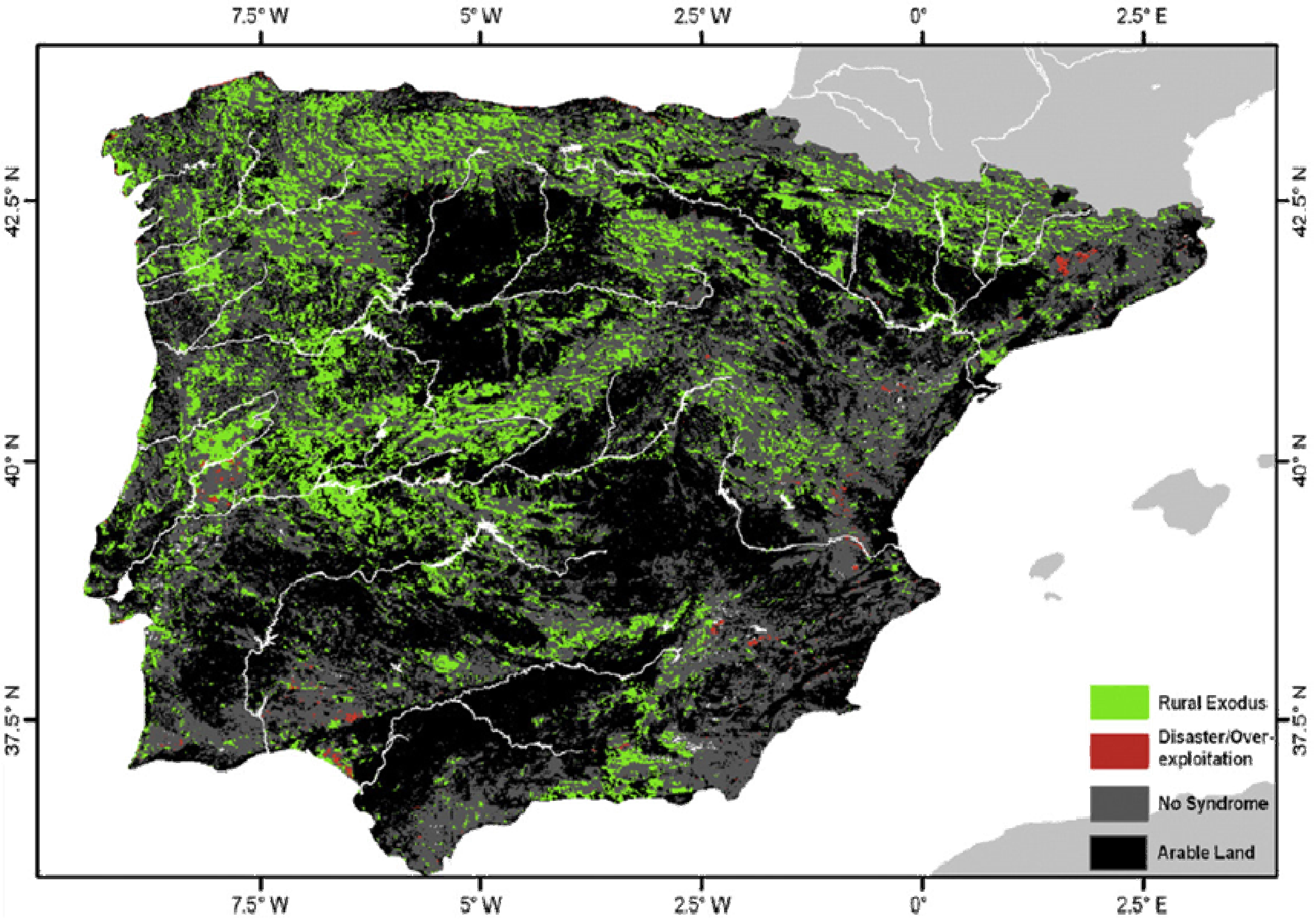
Agricultural land abandonment

Forest management changes



Impacts on Mediterranean basin

There are also important land use changes in the North rim



Source: Hill et al, 2008, Global and Planetary Change 64

Impacts in the Mediterranean basin

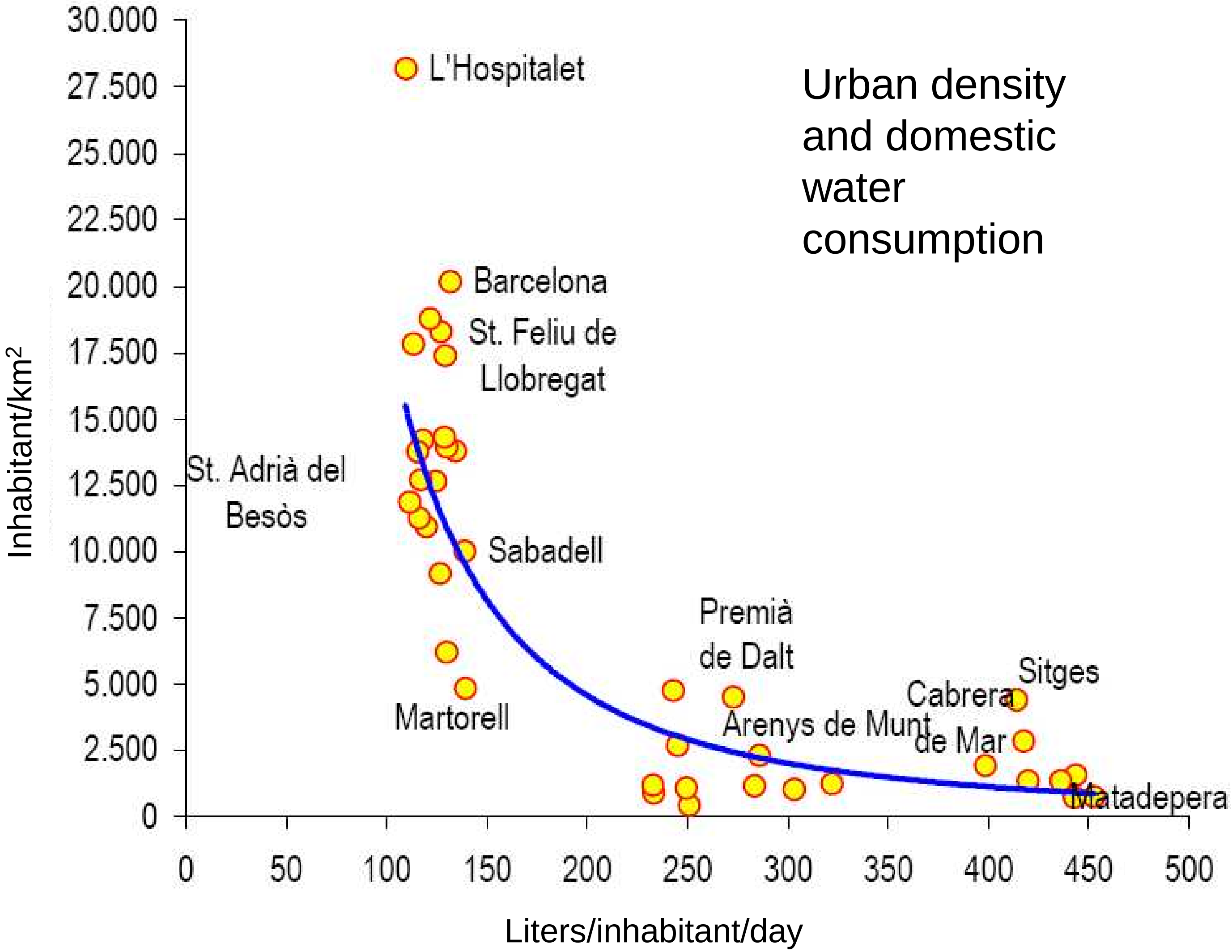
Land use changes

Tarragona surroundings, year 2006

Source: MCSC http://www.creaf.uab.cat/mcsc

Impacts in Mediterranean basin

Changes in urban sprawl in Catalonia



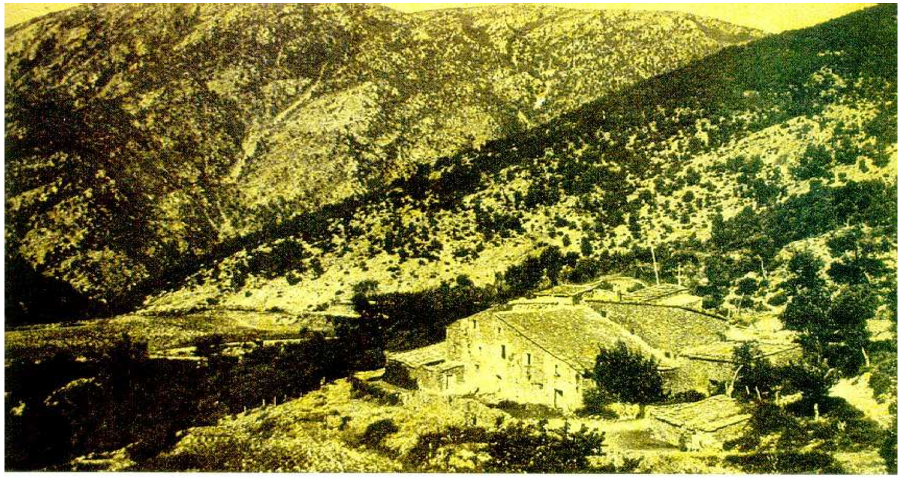
Urban density and domestic water consumption

Source: Tello (2005), from Ribera et al. 2001.

Impacts in the Mediterranean basin

Changes which imply a forest surface increase

MONTSENY (CATALONIA)



BEFORE

NOW

Impacts in the Mediterranean basin

Changes which imply a forest surface increase

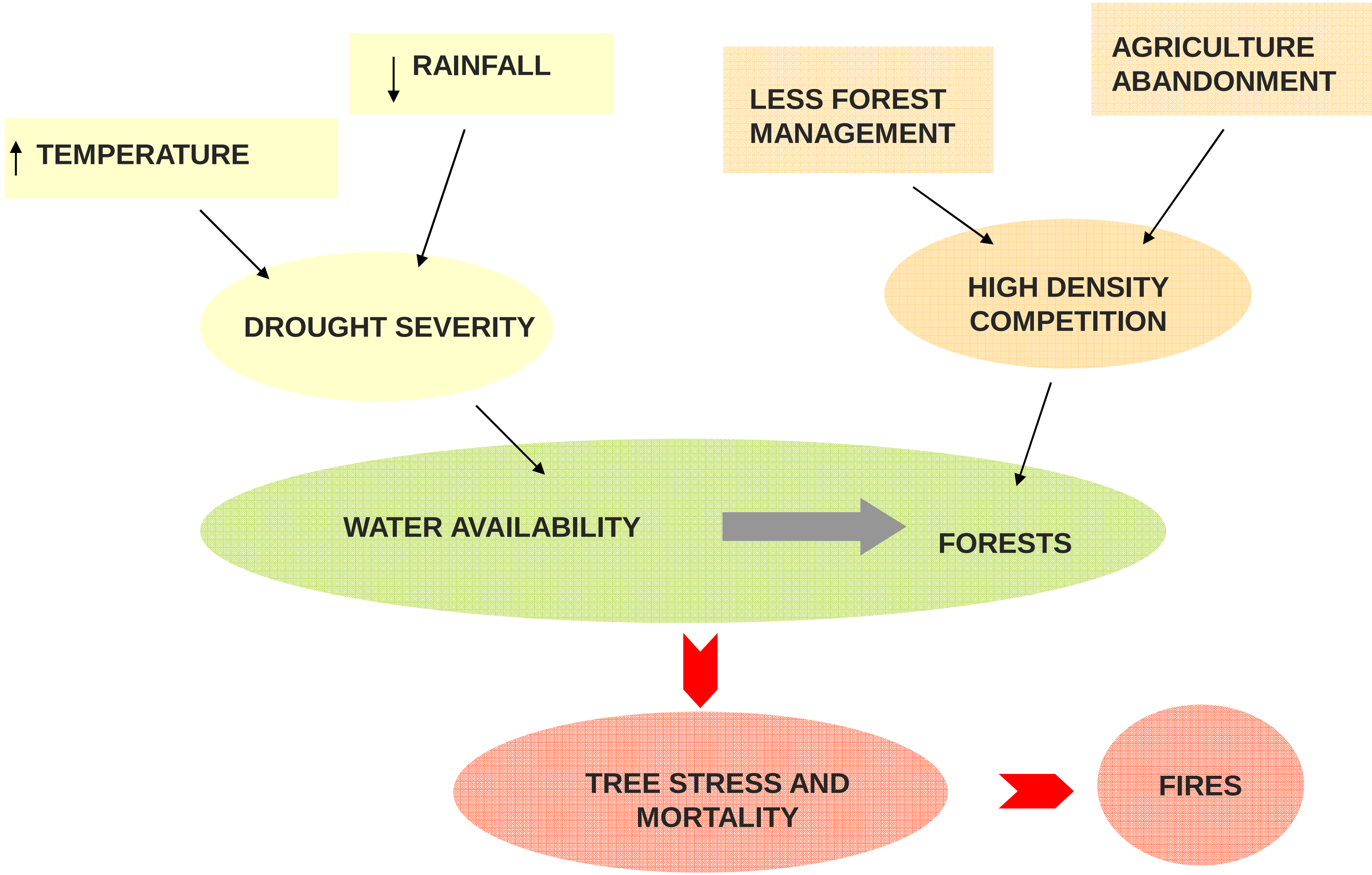
COLLSEROLA (CATALONIA)

BEFORE

NOW

Impacts in the Mediterranean basin

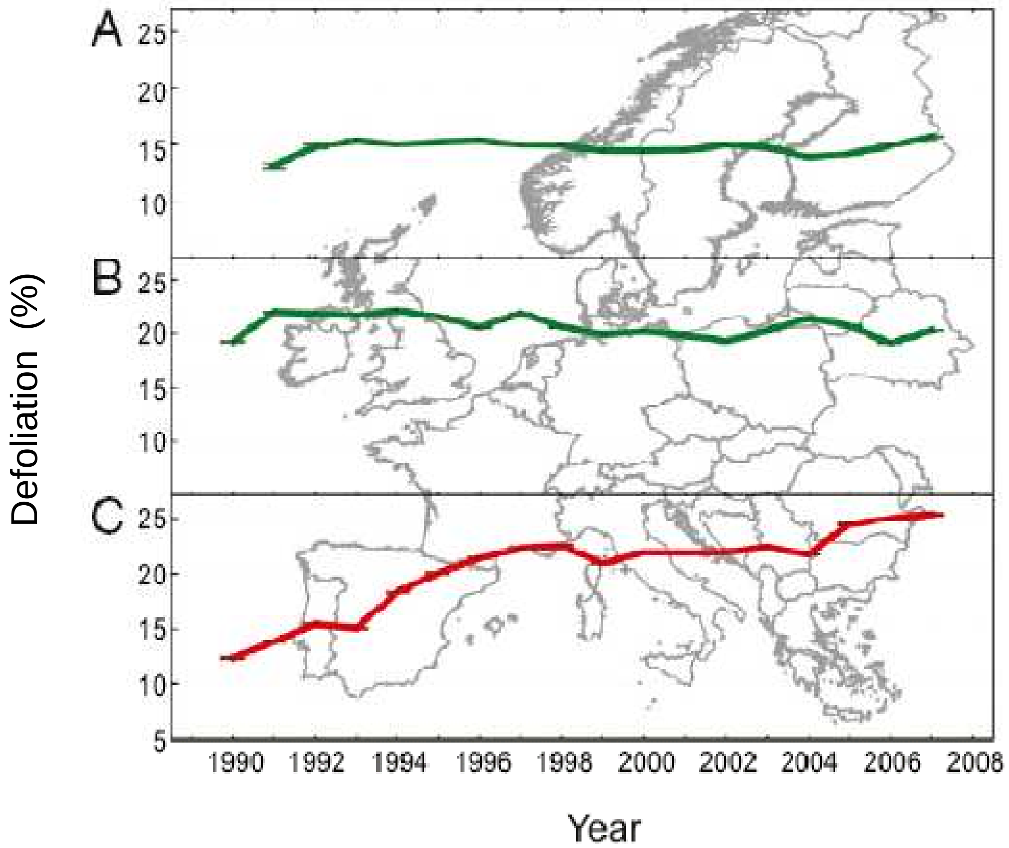
Changes which imply a forest surface increase



Impacts in the Mediterranean basin

Tree mortality

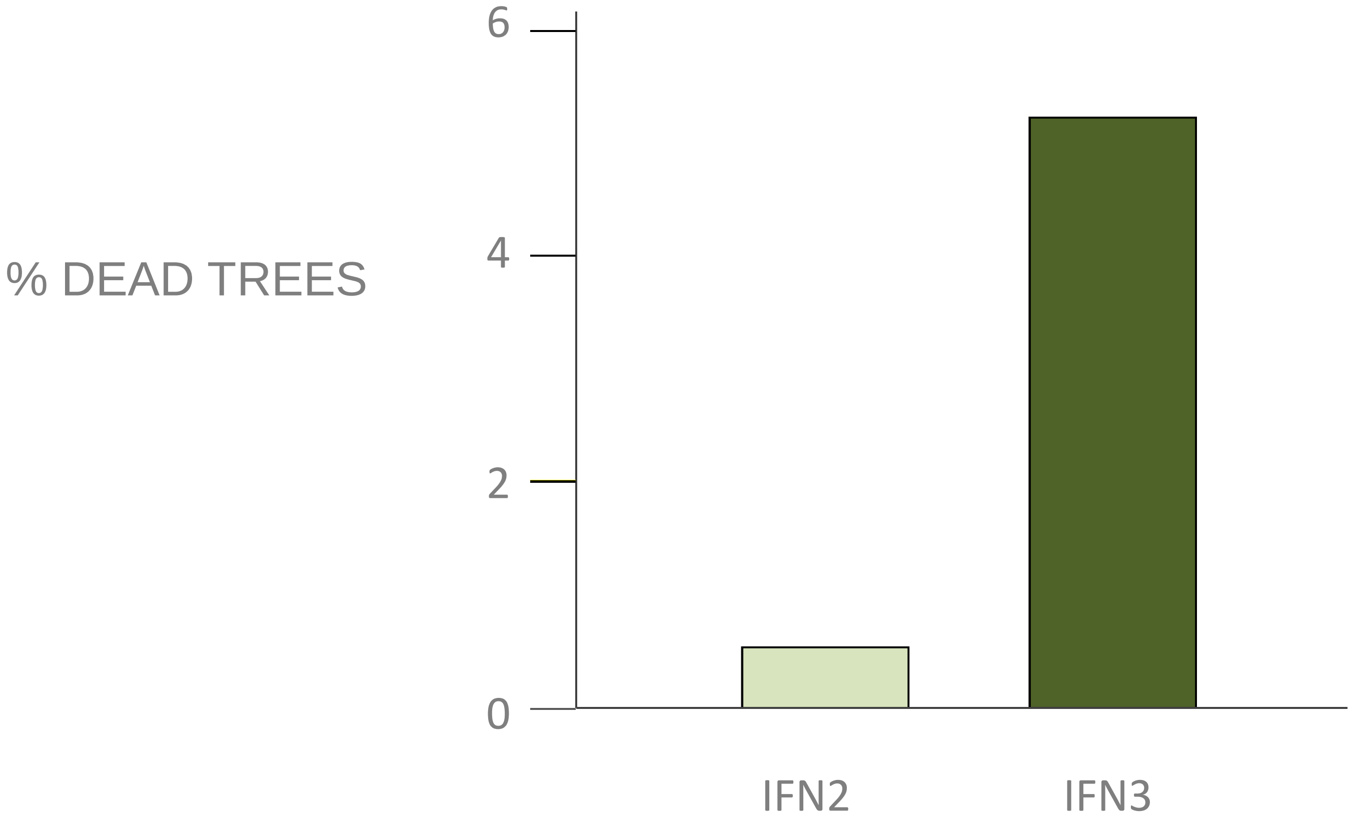
Impacts in the Mediterranean basin
Forest decline



Source: Carnicer *et al.* (2011)

Impacts in the Mediterranean basin

Tree mortality



Mortality of Scots pine in Pallars (Pyrenees, 2005)

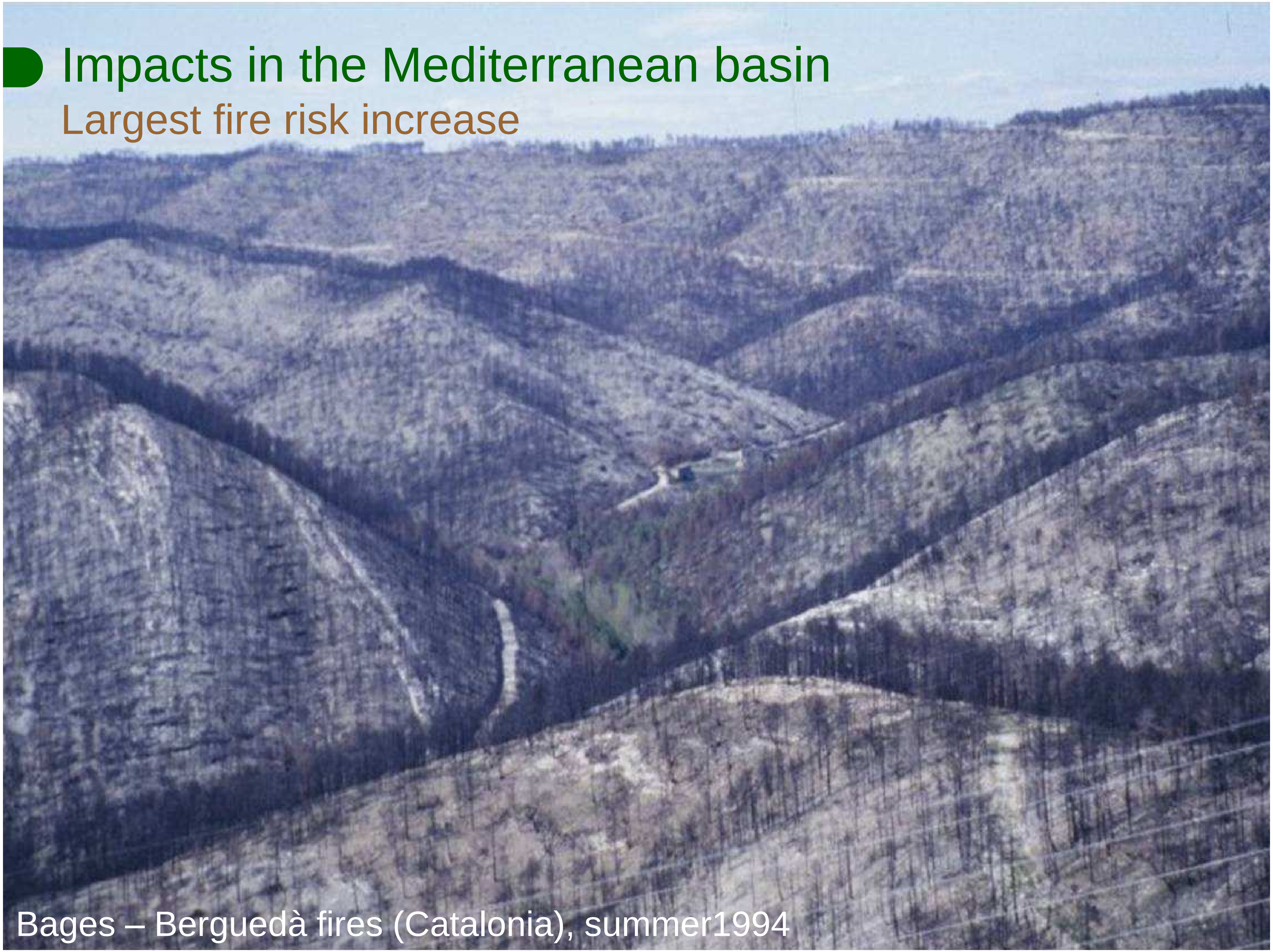
Impacts in the Mediterranean basin

Fire risk increase

Simultaneous fires (Greece, summer 2007)

Impacts in the Mediterranean basin

Largest fire risk increase



Bages – Berguedà fires (Catalonia), summer1994

ACCUA

A scientific project to assess water vulnerability and improve its management

The project

ACCUA project

The project

MAIN AIMS:

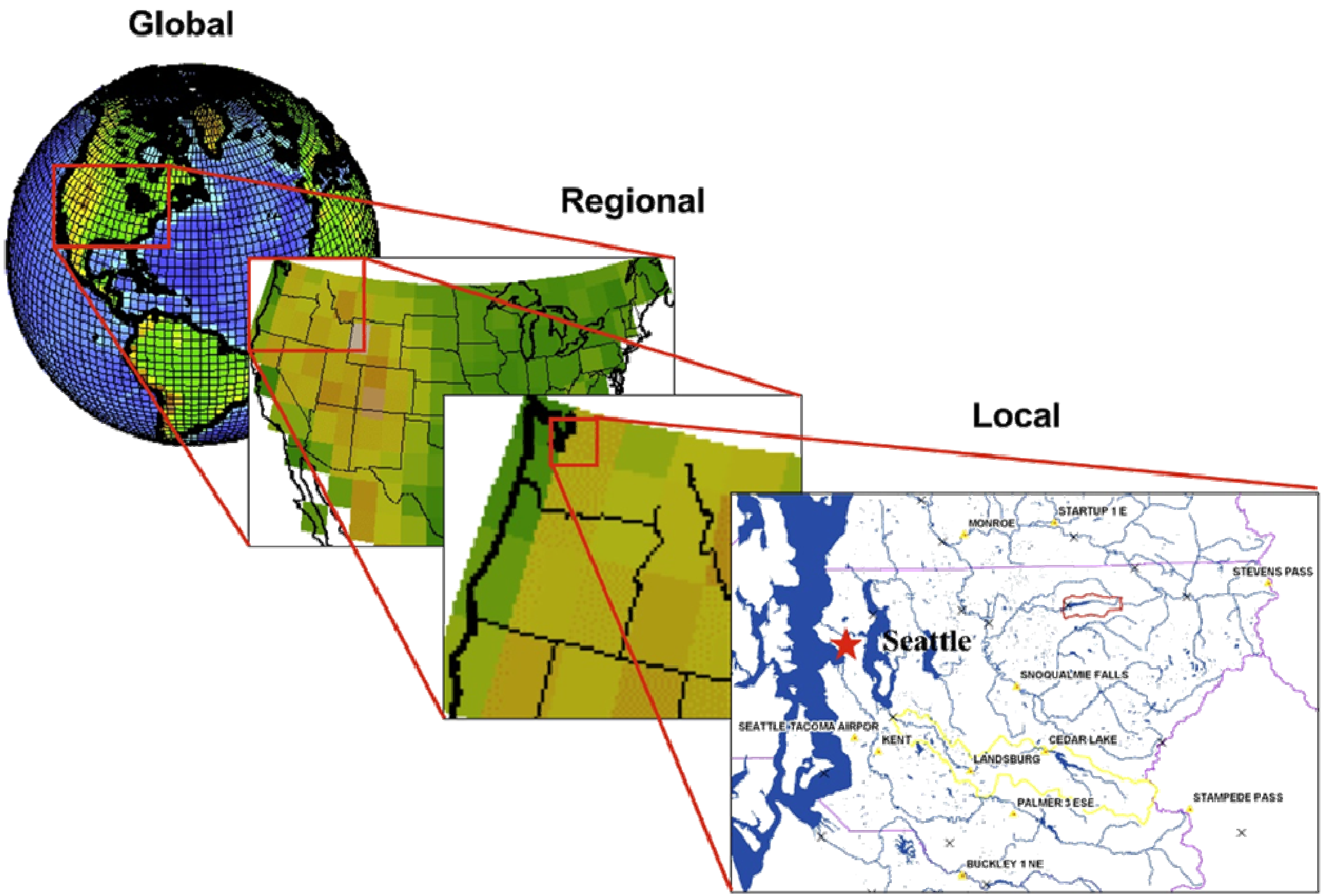
- Assess **territorial vulnerability** of three diverse Mediterranean watersheds in Catalonia with regard to the main effects of **global change** on **water availability**

- Define possible **adaptive options** based on the assessment of territorial and social vulnerability

The project has been developed during **three years** (2008-20011) by **four** different **research institutions** with an interdisciplinary approach.

ACCUA project

Downscaling



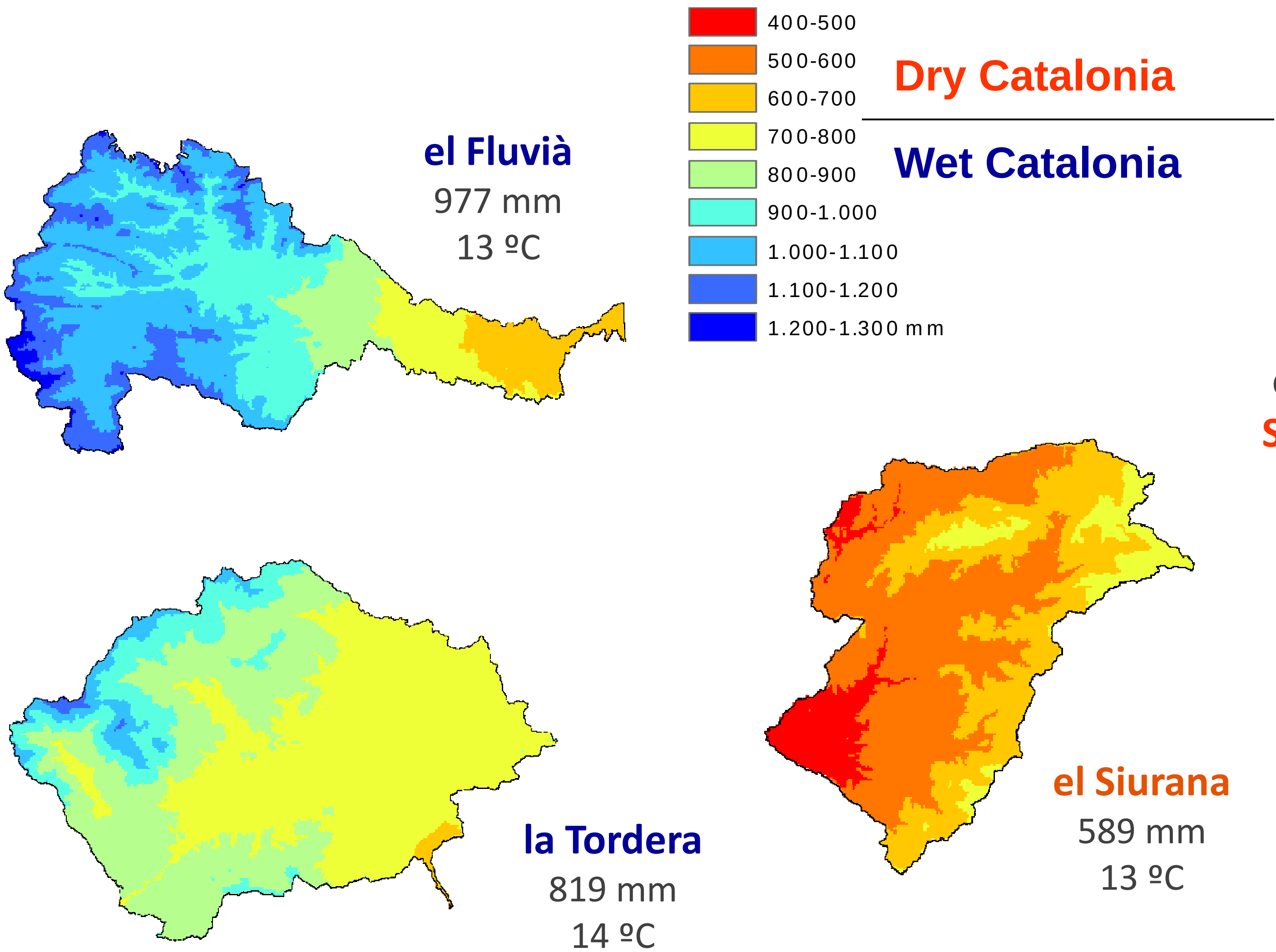
The watersheds

The watersheds

Study areas are three medium size **watersheds**:

- Fluvià (977 mm, 13 ºC)
- Tordera (819 mm, 14 ºC)
- Siurana (589 mm, 13 ºC)

The watersheds

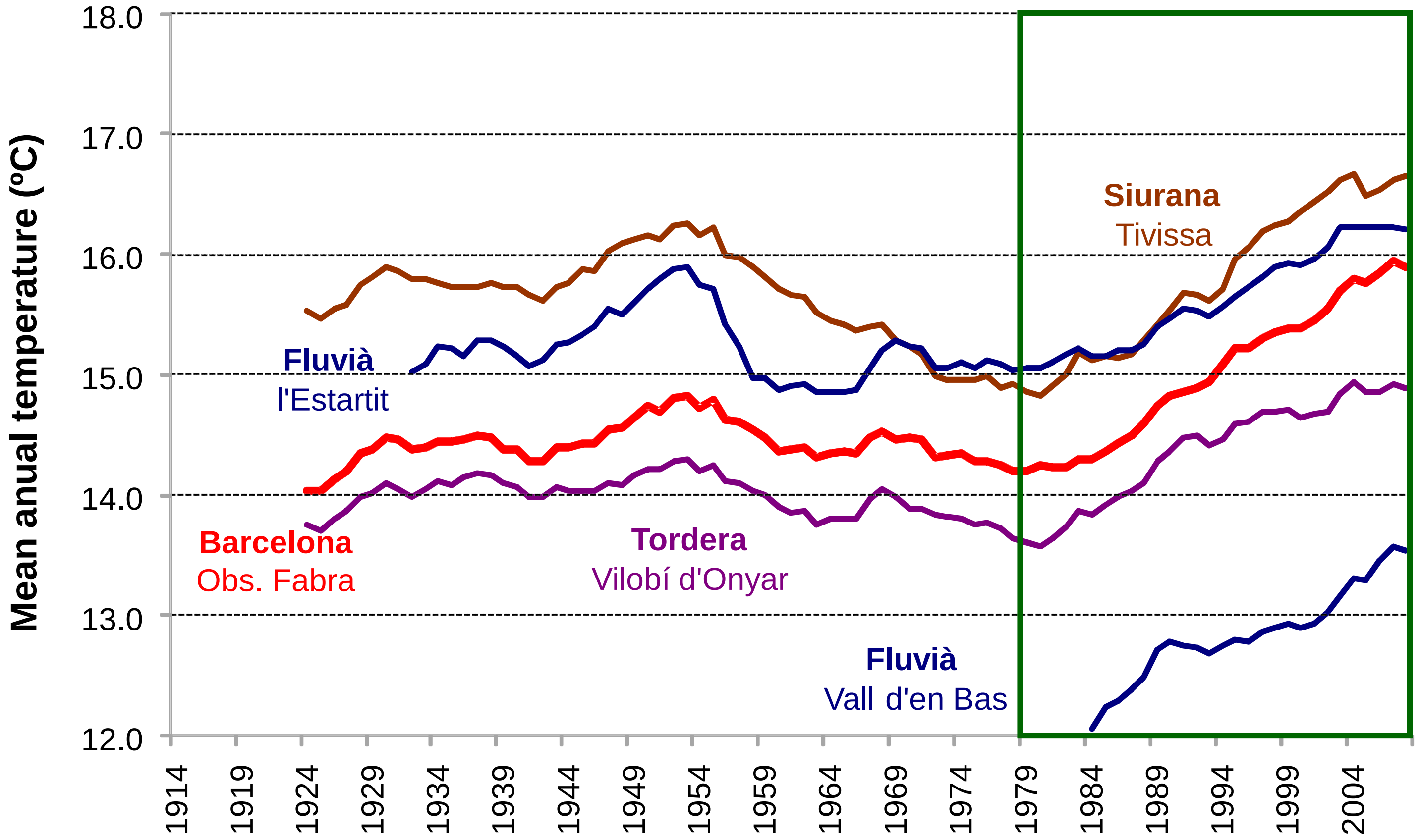


Fluvià and **Tordera** represent **wet** conditions whereas **Siurana** represents a drier ones

Source: from Digital Climatic Atlas of Catalonia (2000)

The watersheds

Observed temperature trends (1914-2008)

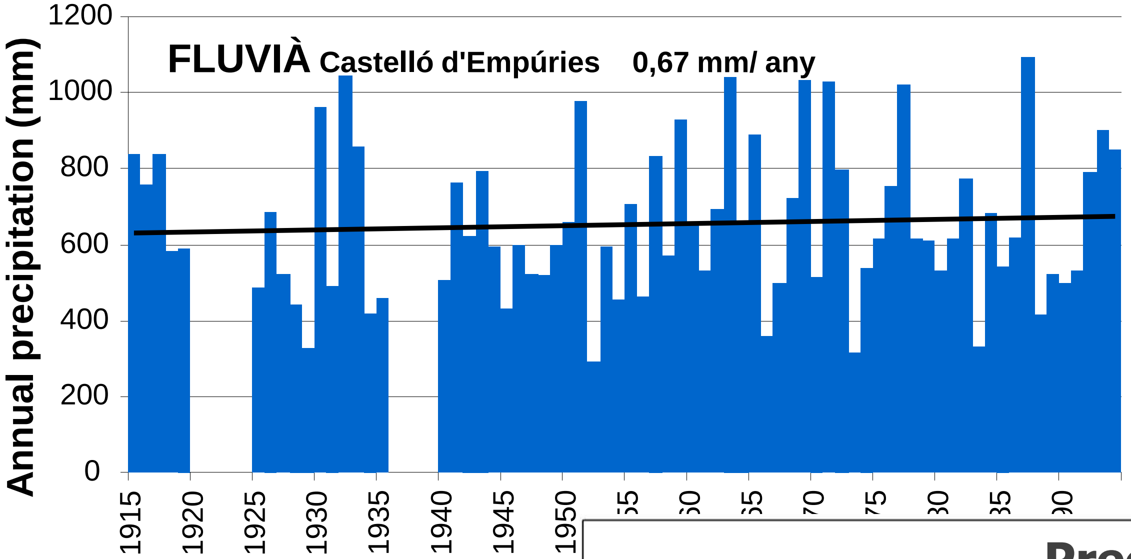


A **1.9 ºC** temperature increase since **1979** has been monitored at the three watersheds

Source: SMC and NESATv2 data base from Climate Change Research Group. Universitat Rovira i Virgili.

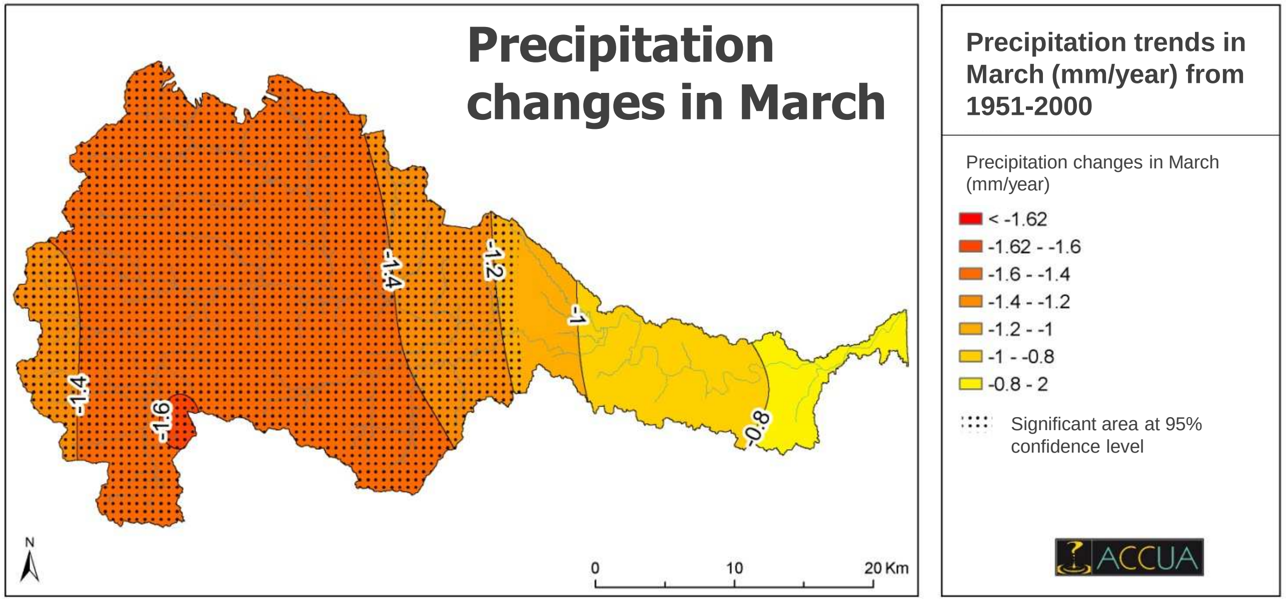
The watersheds

Observed precipitation trends



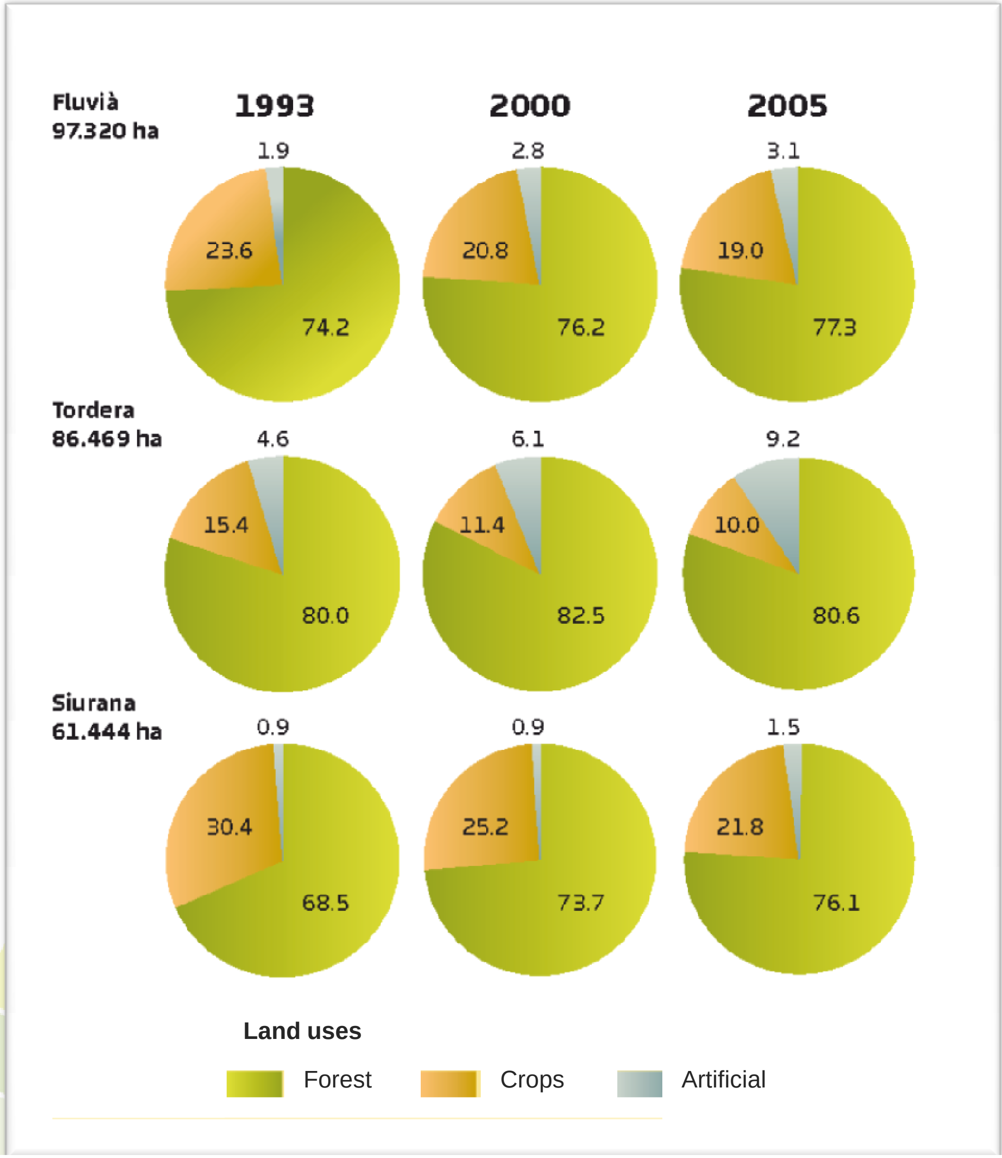
No significant **changes** in annual precipitation...

...but **significant** changes in certain **months**



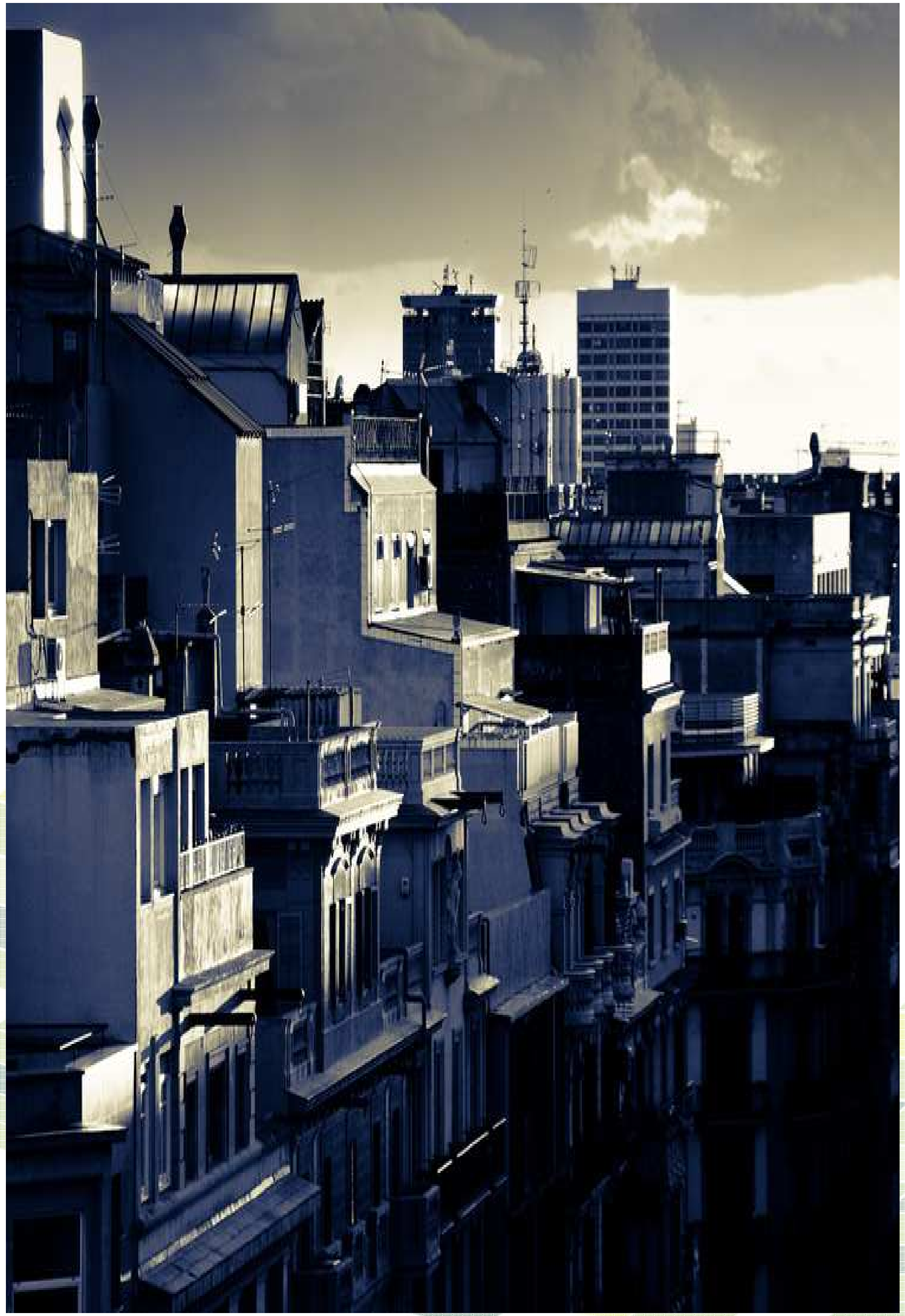
The watersheds

Land use changes



- A slight **increase** of forest surface is observed
- A global **decrease** of crops, specially important in Siurana
- A global **increase** of artificial, specially in Tordera

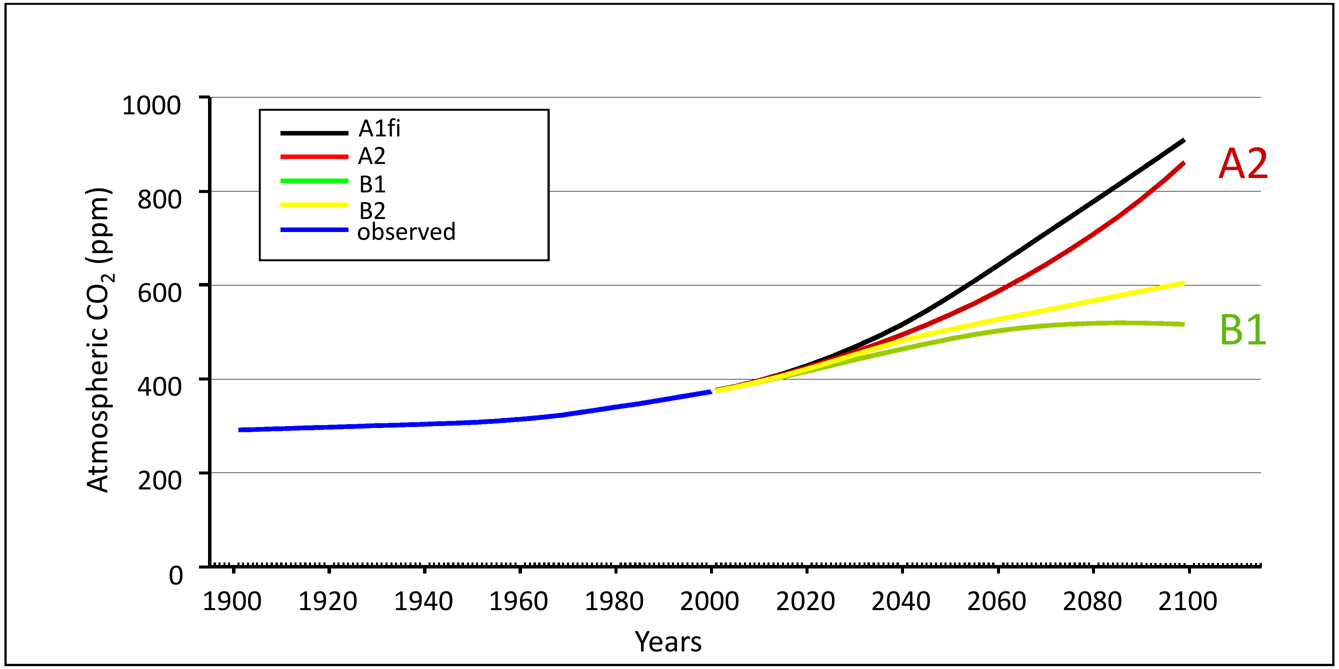
Source: MCSC - CREAF



The scenarios

The scenarios

IPCC emission scenarios

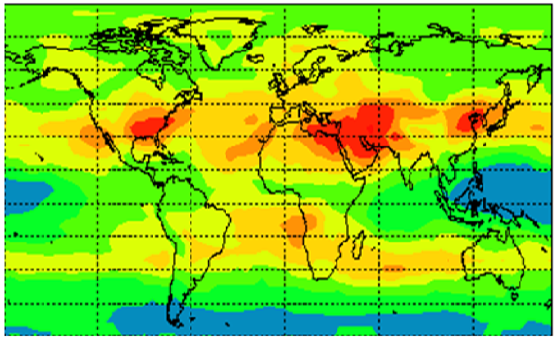


A2 storyline describes a future World with high economic and demographic growth. It implies a global average warming of **3.5 ºC** at the end of the century respect to 1980-2000 period.

B1 storyline describes a future World with a material intensity reduction, with clean and efficient energy sources, and a stabilised World population. It implies an average global warming of **1.8 ºC**.

Source: IPCC 2007

The scenarios
Climate projections



Global Circulation Models (GCMs)
with low spatial resolution
(**ECHAM5**) – 150 -200 km

downscaling

Dynamic downscaling
1971-2100 SMC
Catalan Meteorological
Service

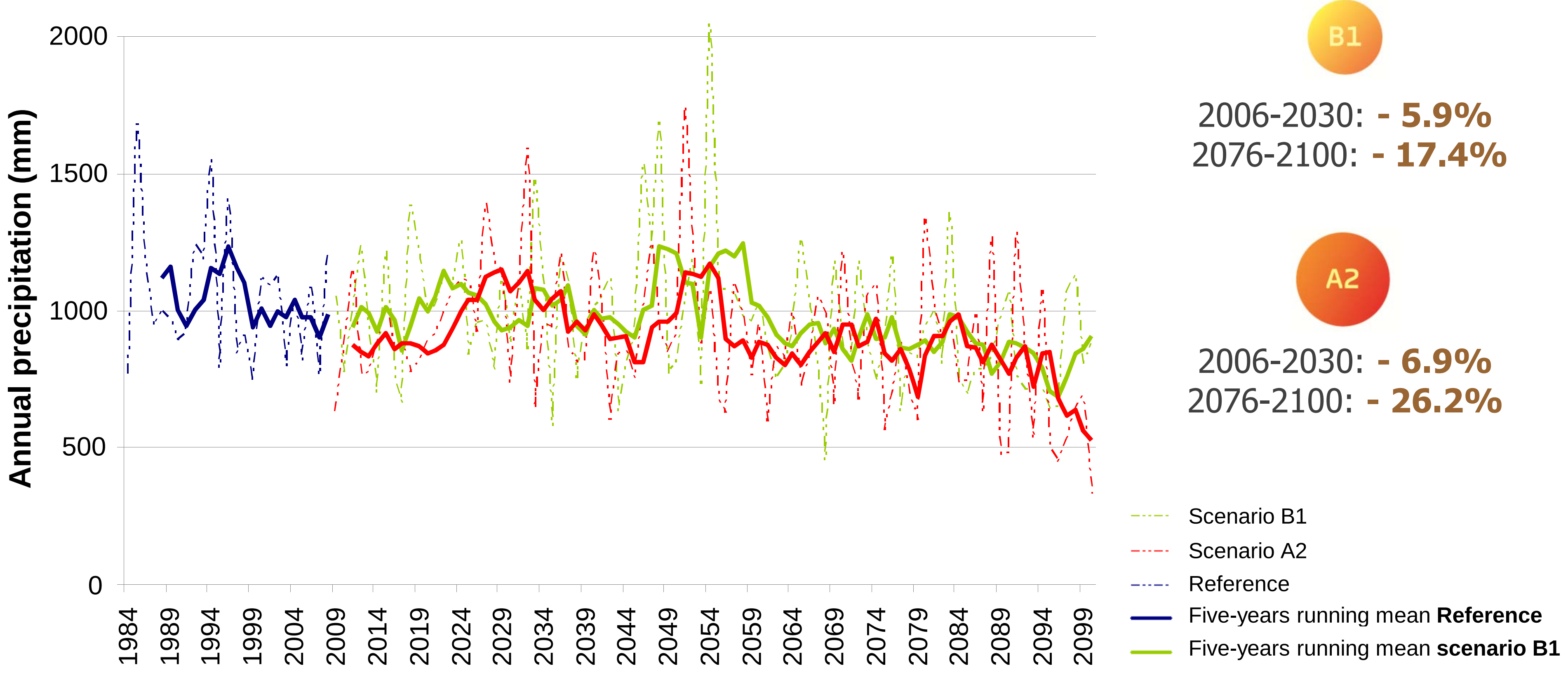
Future climate series
adapted to local
conditions

The scenarios

Climatic scenarios at regional scale

FUTURE PRECIPITATION TRENDS

FUTURE TEMPERATURE TRENDS



B1

2006-2030: **- 5.9%**
2076-2100: **- 17.4%**

A2

2006-2030: **- 6.9%**
2076-2100: **- 26.2%**

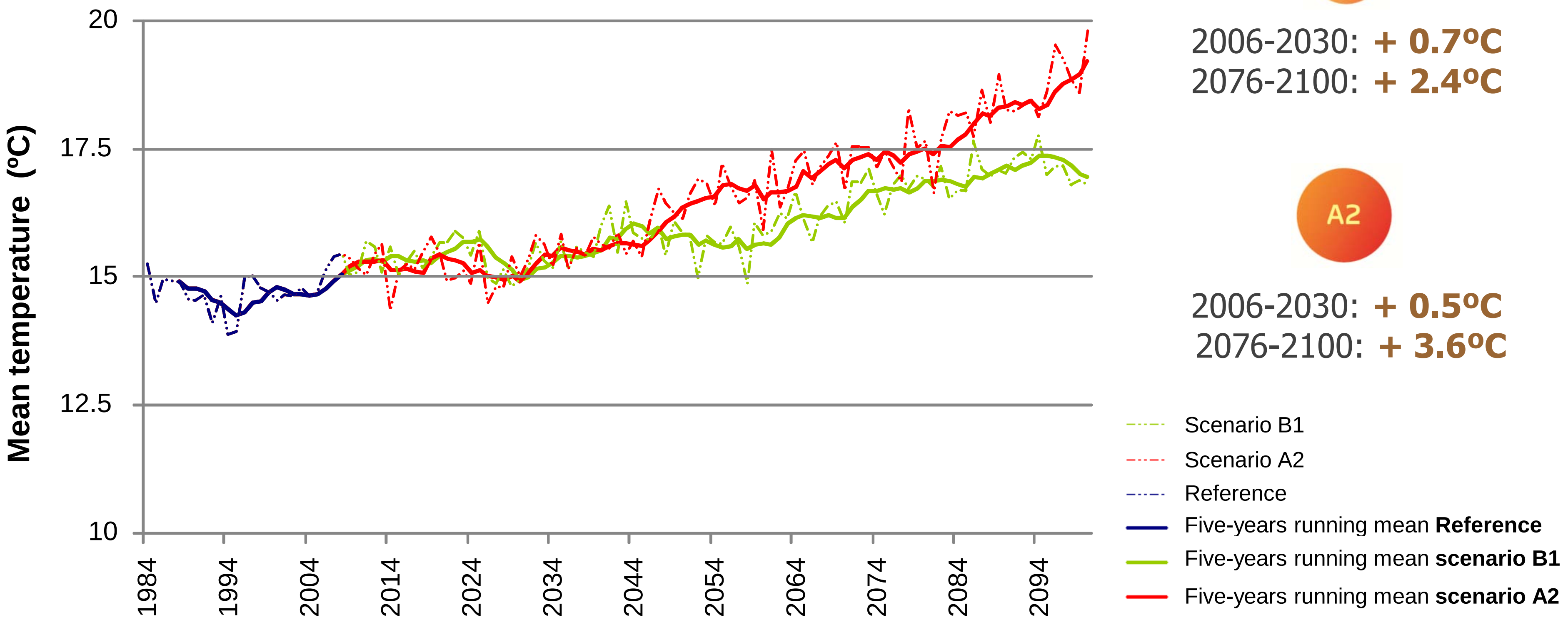
Source: SMC 2010

The scenarios

Climatic scenarios at regional scale

FUTURE PRECIPITATION TRENDS

FUTURE TEMPERATURE TRENDS



B1

2006-2030: **+ 0.7ºC**
2076-2100: **+ 2.4ºC**

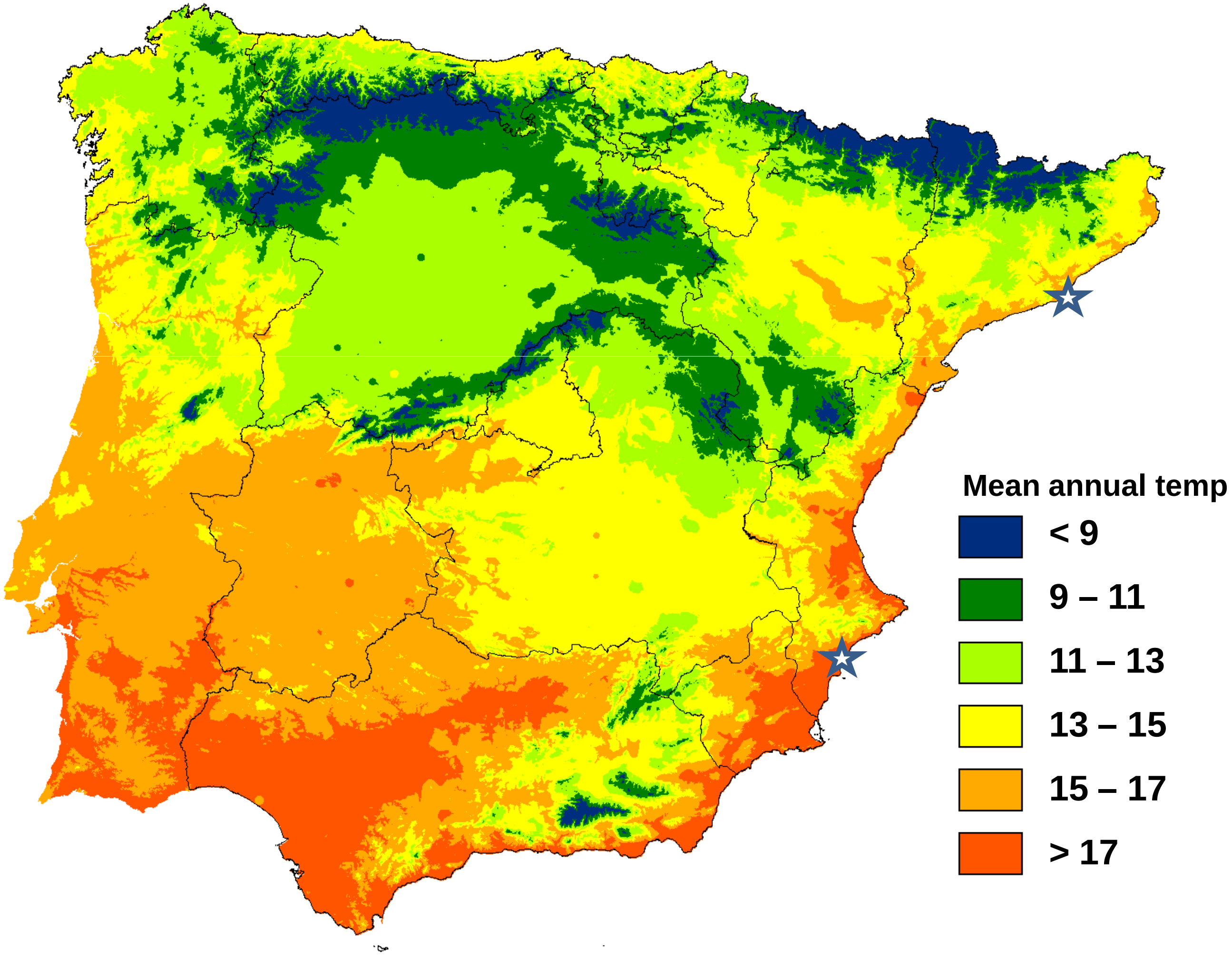
A2

2006-2030: **+ 0.5ºC**
2076-2100: **+ 3.6ºC**

Source: SMC 2010

The scenarios

Temperature trends



A **2 ºC** change in mean annual temperature could imply important effects. It is the difference between **Barcelona** and **Alacant.**

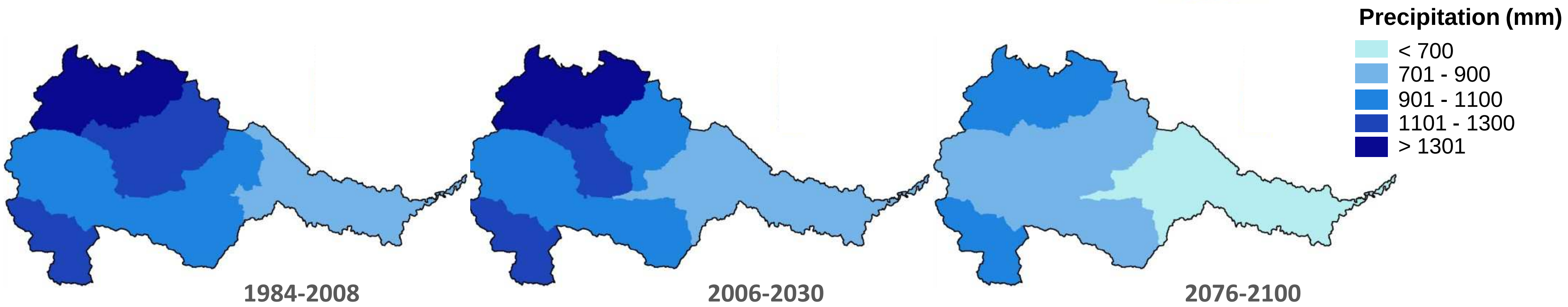
Rainfall (mm)

The scenarios

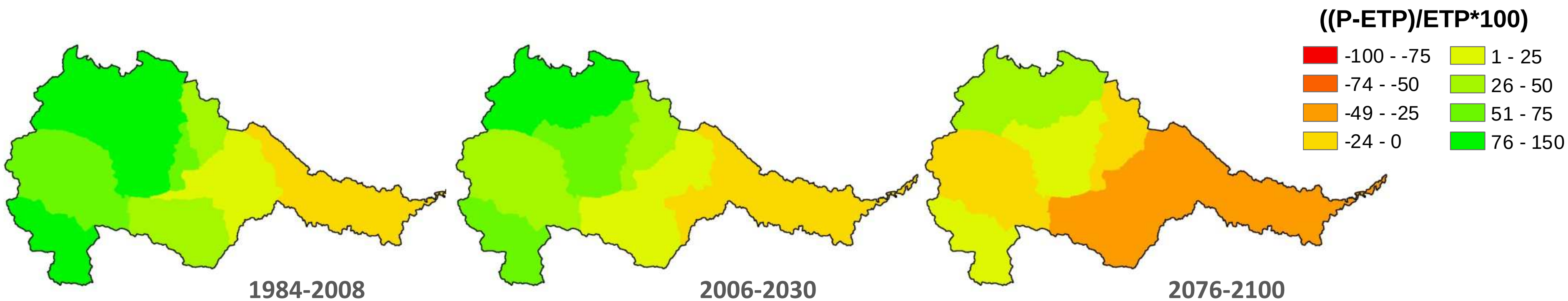
Climatic scenarios at regional scale

A2

RAINFALL DISTRIBUTION (mm/yr)



WATER STRESS INDEX DISTRIBUTION



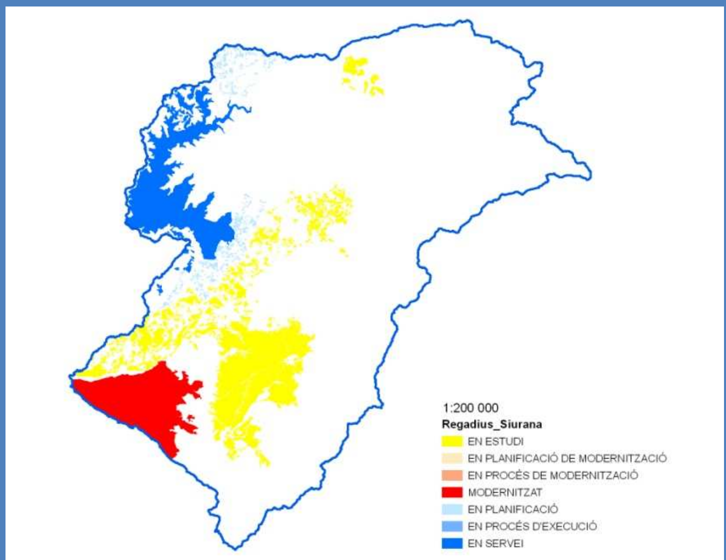
Source: ACCUA from SMC 2010 projections

The scenarios

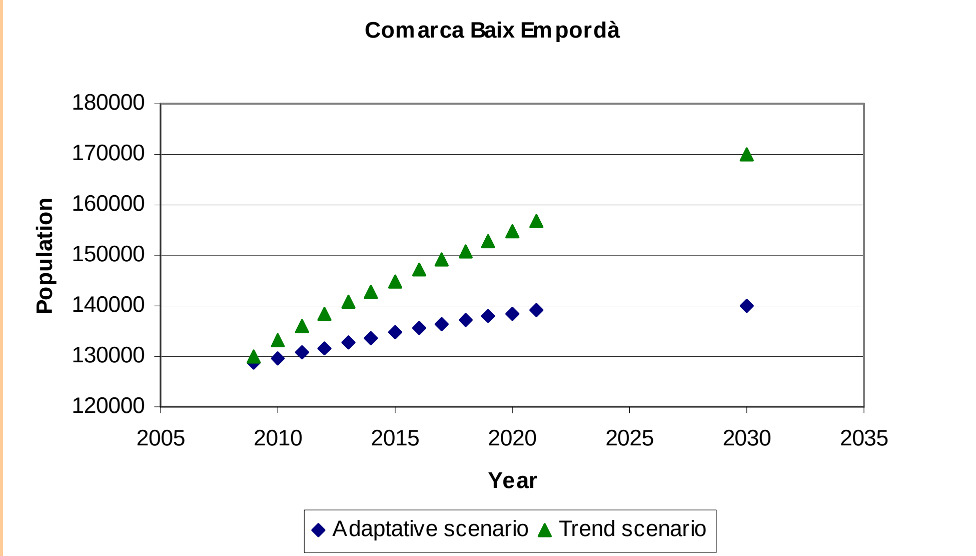
Socio-economic scenarios

- population
- economic development
- agriculture management
- forest management
- water use management
- land planning

irrigation projects (trend scenario)



population projections



The scenarios
Socio-economic scenarios

FUTURE TERRITORIAL PROJECTIONS FOR 2030..

... UNDER A SUSTAINABLE SCENARIO

Socio-economic context

- Moderate economic growth
- Moderate demographic growth
- Restraint of energy consumption

... UNDER A TREND SCENARIO

Socio-economic context

- Fast economic growth
- High demographic growth
- Intensive use of fossil fuels
- Globalization

Source: ACCUA from ACA data and IDESCAT data

The scenarios

Socio-economic scenarios. Land cover scenarios 2030

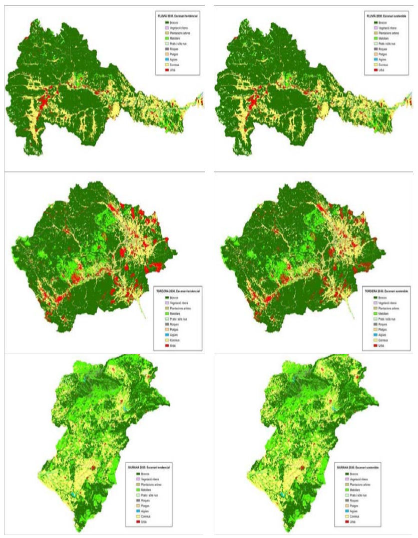
ACCUA scenarios

SCENARIO CATALONIA 2030:
TRENDING SCENARIO
SUSTAINABLE SCENARIO

Land Change Modeler Extension - IDRISI

Analysis and prediction of changes.
Analysis of change explanatory variables.

Land cover scenarios 2030



Vulnerability of main agricultural classes

Main land cover flows

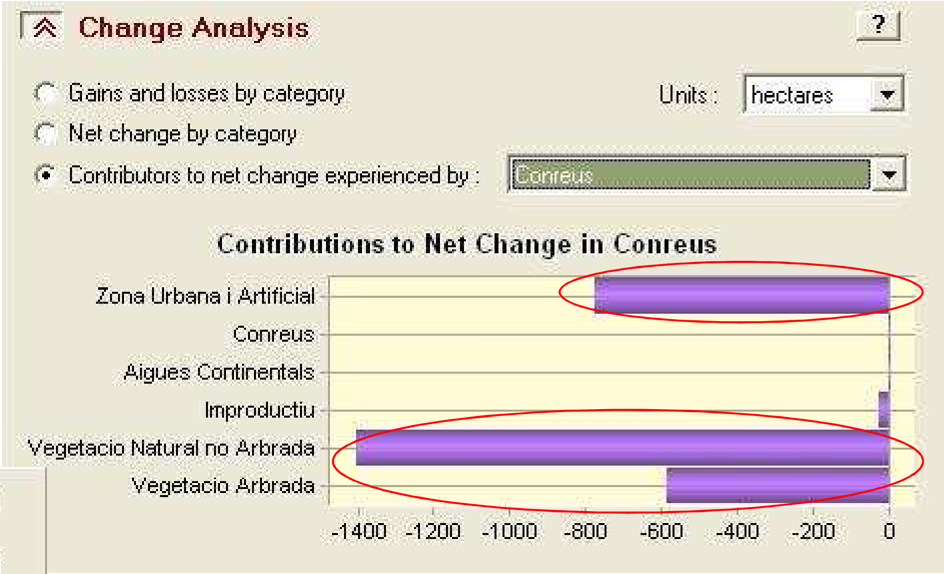
Urban sprawl

The scenarios

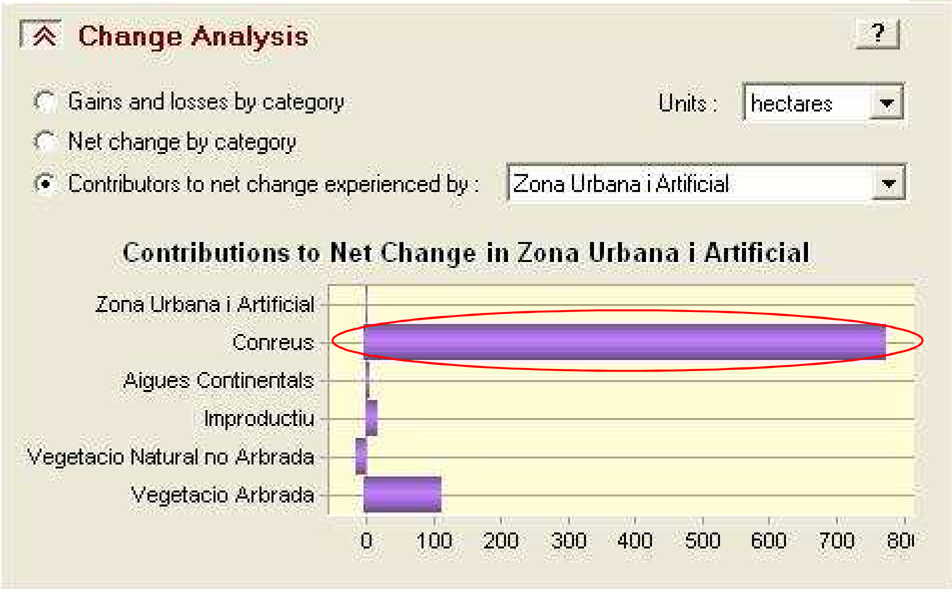
Socio-economic scenarios. Land cover scenarios 2030

Change analysis between 1993-2000
Class changes: eg. Crops and Urban Area

Changes in crop class 1993 - 2000



Changes in urban area class 1993 - 2000



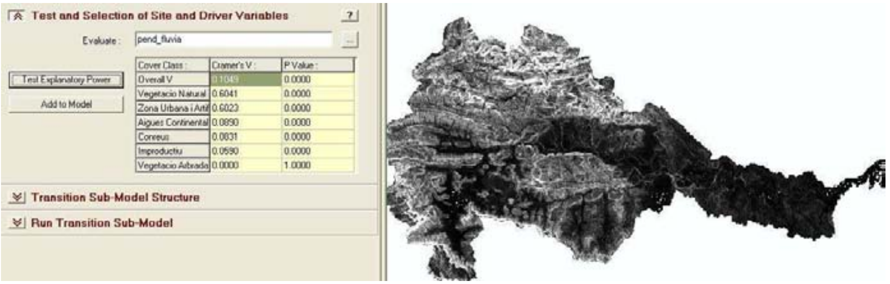
Main processes detected
Urban sprawl
Agricultural land abandonment

The scenarios

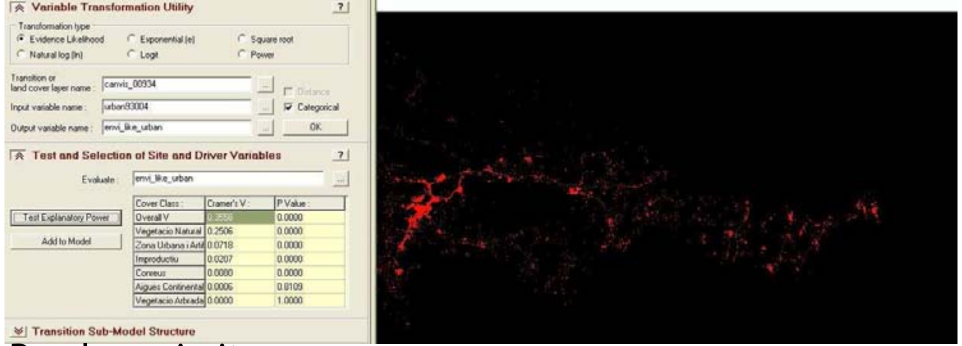
Socio-economic scenarios. Land cover scenarios 2030

URBAN SPRAWL → Selected variables for transition maps

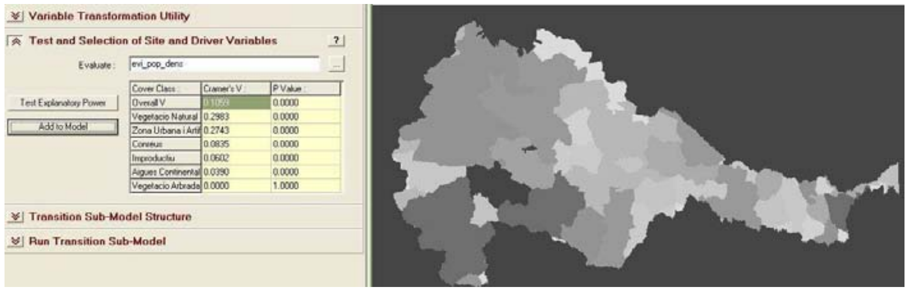
Slope



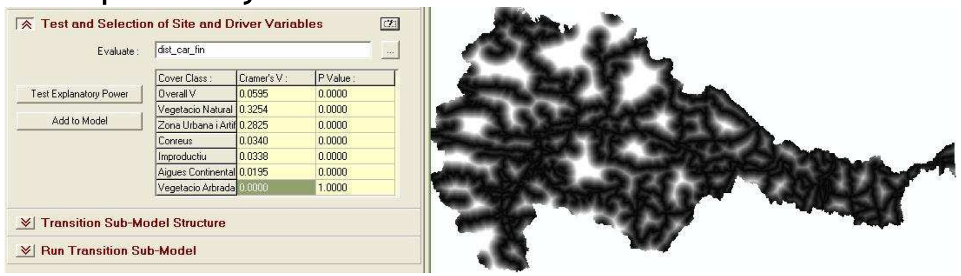
Urban area 1993 + 2000



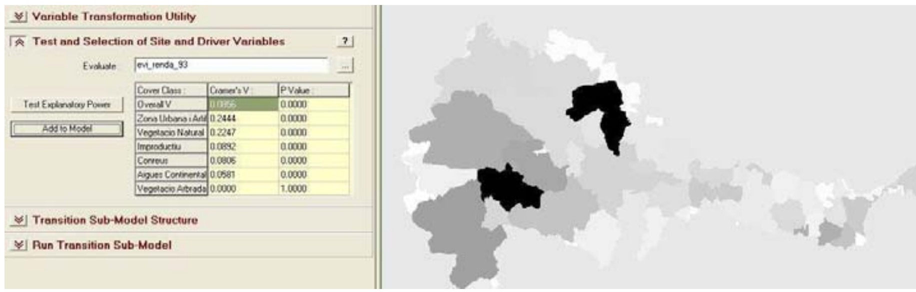
Population density



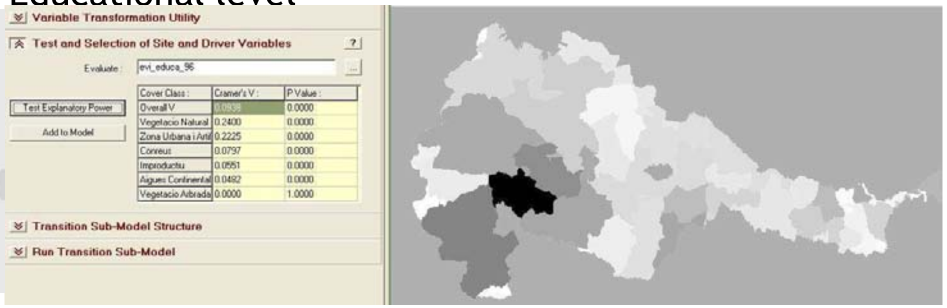
Road proximity



Incomes



Educational level

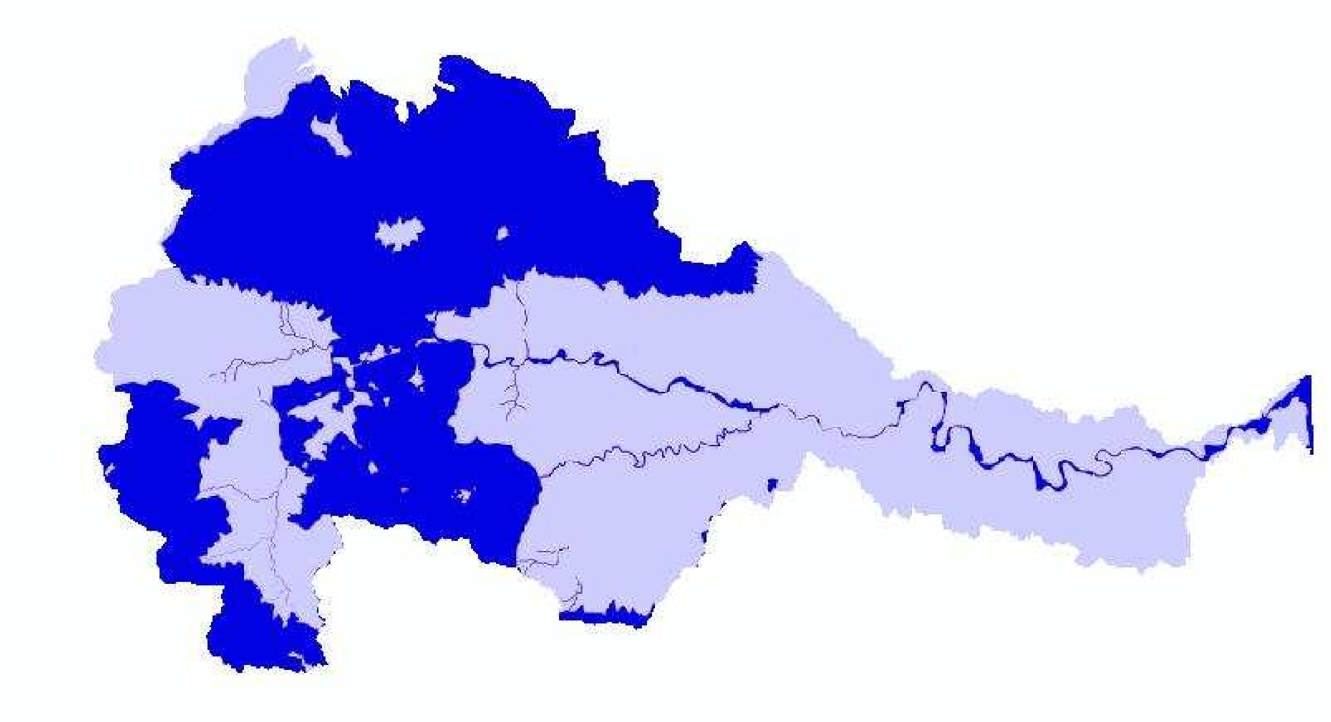


The scenarios

Socio-economic scenarios. Land cover scenarios 2030

URBAN SPRAWL → Limitations to urbanization

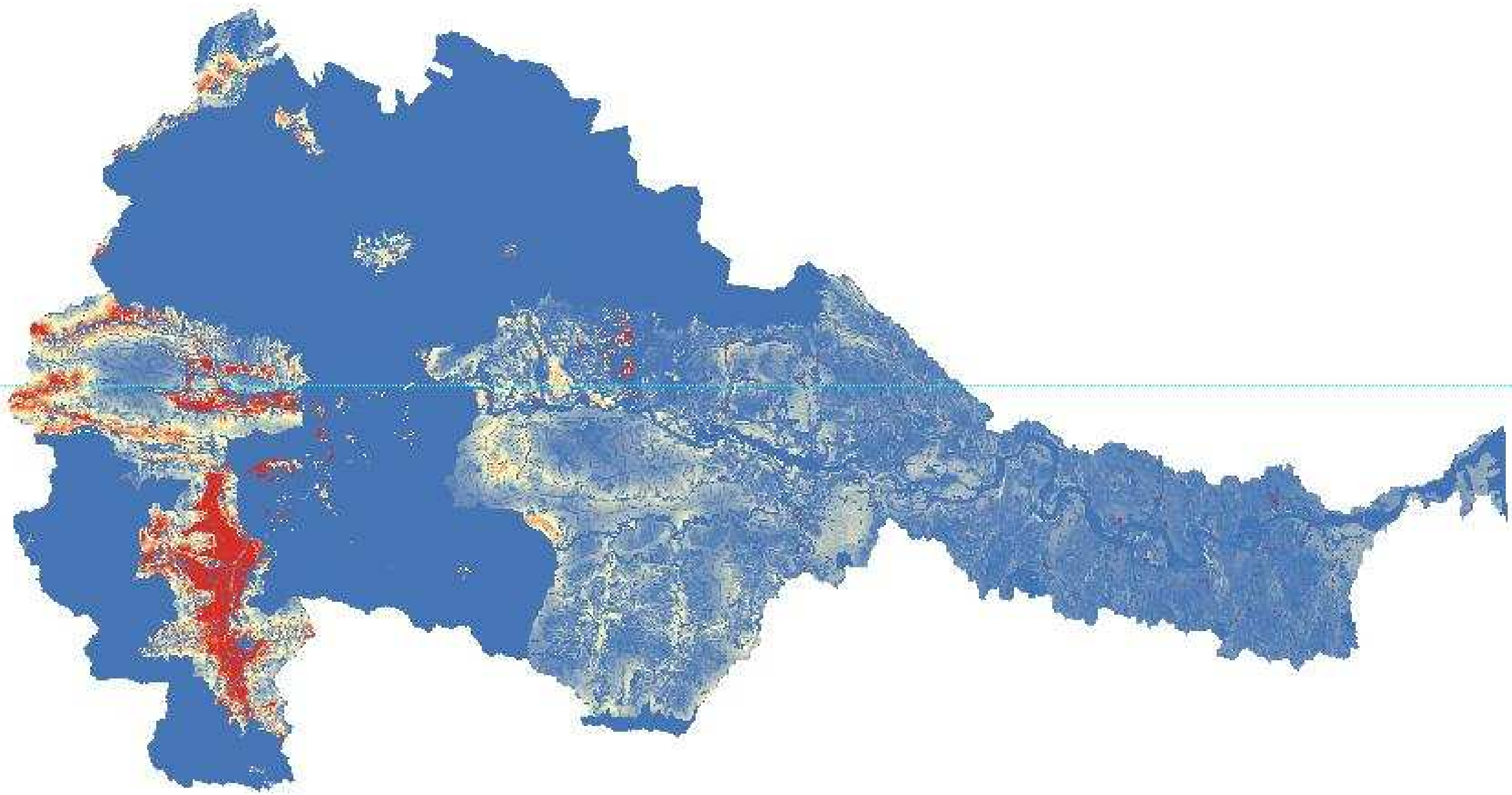
Natura 2000



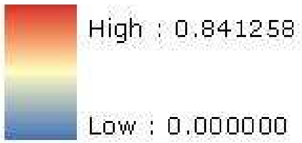
The scenarios

Socio-economic scenarios. Land cover scenarios 2030

URBAN SPRAWL RESULTS→ Soft Prediction Map 2030



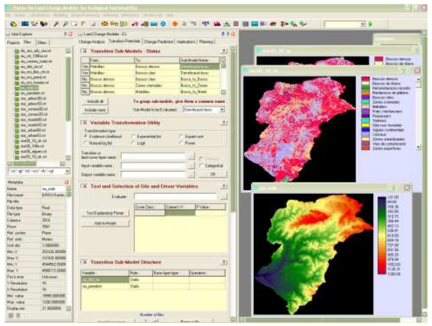
Probability of changing to urban use



The scenarios

Land cover scenarios 2030

Land Change Modeler (Idrisi)

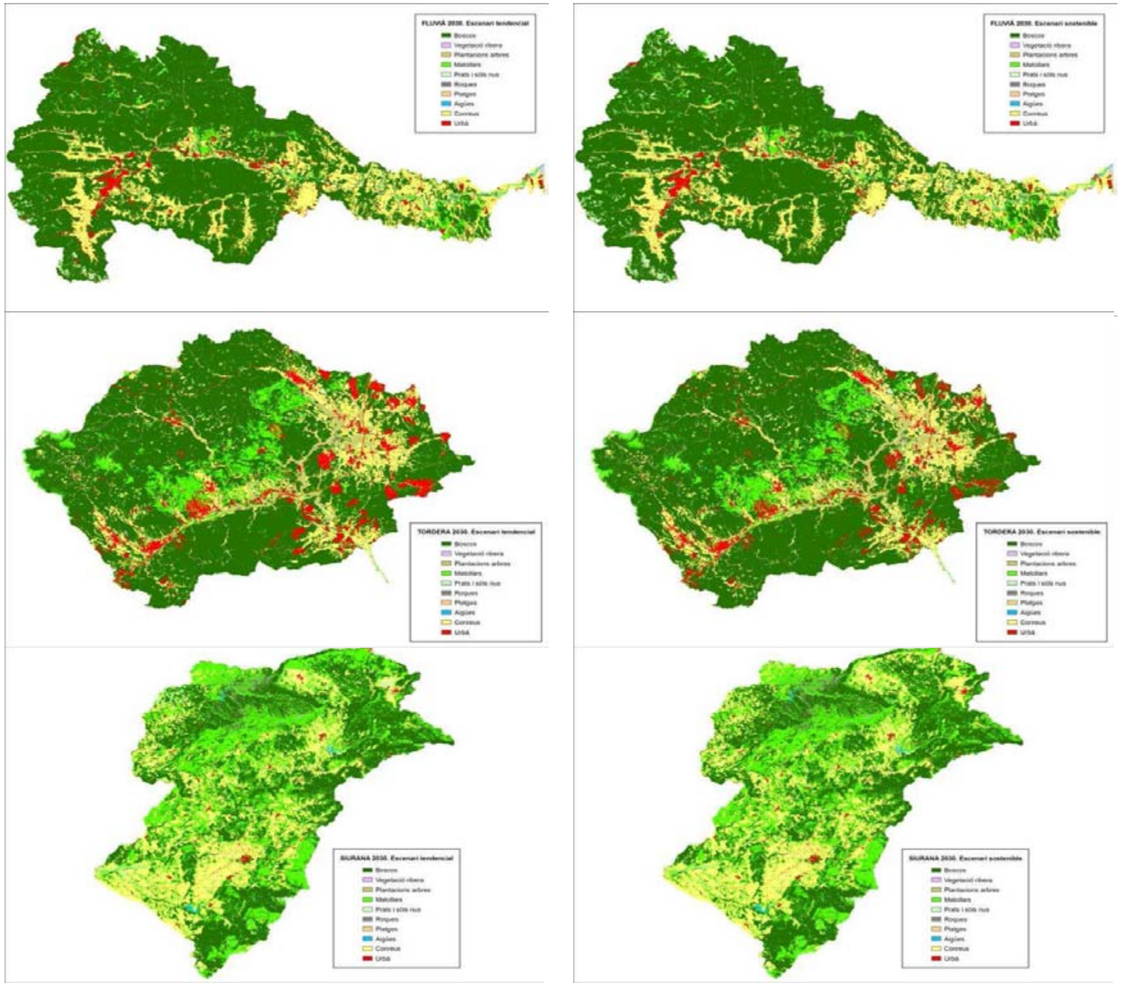


Trend | Sustainable

Fluvià

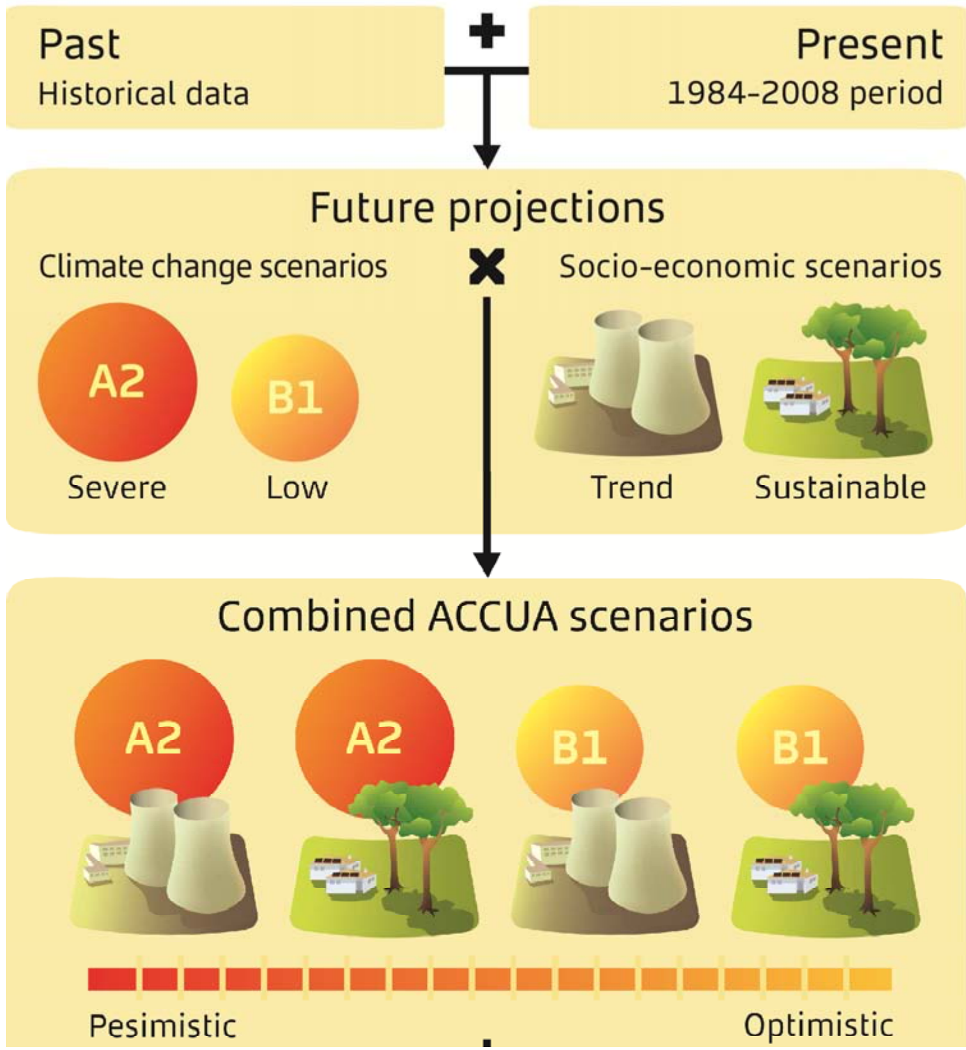
Tordera

Siurana



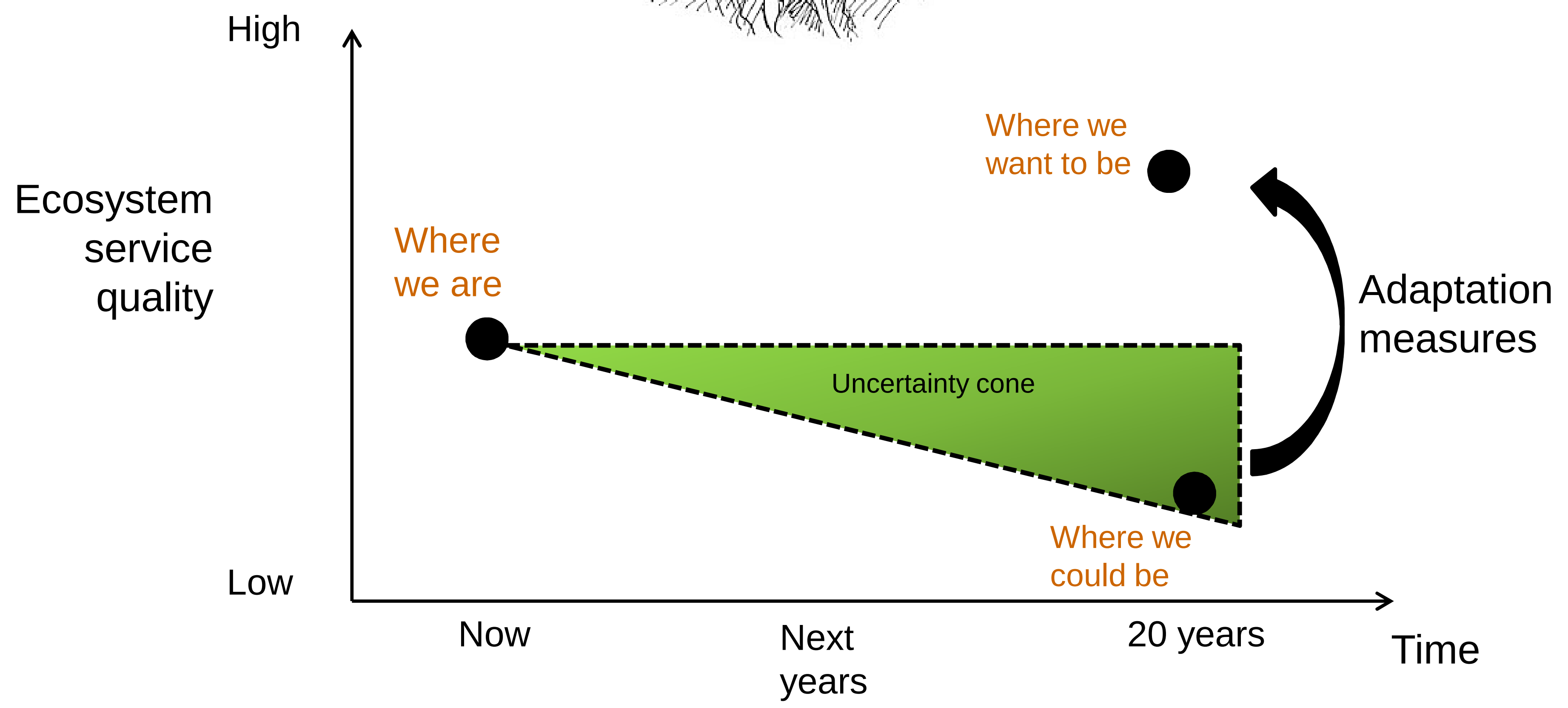
The scenarios

The four ACCUA scenarios



The scenarios

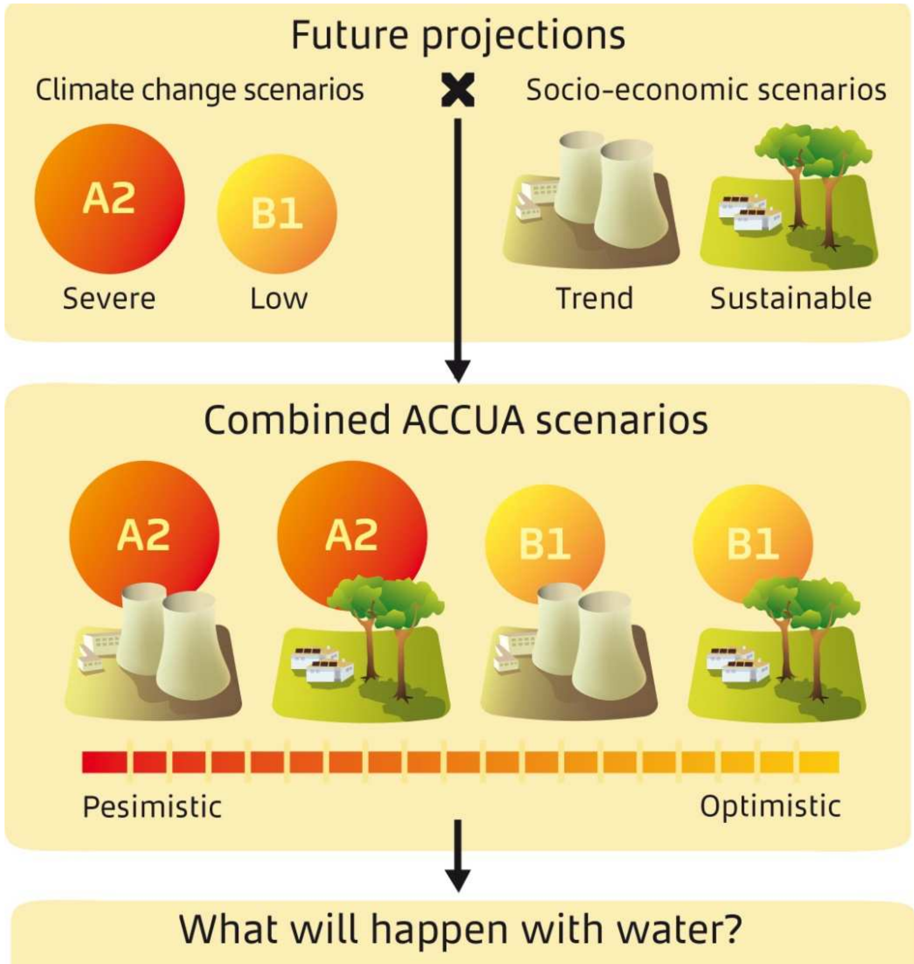
The uncertainty



Source: WaterChange project (CETaqua)

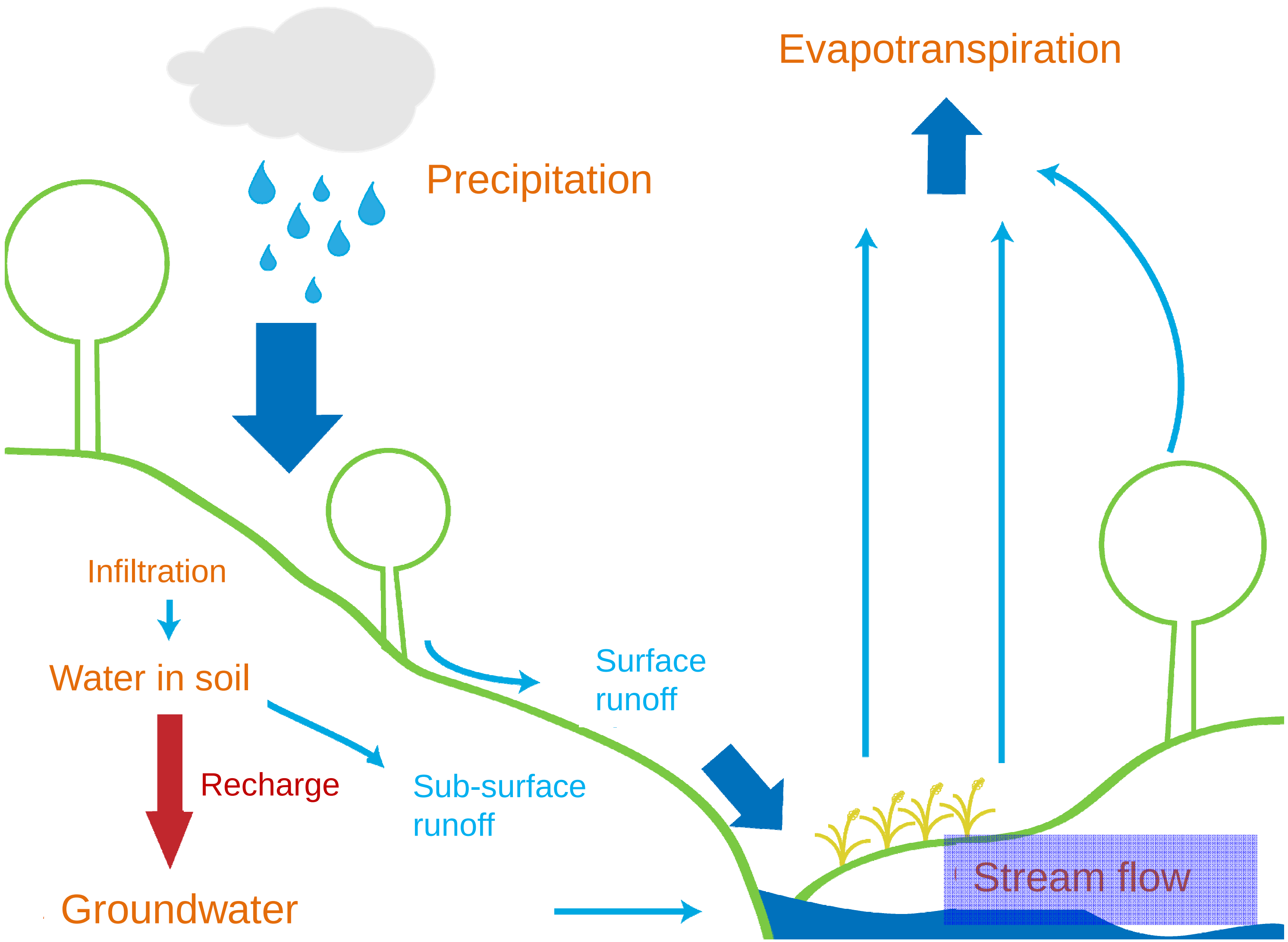
Global change impacts and vulnerabilities on water bodies, forests, crops and population

Impacts on water bodies



Impacts on water bodies

What are the components of the water balance?

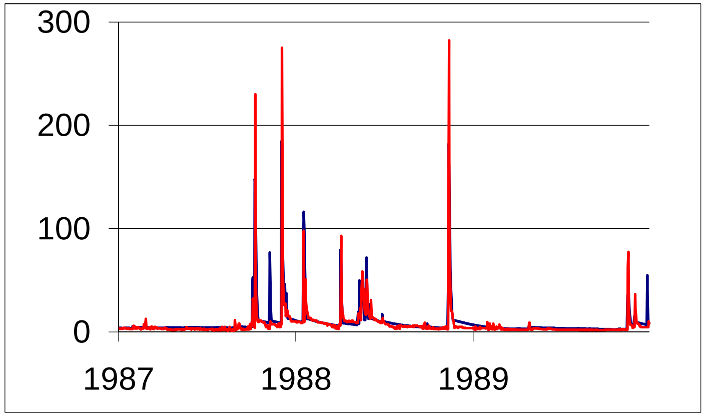


Impacts on water bodies

Methodology

Hydrological model - SWAT (baseline period)

Calibration and validation



Scenarios

Climatic scenarios

Socioeconomic scenarios

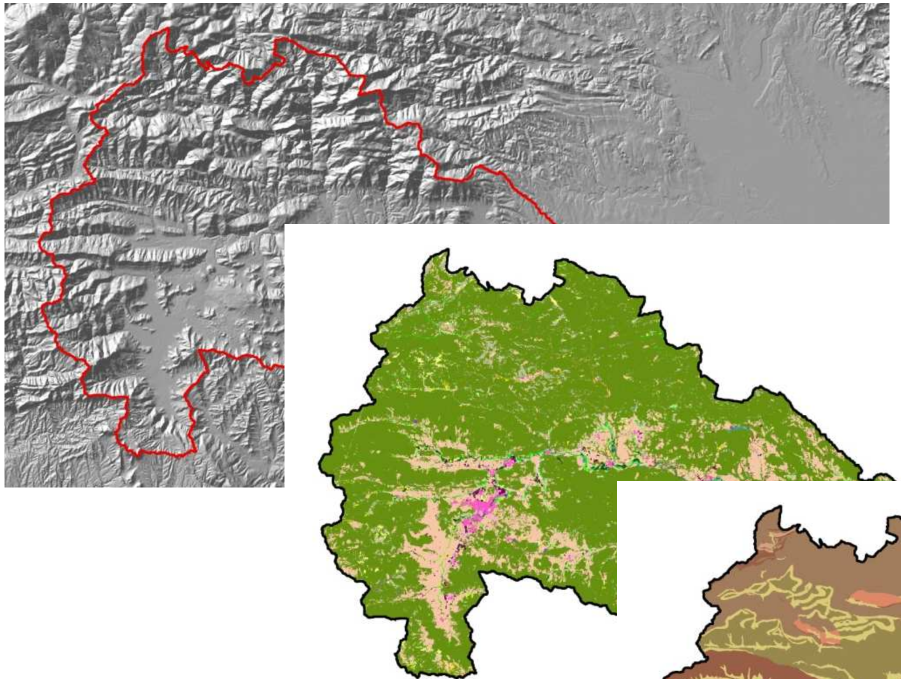
Simulations

Water balance under each scenario

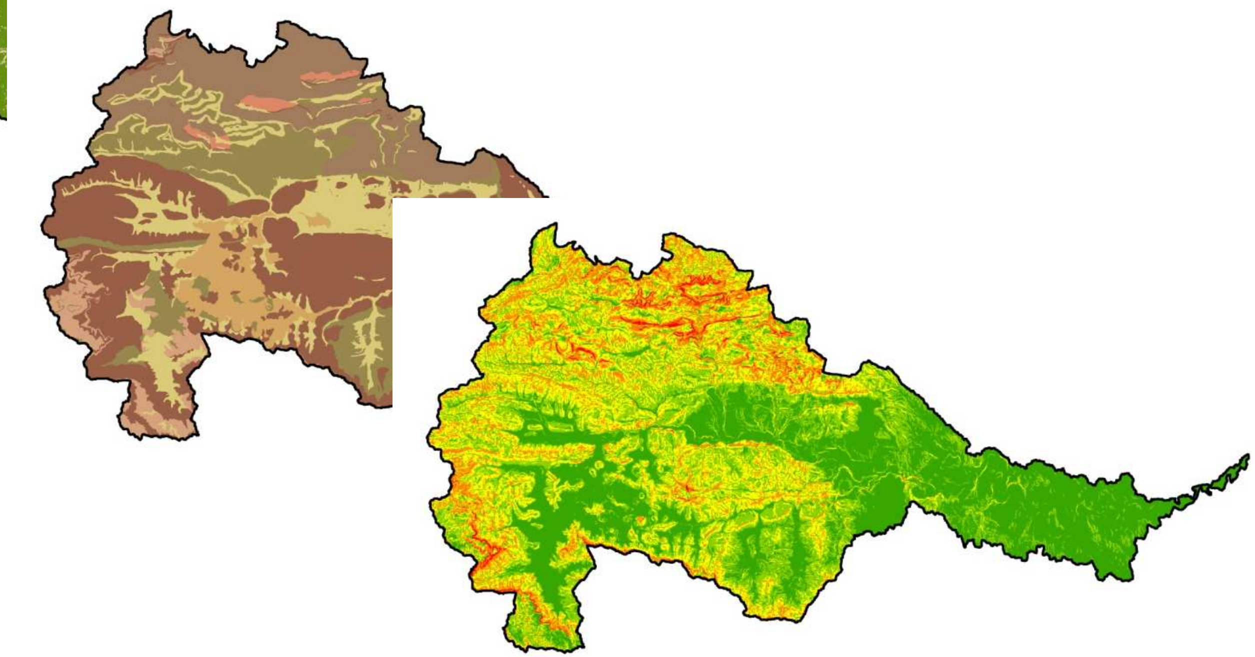
ACCUA

Impacts on water bodies

Modelling with SWAT program



- Water balance model
- Distributed and continuous hydrological model coupled to a GIS interface
- SWAT estimates superficial and sub-superficial flow, aquifers recharge, erosion, sediments deposition and movement, …



SWAT Soil & Water Assessment Tool

Impacts on water bodies

Modelling with SWAT program

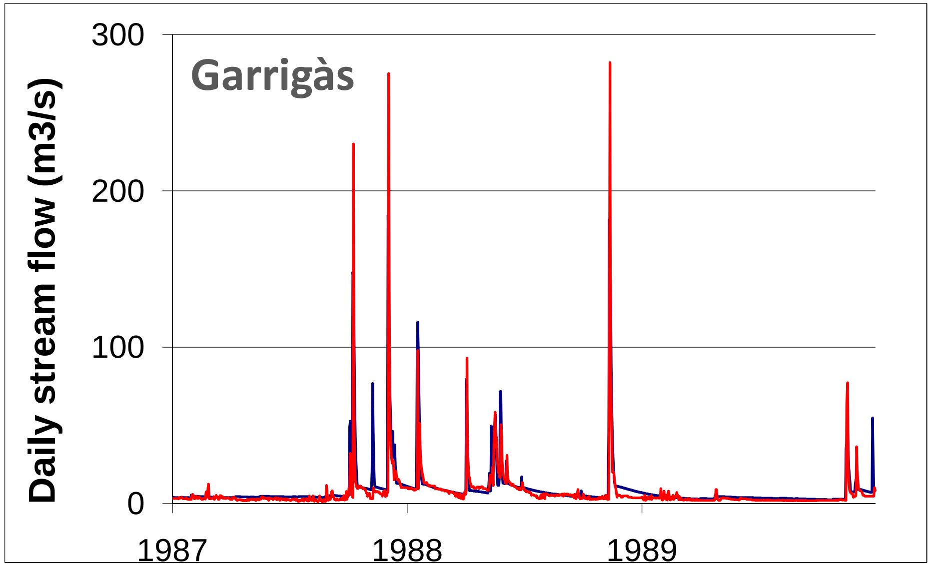
- **Model calibration**: Based on stream flow series from 4 gauging stations and climatic series from 8 meteorological stations
- **Available data**: 1984-2008 (25 years)
- **Calibration and validation**: Daily time step, 3 - 4 years periods
- **Objectives:**
  - simulated hydrograph similar to observed one,
  - mean flow values and total contributions similar between simulated and measured data,
  - Adequate values of statistics (Nash and Sutcliffe efficiency coefficient (NSE) and RMSE-observations standard deviation ratio (RSR))

Impacts on water bodies

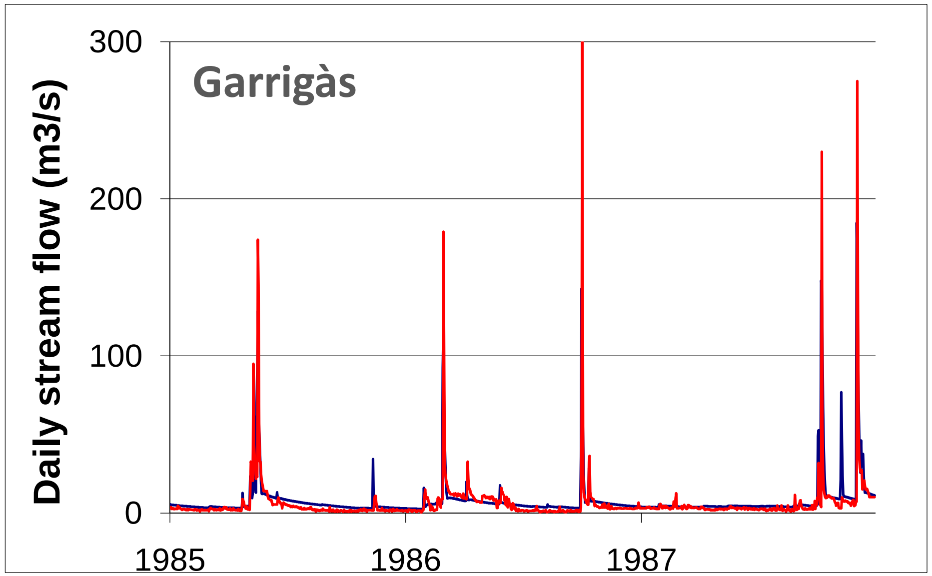
SWAT calibration and validation

Daily data

Calibration



Validation

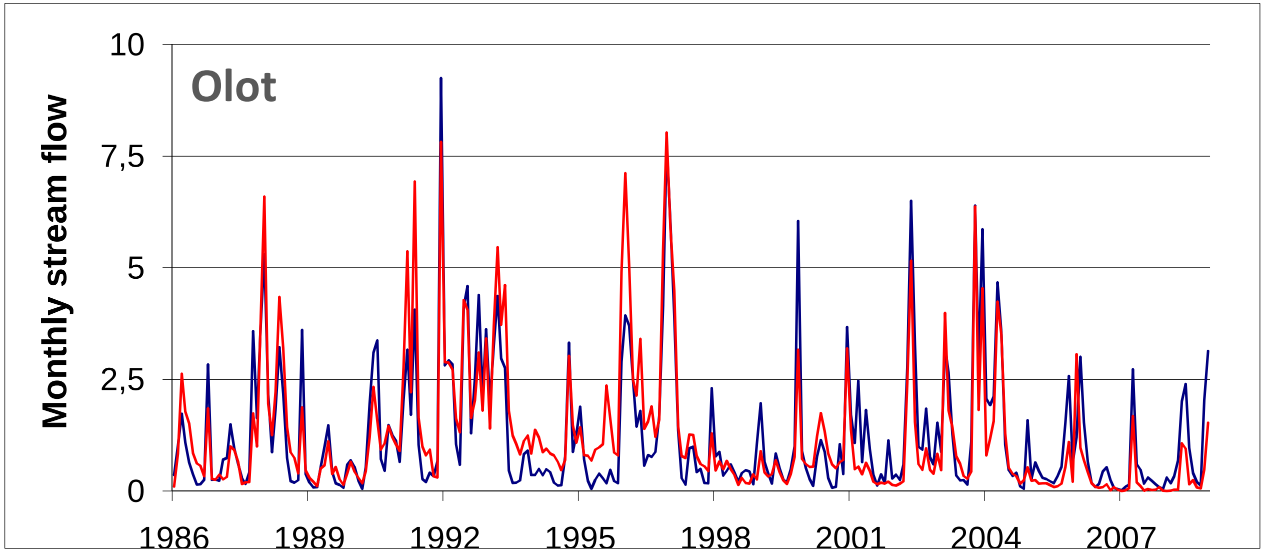


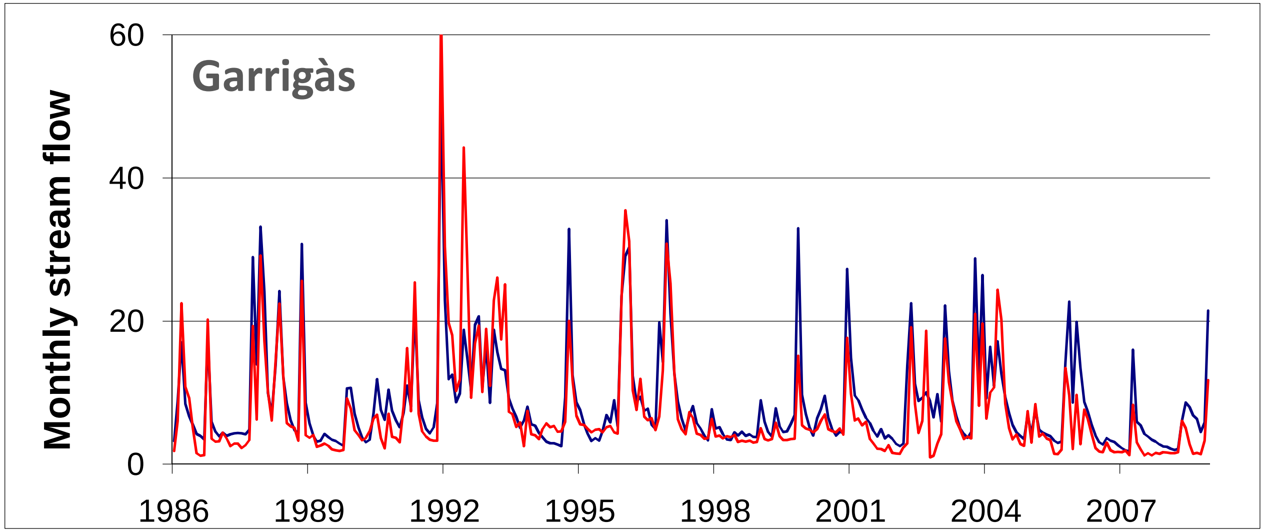
	Simulated mean daily discharge (m3/s)	Observed mean daily discharge (m3/s)	Statistics	
			NSE	RSR
Calibration	9.1	7.1	0.5	0.7
Validation	8.5	7.1	0.5	0.7

Impacts on water bodies

SWAT validation

Monthly data





	Simulated mean daily discharge (m3/s)	Observed mean daily discharge (m3/s)
Olot	1.2	1.2
Esponellà	8.4	7.2
Garrigàs	8.5	7.3

Observed data

SWAT simulated data

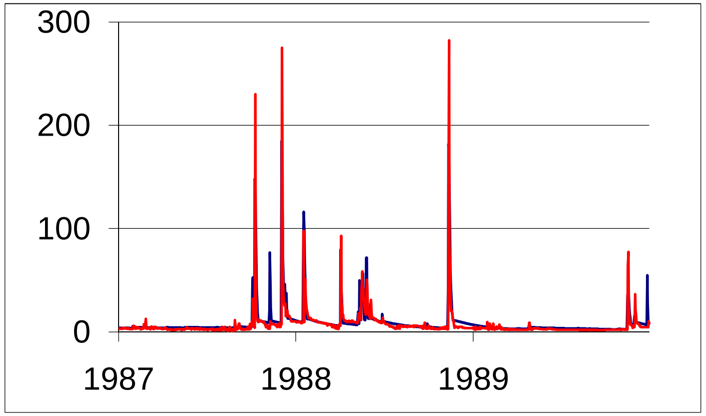
	Statistics	
	NSE	RSR
Olot	0.8	0.5
Esponellà	0.6	0.6
Garrigàs	0.7	0.5

Impacts on water bodies

Methodology

Hydrological model - SWAT (baseline period)

Calibration and validation →



↓

Scenarios

← Climatic scenarios

← Socioeconomic scenarios

Simulations ↓

Water balance under each scenario

Impacts on water bodies

Stream flow changes in 2006-2030

RELATIVE STREAM FLOW CHANGES FROM 2006-2030 RESPECT 1984-2008 (%)

	Stream flow variation at headwater	Stream flow variation at river mouth
B1	- 8 %	- 5 %
B1	- 11 %	- 5 %
A2	- 20 %	-13 %
A2	- 20 %	-13 %

- Generalized **stream flow reduction**, more severe at A2 scenario (-13 to -20 %)
- The highest reductions are expected in the **headwater**
- The **socioeconomic scenarios** (changes in land and water use) **are not relevant** in water balance → Strong effect of **forests** in water balance

Impacts on water bodies

Stream flow changes in 2076-2100

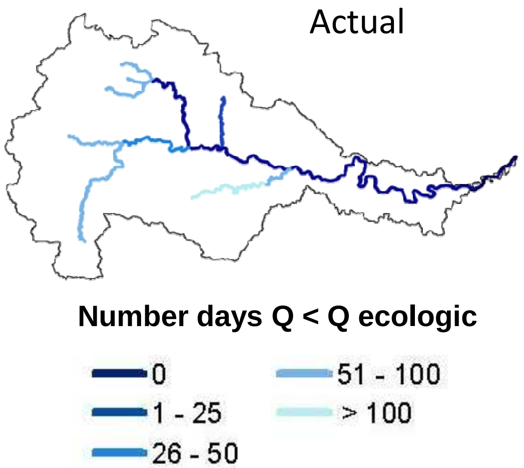
RELATIVE STREAM FLOW CHANGES FROM 2076-2100 RESPECT 1984-2008 (%)

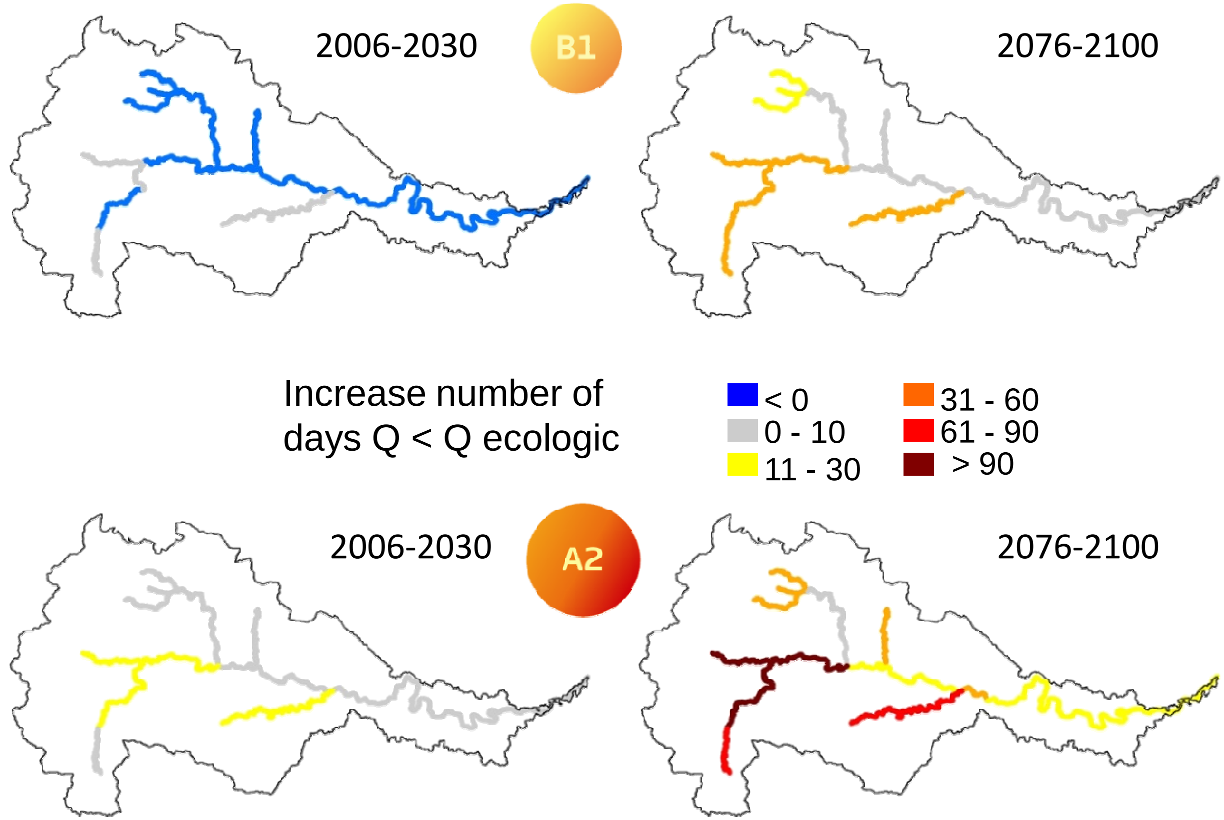
	Stream flow variation at headwater	Stream flow variation at river mouth
B1	- 31 %	- 22 %
A2	- 48 %	- 39 %

- **Generalized stream flow reduction** at the end of the Century, more severe at A2 scenario **(-39 to -48 %)**
- The **strongest reductions** are expected at Fluvià **headwater** (-31 to -48 %)

Impacts on water bodies

Ecological flow variation



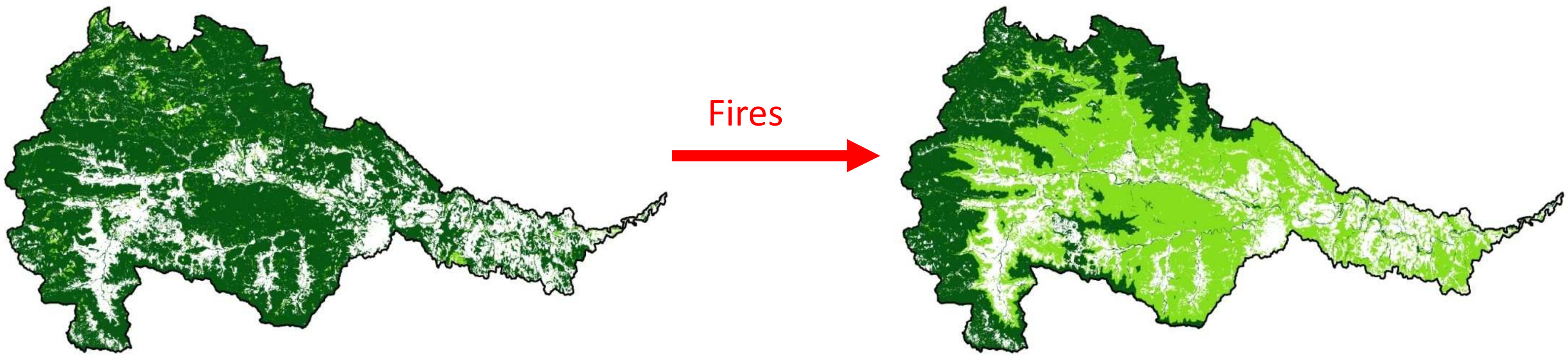


At the end of the Century, the **number of days** per year with stream flow lower than ecological flow **will increase** (more than **90** days in A2)

Impacts on water bodies

Disturbance effects on water balance: simulation experiment

WHAT WILL HAPPEN IF FOREST SURFACE IS REDUCED TO THE HALF BY 2030?



Land cover (MCSC, 2005)

- Shrublands
- Forests

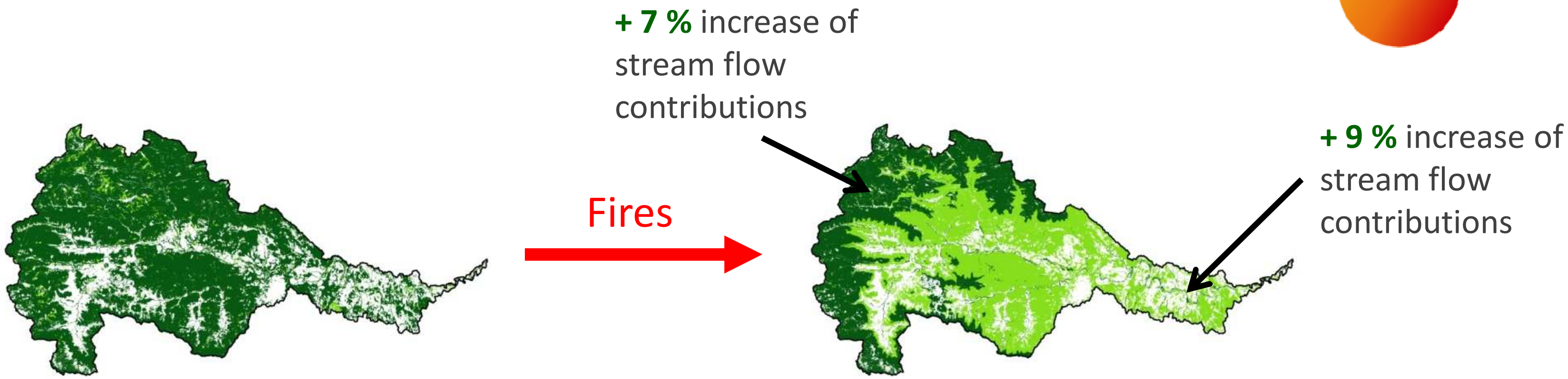
Land cover if forest surface is reduced to the half

- Shrublands
- Forests

Impacts on water bodies

Disturbance effects on water balance: simulation experiment

A2



Maxim stream flow = **117.6** m^3/s

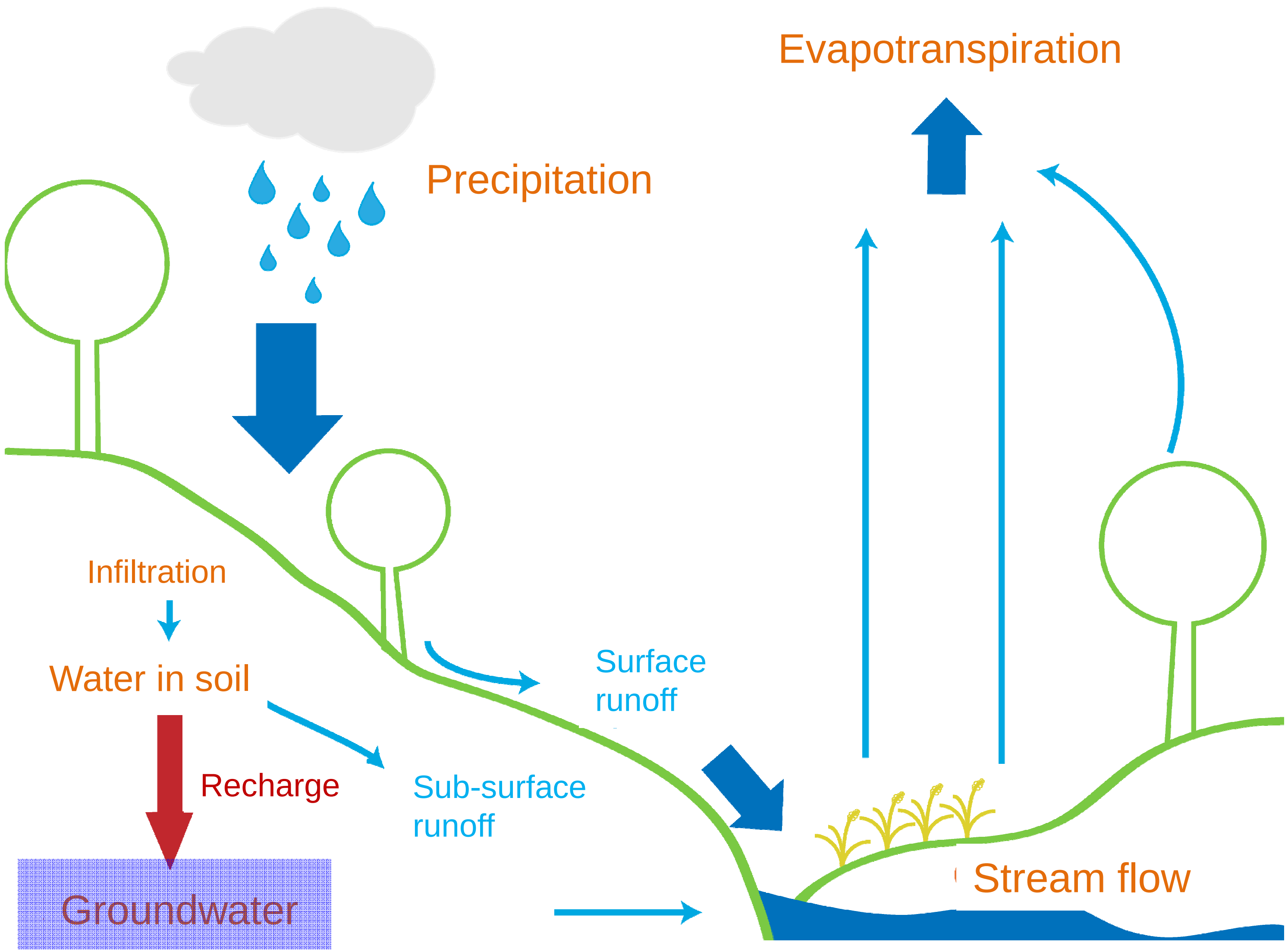
Maxim stream flow = **150.3** m^3/s

The **reduction** of **forest** surface and the **increment** of **shrublands** will imply:

- **Increase** of the **superficial stream flow contributions** along the watershed due to the reduction of actual evapotranspiration and infiltration.
- Increase of the **maxim stream flow**, increasing the **flood risk**
- Increase of the **flow variability**, tending to more extreme situations → **Forest** as water balance **regulators**.

Impacts on water bodies

What are the components of the water balance?



Impacts on water bodies

Groundwater changes in 2000-2025

RELATIVE GROUNDWATER CHANGES FROM 2000-2025 RESPECT 1984-2008 (%)

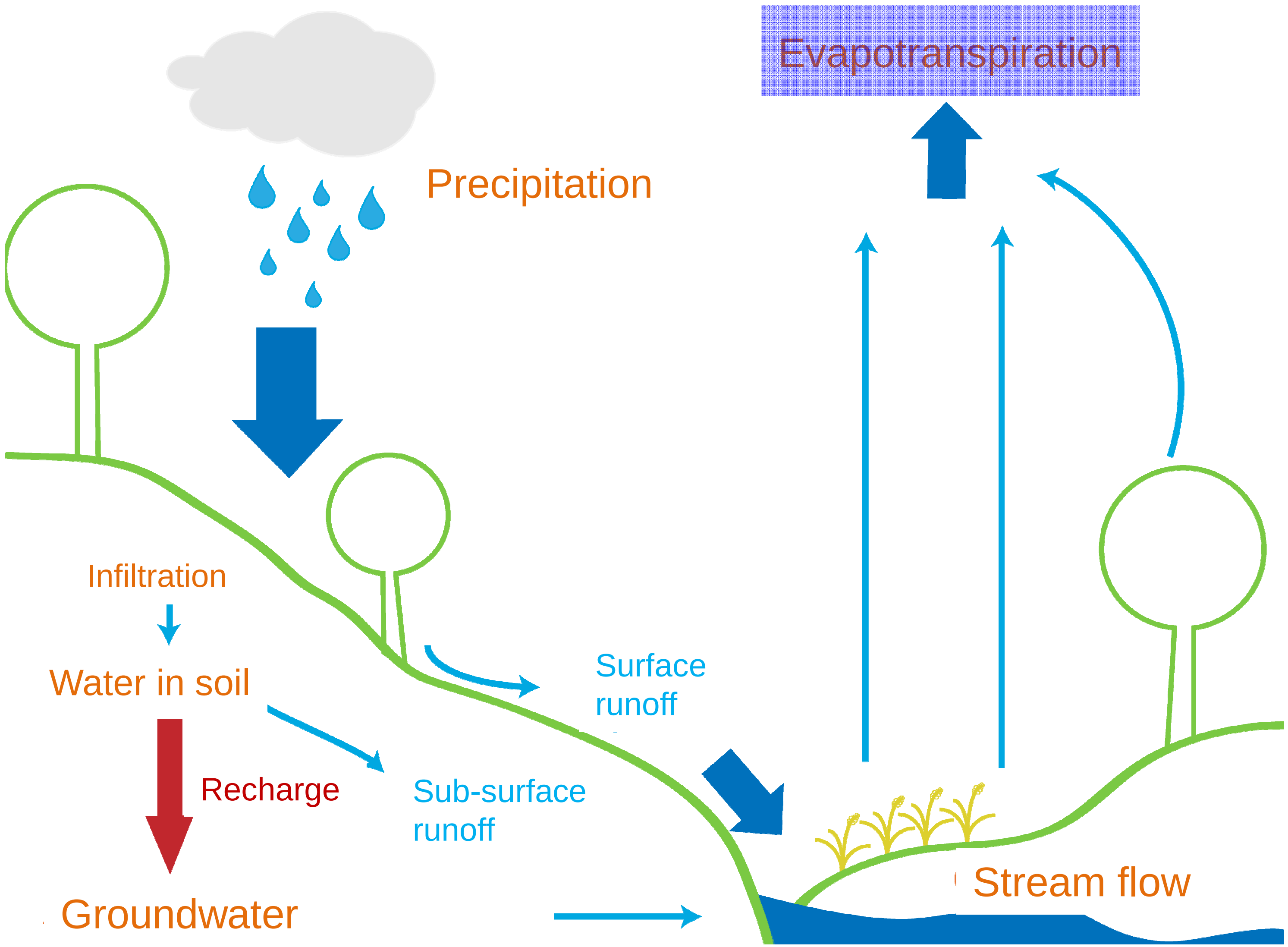
	Groundwater variations
B1	- 9 %
A2	- 14 %

- Generalized **groundwater reduction**, more severe at A2 scenario (-14%)

Source: UPC

Impacts on water bodies

What are the components of the water balance?

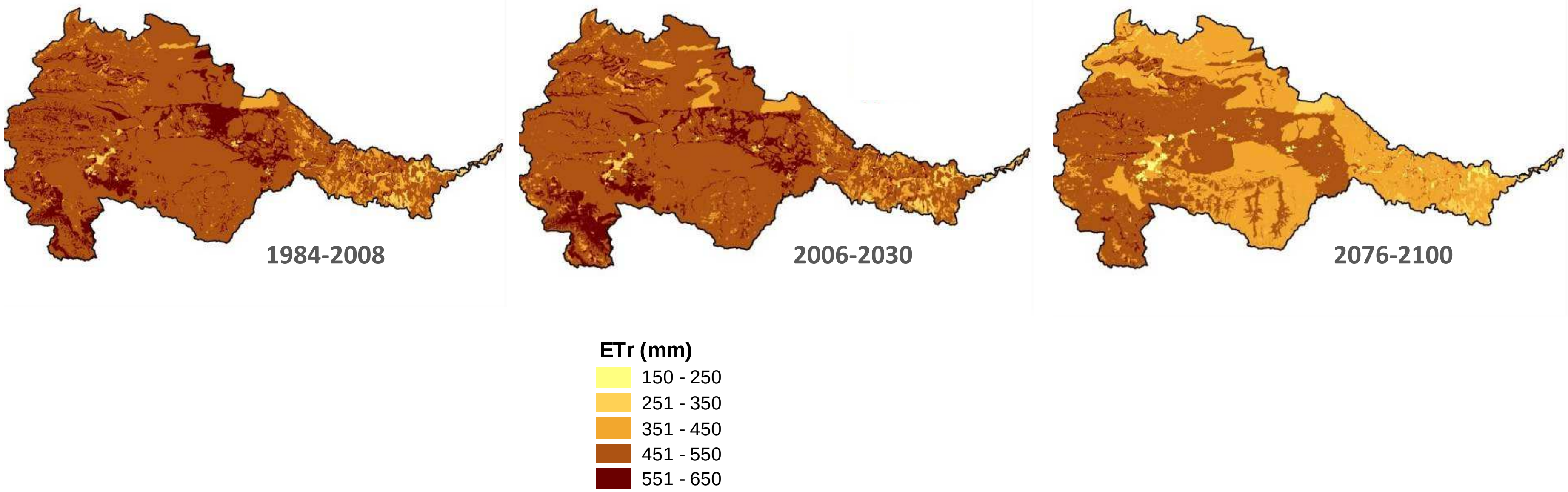


Impacts on water bodies

Actual evapotranspiration changes

ACTUAL EVAPOTRANSPIRATION DISTRIBUTION (mm/year)

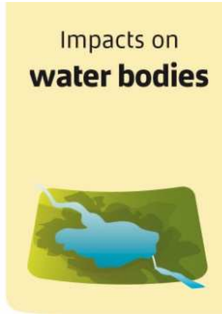
A2



- At the end of the Century, a **14 to 25 % reduction of real evapotranspiration** is expected

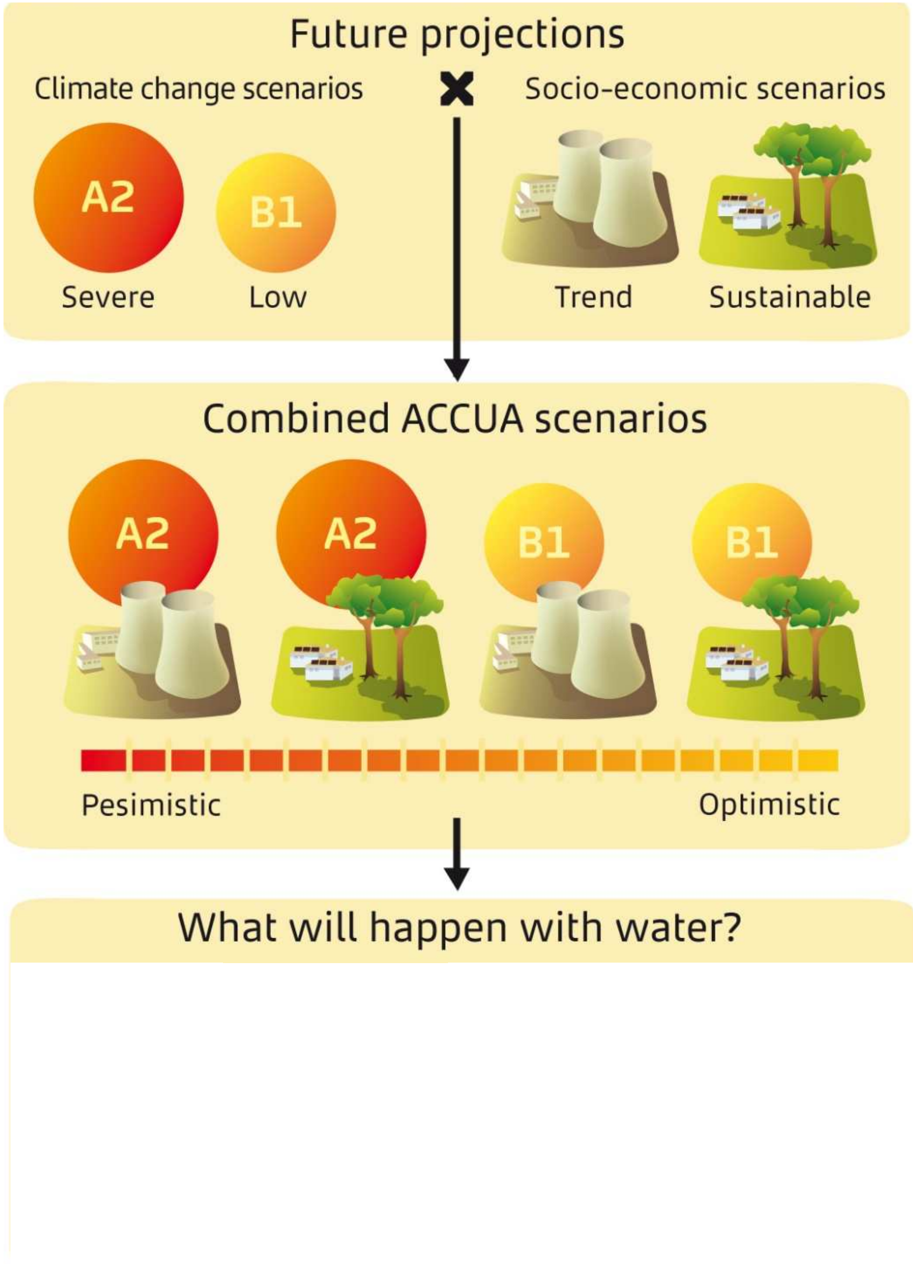
Impacts on water bodies

Conclusions



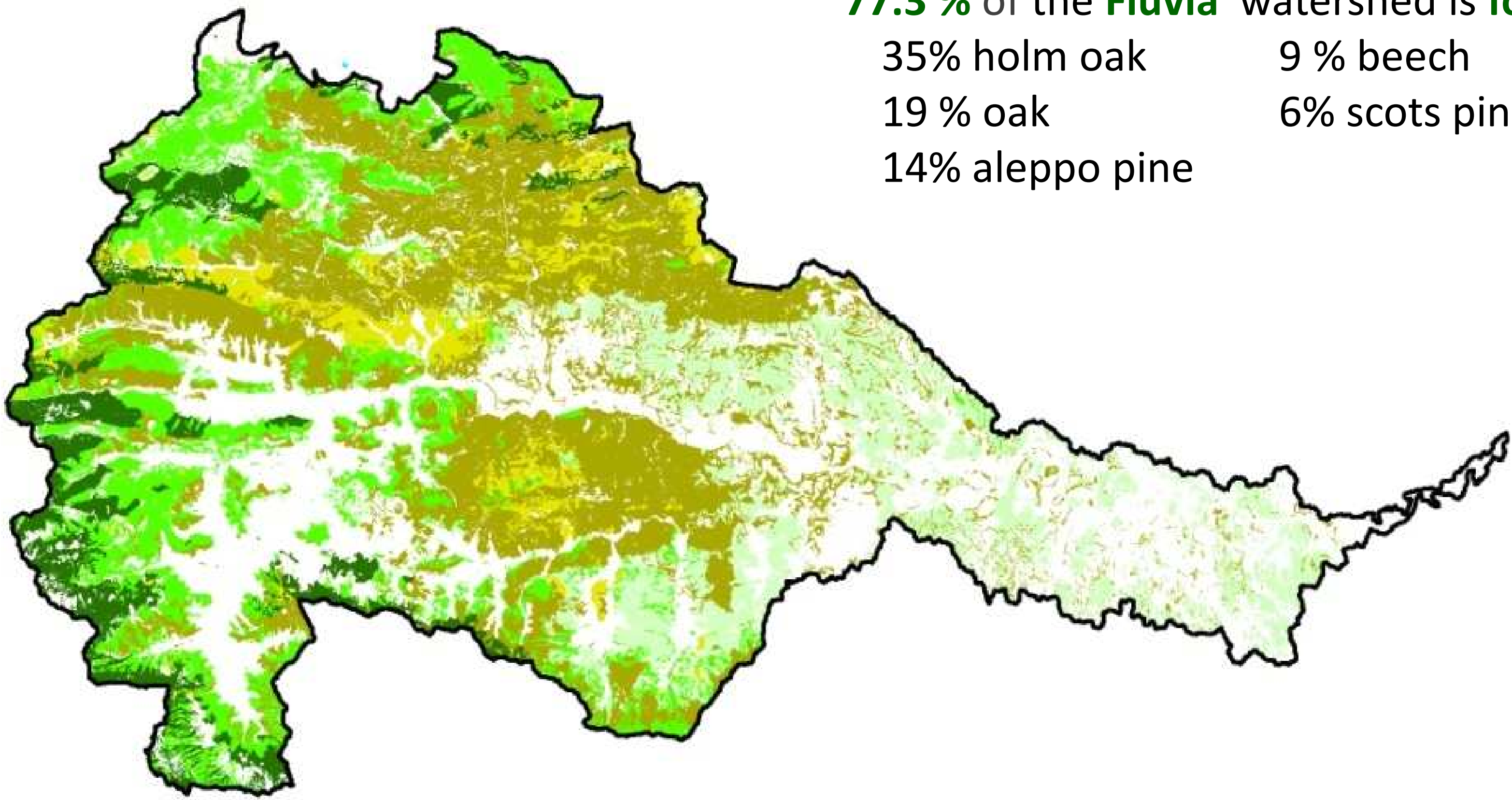
- A **strong alteration on water dynamics** is expected during the XXI Century
- A **reduction** in stream flow and groundwater **contribution** is expected, **more severe** in the **A2** scenario than in the B1
- Reductions are especially **severe** in the wetter **headwaters**
- **Socioeconomic scenarios** for 2030 have not a **relevant influence** in water balance
- **Forests** have an essential role as **regulators of the hydrologic cycle**, dimming the extreme events and reducing maximum stream flow, smoothing the **flood risk**
- At the end of the Century, the **number of days per year** with stream flow **lower** than the **ecologica**l one will increase

Impacts on forests



Impacts on forests

Main forest species distribution



77.3 % of the **Fluvià** watershed is **forest land:**

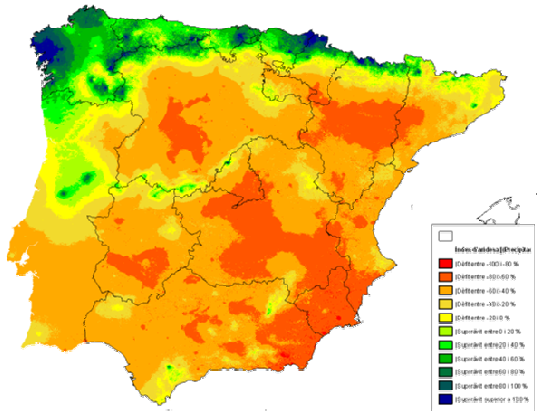
- 35% holm oak
- 19 % oak
- 14% aleppo pine
- 9 % beech
- 6% scots pine

Source: MCSC 2005

Impacts on forests
Species bioclimatic suitability

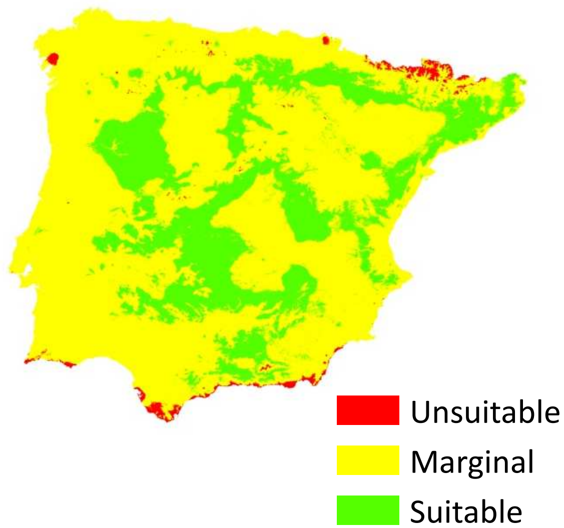
BIOCLIM algorithm: it estimates bioclimatic envelopes using species distribution and other explaining variables:

- Climatic variables : **Precipitation** and **Mean temperature** of the coldest month (according to the Woody Plant Atlas of Catalonia)
- Current species distribution according to **IFN3**



The algorithm generates maps with three classes:

- **Suitable**: optimal sites for the species
- **Marginal**: suboptimal range for the species
- **Unsuitable**

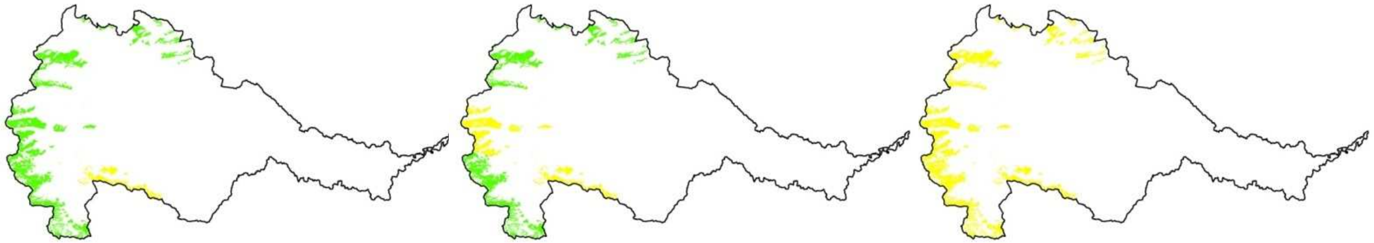


Impacts on forests

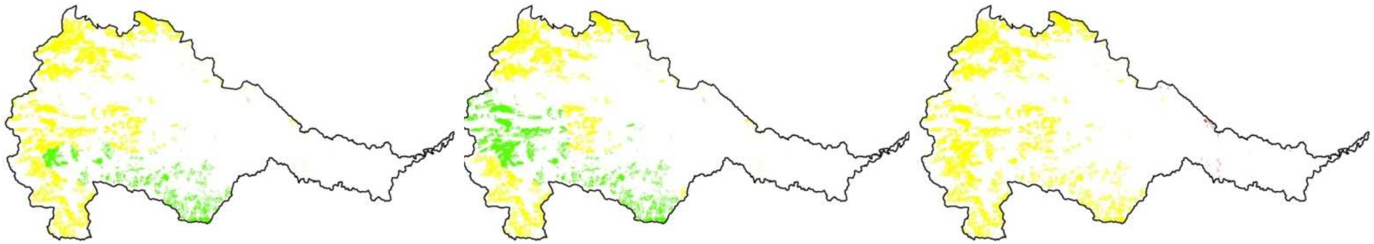
Species bioclimatic suitability

A2

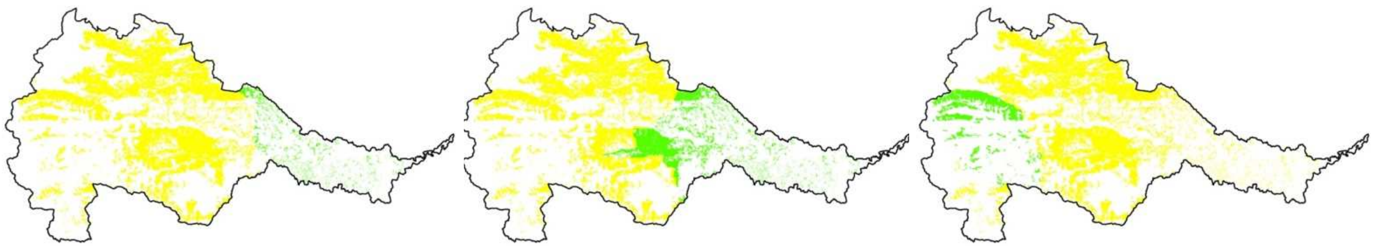
Beech



Oak



Holm oak



- The species associated to **wet areas** (beech, oak, scots pine ...) could change to **marginal** conditions.

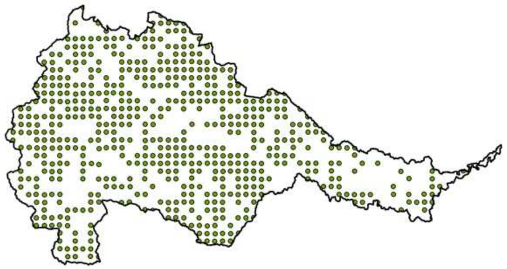
- **Holm oak** suitable area could move to **higher** areas

Unsuitable
Marginal
Suitable

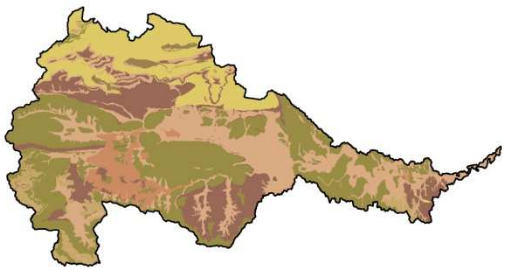
Source: BIOCLIM

Impacts on forests
Forest functioning

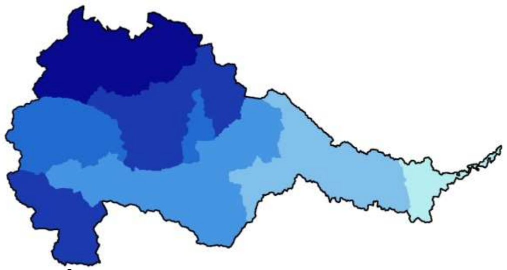
GOTILWA+ FOREST MODEL



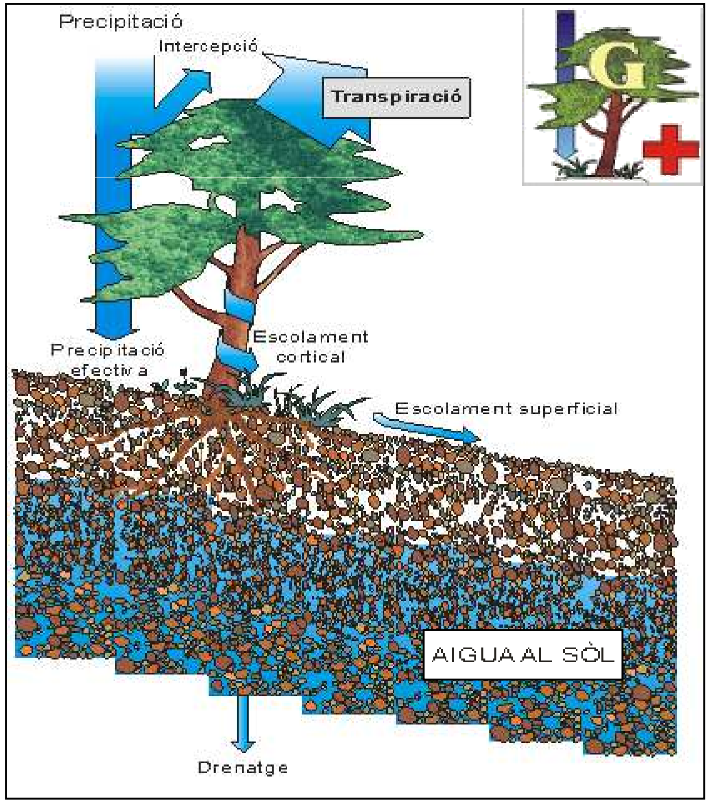
IFN2-IFN3: forest inventories



Soil map



Climate

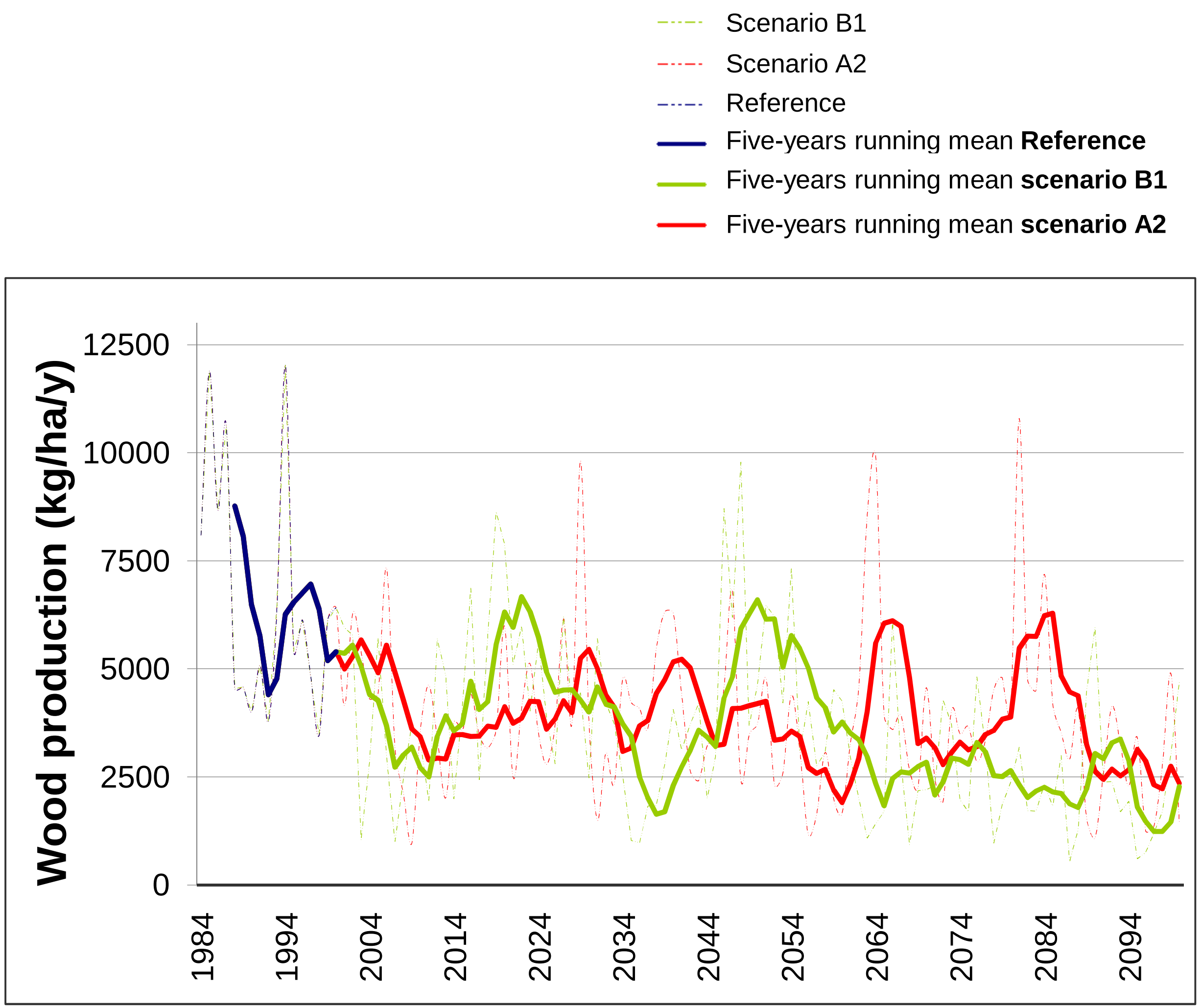


Impacts on forests

Forest functioning

WOOD PRODUCTION (kg/ha/yr)

Wood production shows a **higher variability**, with a strong rainfall dependency. A **decreasing trend** is expected

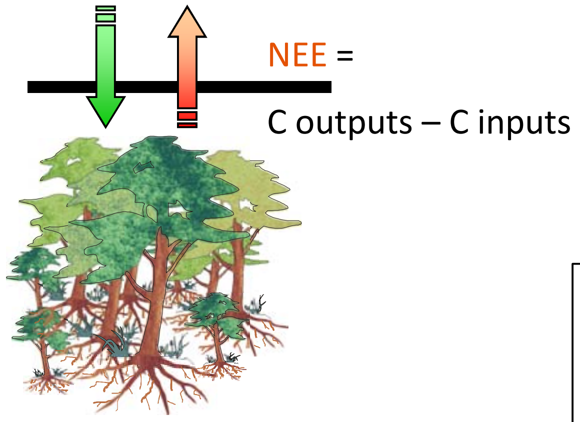


Source: GOTILWA+ model

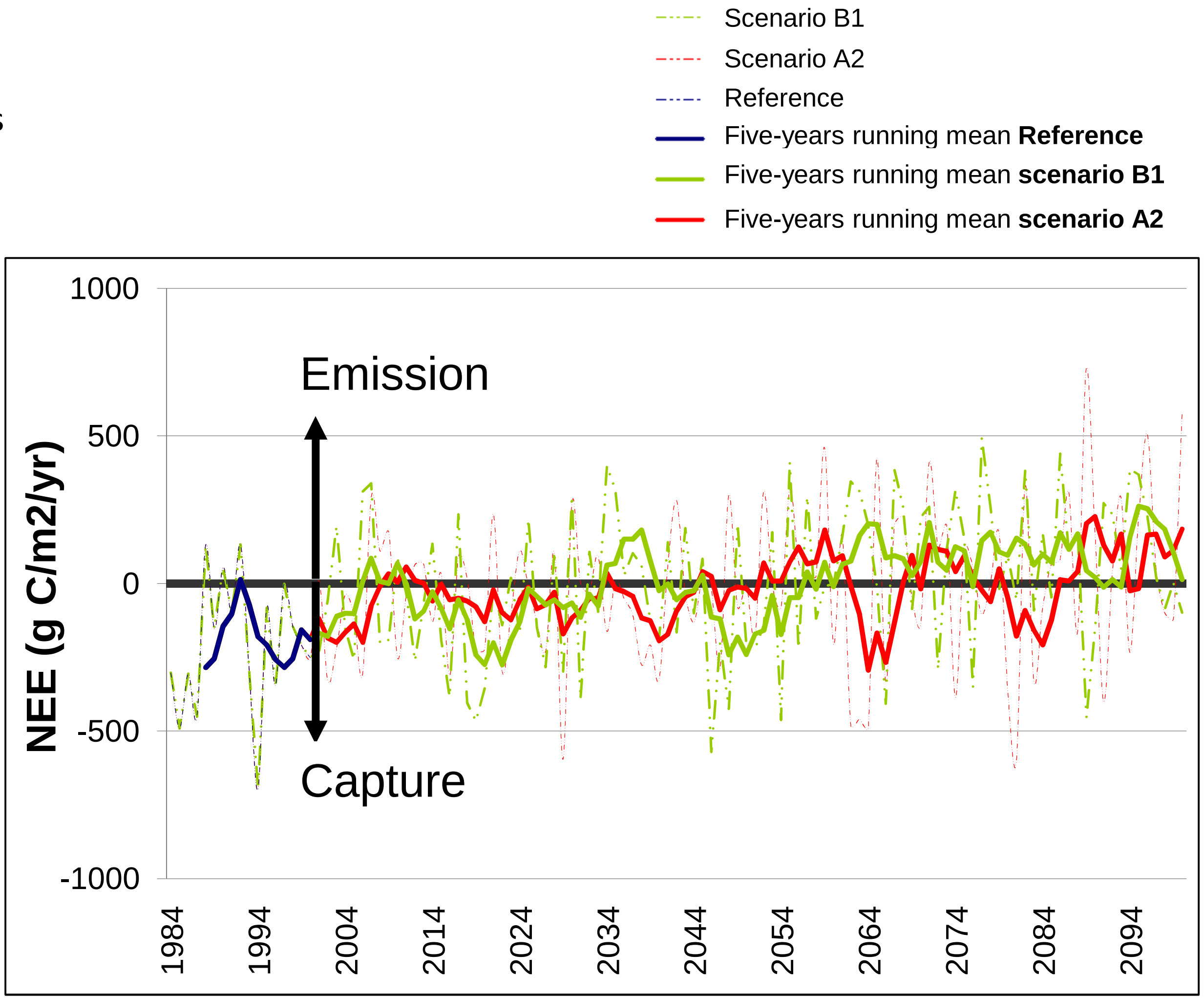
Impacts on forests

Forest functioning

CARBON NET EXCHANGE IN FOREST ECOSYSTEM



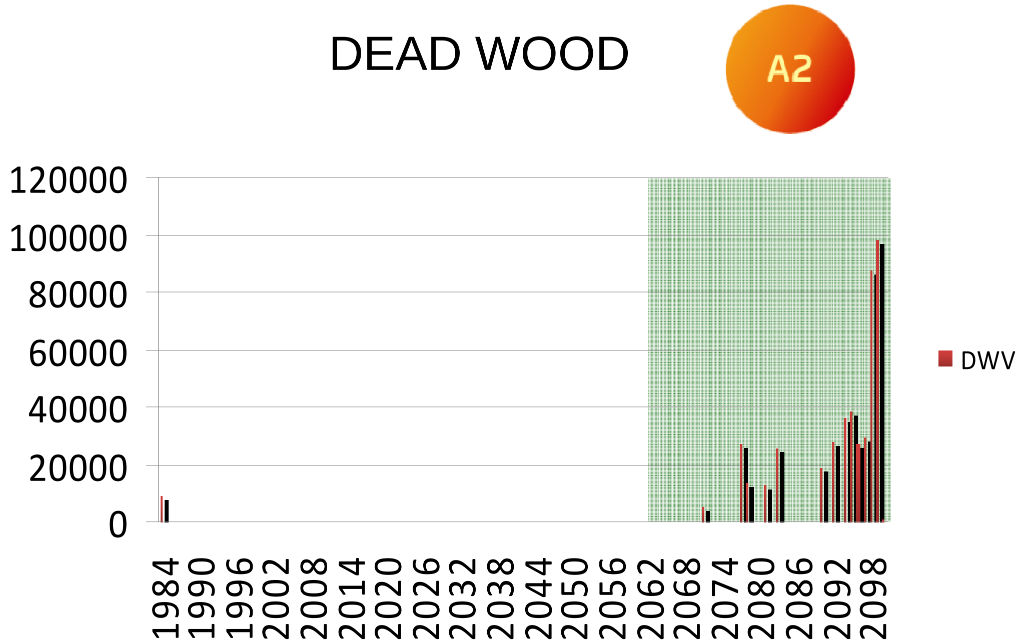
Many **forests**, specially wet forests, **could change** their behaviour, from **carbon sinks** to **carbon sources** at the end of the century



Source: GOTILWA+ model

Impacts on forests
Forest functioning

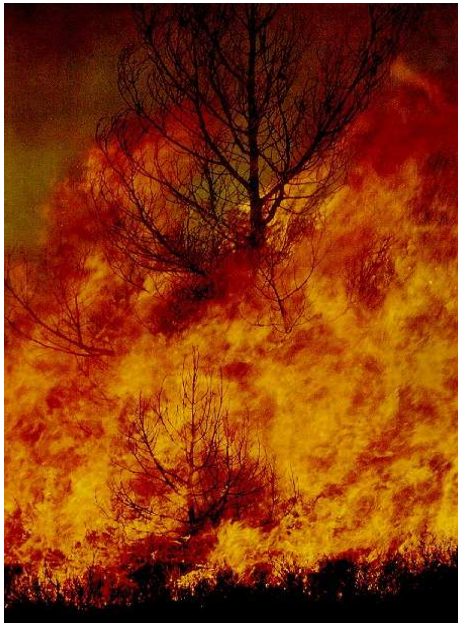
FOREST TREE MORTALITY



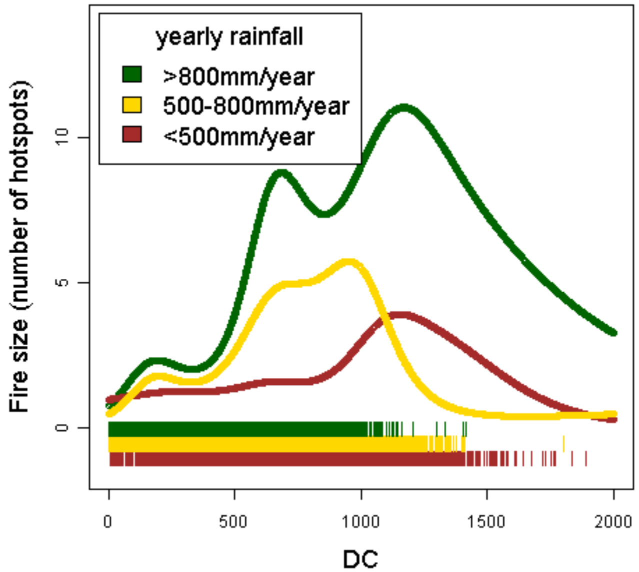
Tree mortality events in unmanaged forests could be more frequent at the end of the century

Impacts on forests
Fire risk

DROUGHT CODE (DC), CANADIAN METEOROLOGICAL INDEX



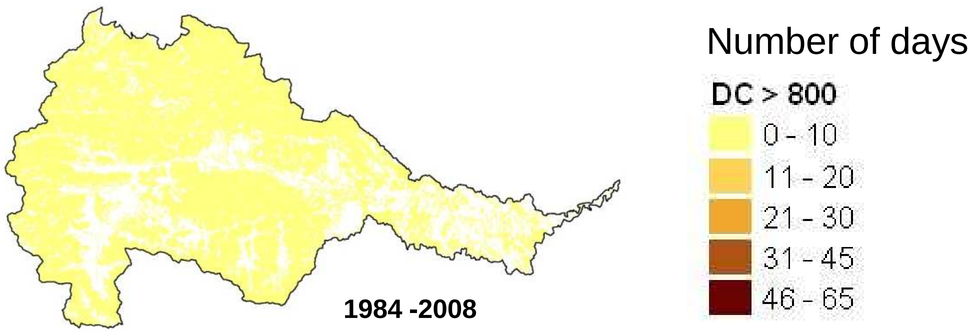
- Index based on **climatic variables** (T and P).
- It estimates **environmental drought and high inflamability** events .
- **DC 600-800** is a threshold used in Catalonia as indicator of very high risk to suffer large fires.



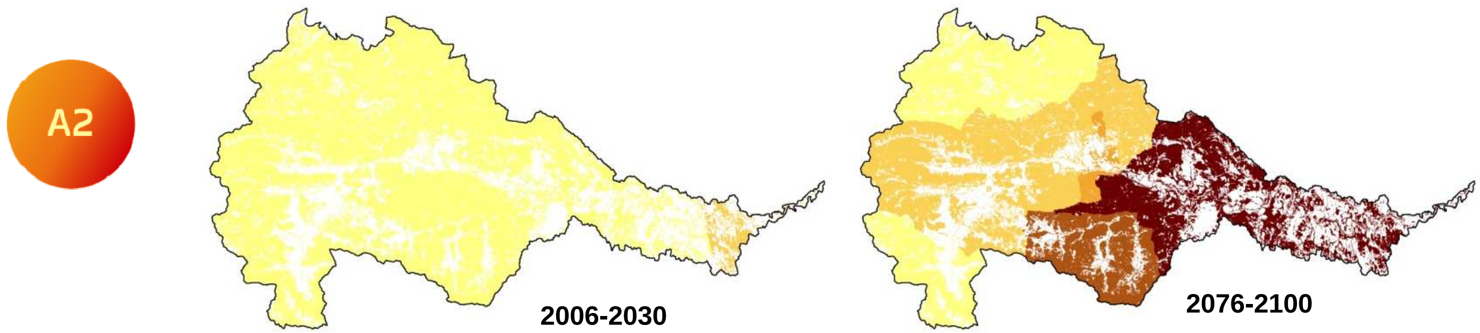
Source: Loepfe *et al,* in press

Impacts on forests
Fire risk

NUMBER OF DAYS PER YEAR WITH DC > 800 (EXTREME RISK)



Fire risk increase at the end of the century could make worst the Mediterranean forest **vulnerability**

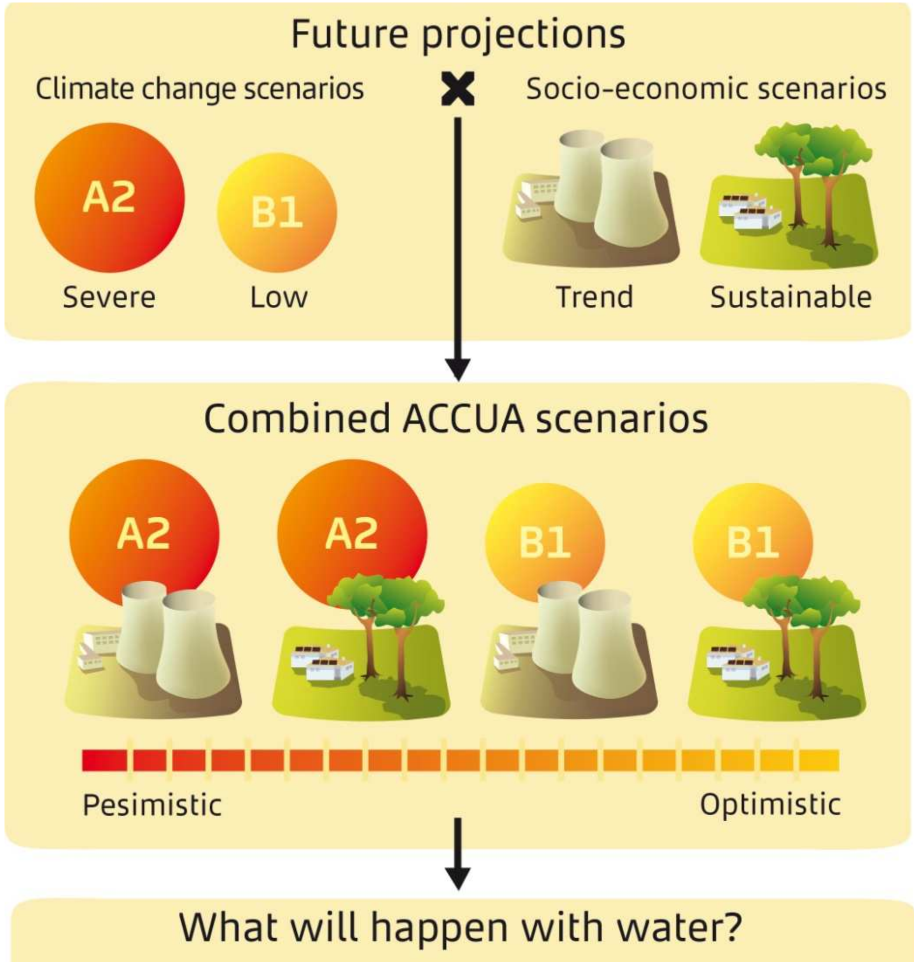


Impacts on forests
Conclusions

Forest could be potentially vulnerables to global change:

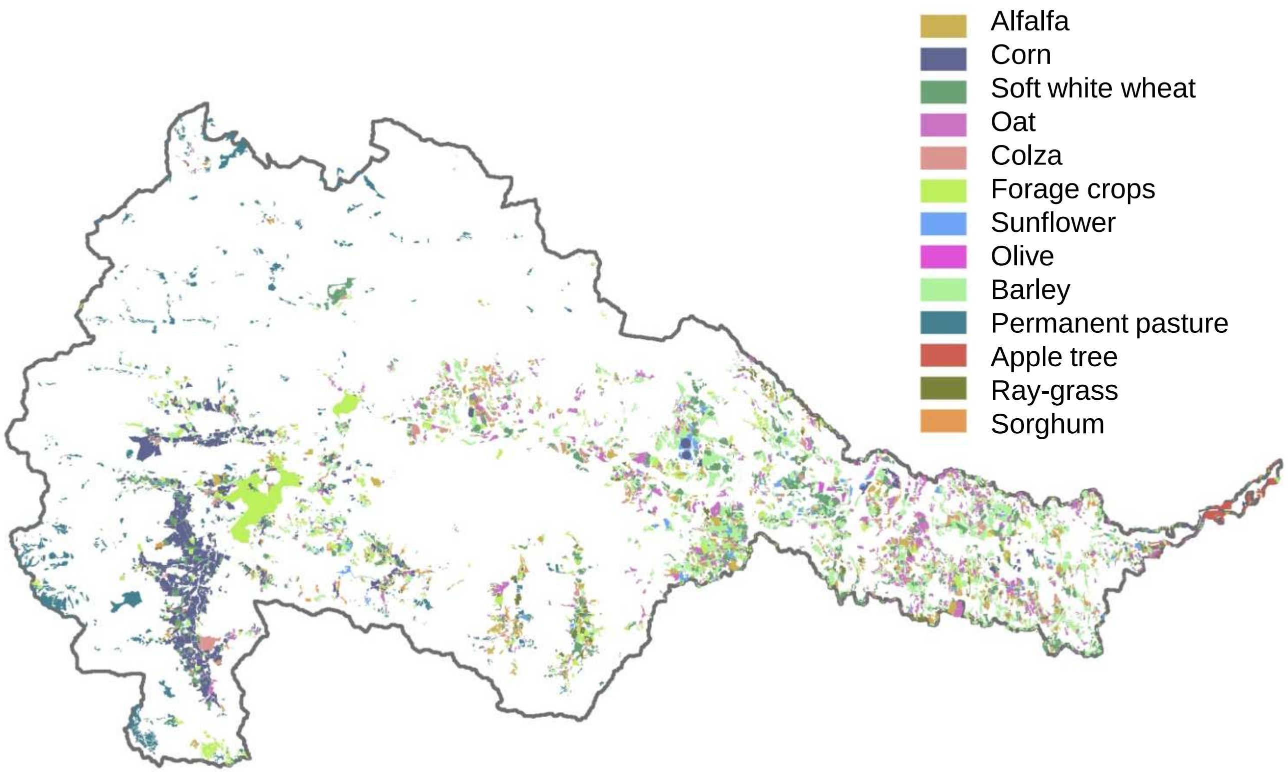
- due to a decrease in **water stored in soil**,
- due to the changes in the species **bioclimatic suitability**, showing worsen effects on the species of wettest areas
- due to **fire risk** increase

Impacts on crops



Impacts on crops

Main crops distribution



- In 2005, the **19 %** of Fluvià watershed surface was occupied by crops

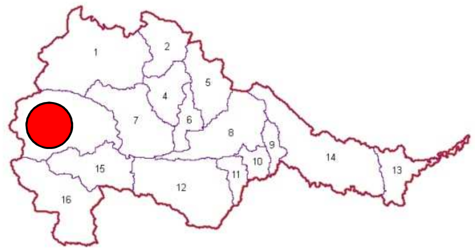
- The **corn** is one of the most distributed crops in the watershed, occupying the **3.5 %** of the crops surface

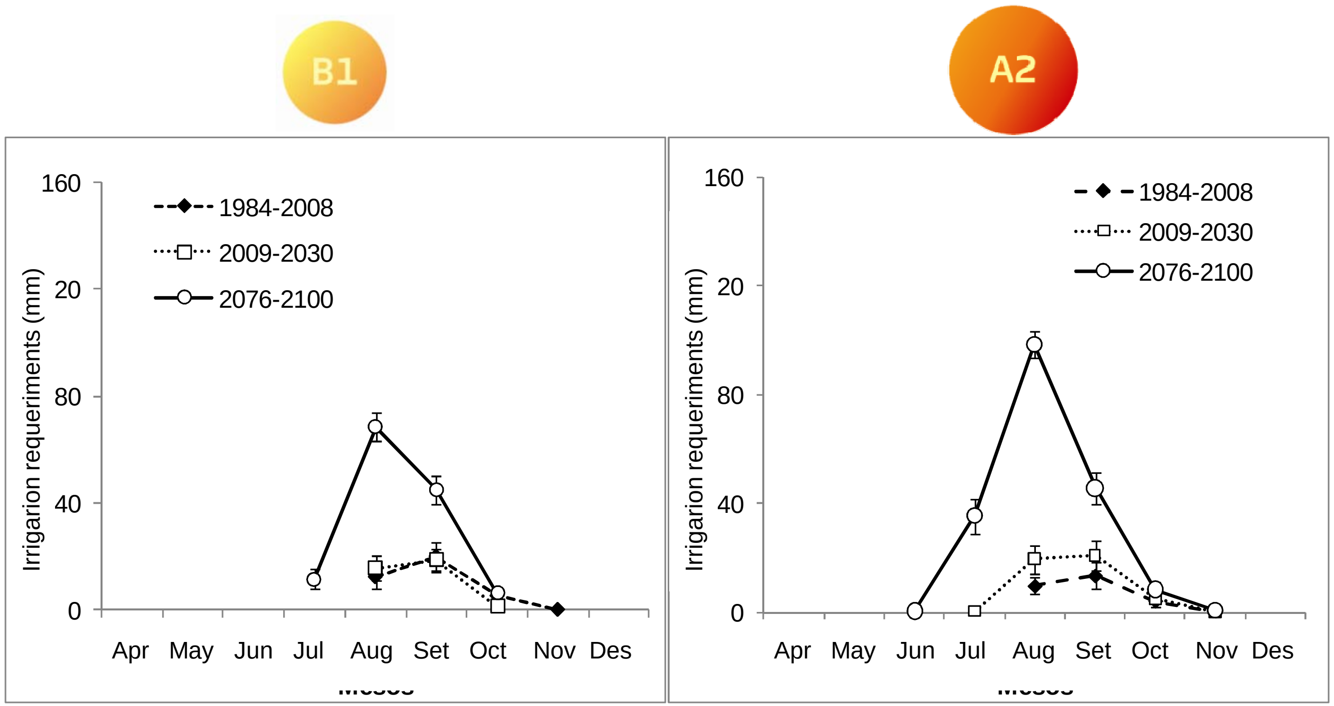
Source: MCSC 2005

Impacts on crops

Crop irrigation requeriments

CORN





Crops will **increase irrigation requirements** and will **amplify** the period in which irrigation is necessary to maintain **actual productions**

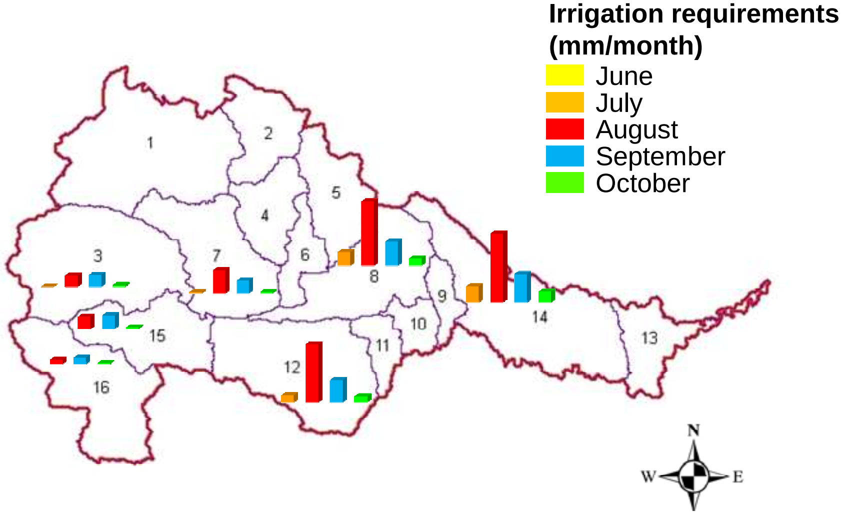
Source: IRTA

Impacts on crops

Crop irrigation requeriments

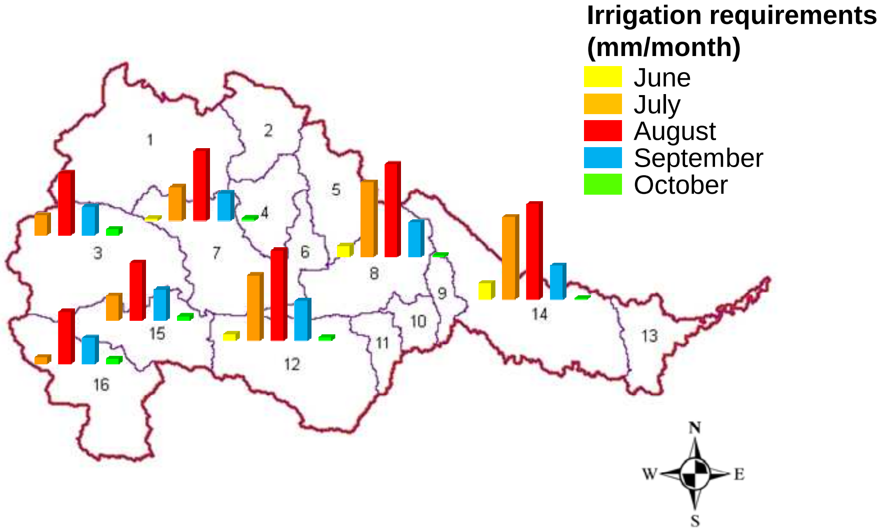
CORN

2008-2030



A2

2076-2100



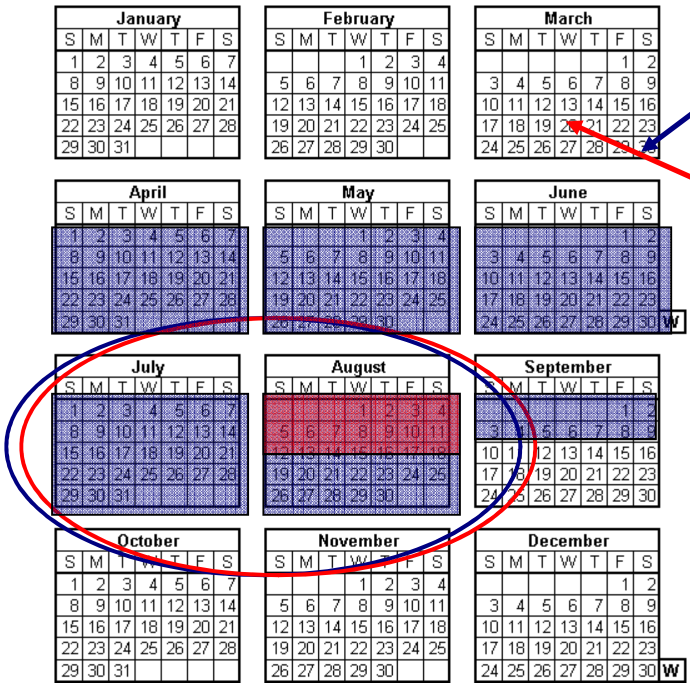
Irrigation requirements in some actual crops, which are **rarely or not currently irrigated**, might be highly **increased** at the end of the XXI Century.

Source: IRTA

Impacts on crops

Changes in crop phenology

CORN



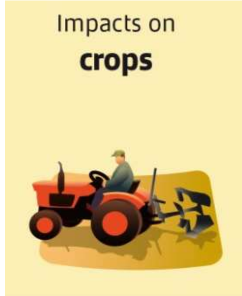
- Nowadays, the **sowing season** starts at the end of **March** in the lower part of the watershed
- At the end of the XXI Century, the **sowing season** might **gain** approximately **10** days

- Nowadays, the number of days per year with **thermal stress** (T> 30ºC) in July and August is **10** days/year
- At the end of the XXI Century, the number of days per year with thermal stress might **double**

- Nowadays, corn requires approximately **160 days** for achieving the **physiological ripeness**.
- At the end of the XXI Century, the number of days might **reduce 20** days per year.

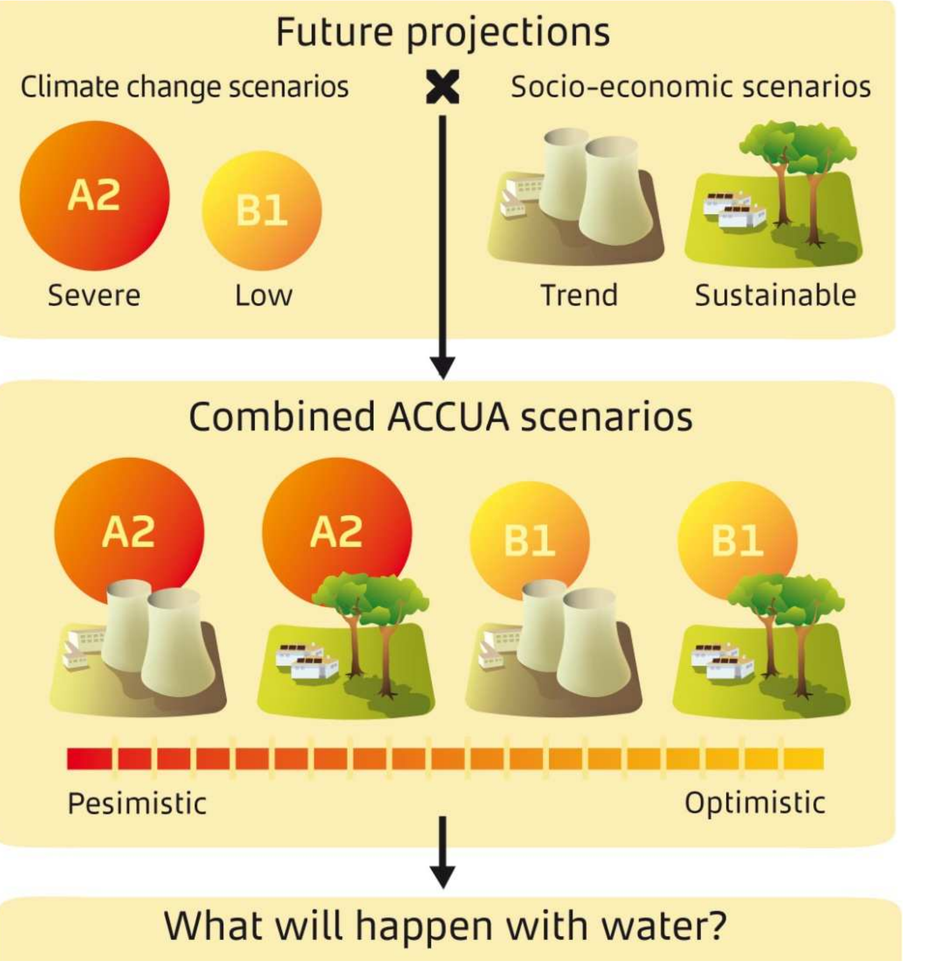
Source: IRTA

Impacts on crops
Conclusions



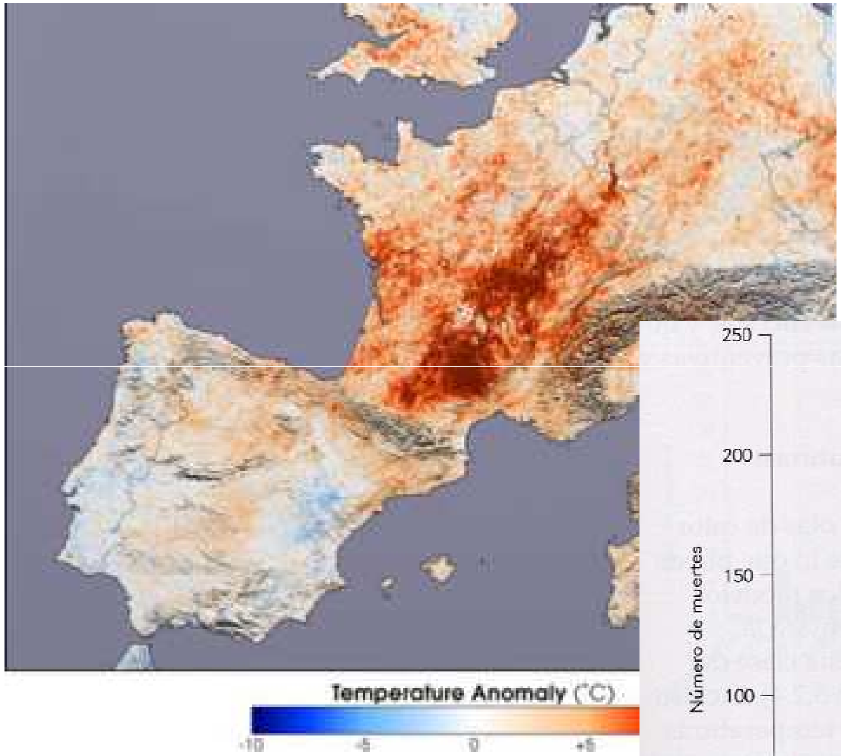
- Agriculture might be deeply affected by climate change if **crops are not able to adapt to the future environmental** and market requirements
- Crops might experiments changes in the **phenology** and in the **irrigation requirements**, in both irrigated and rainfed crops
- Crops, together with forests, have an important role as **carbon sinks**

Impacts on population

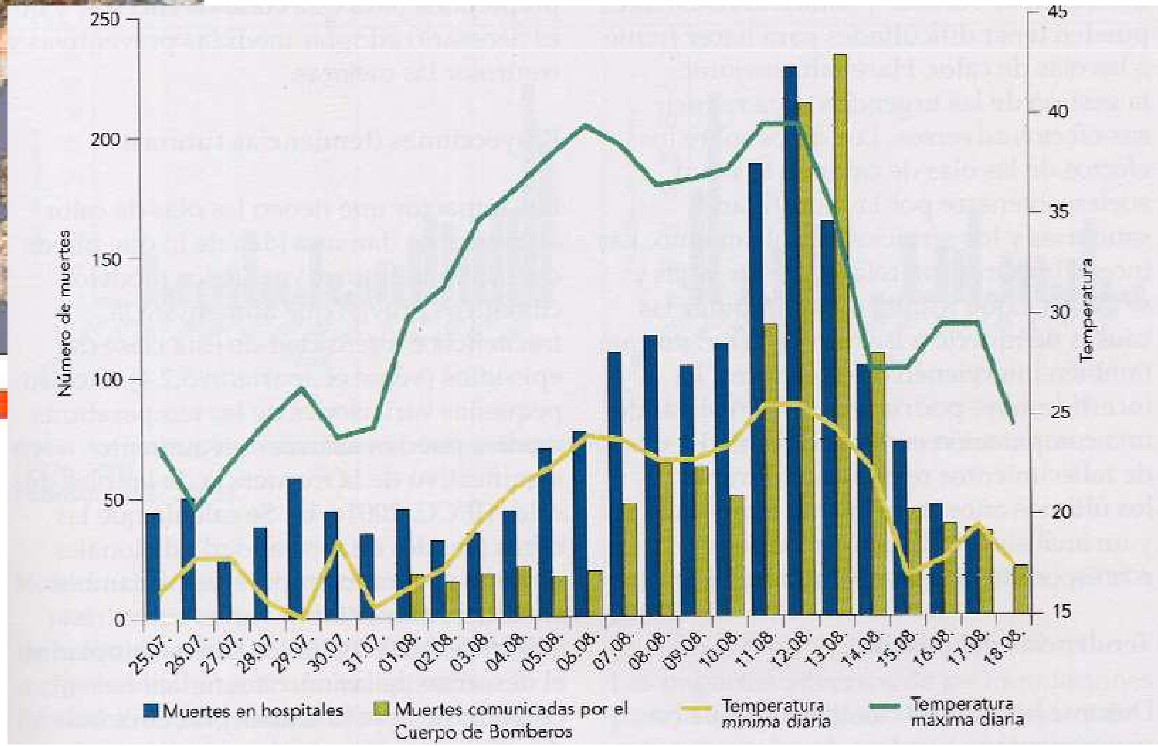


Impacts on population

An exemple of the impacts on human populations

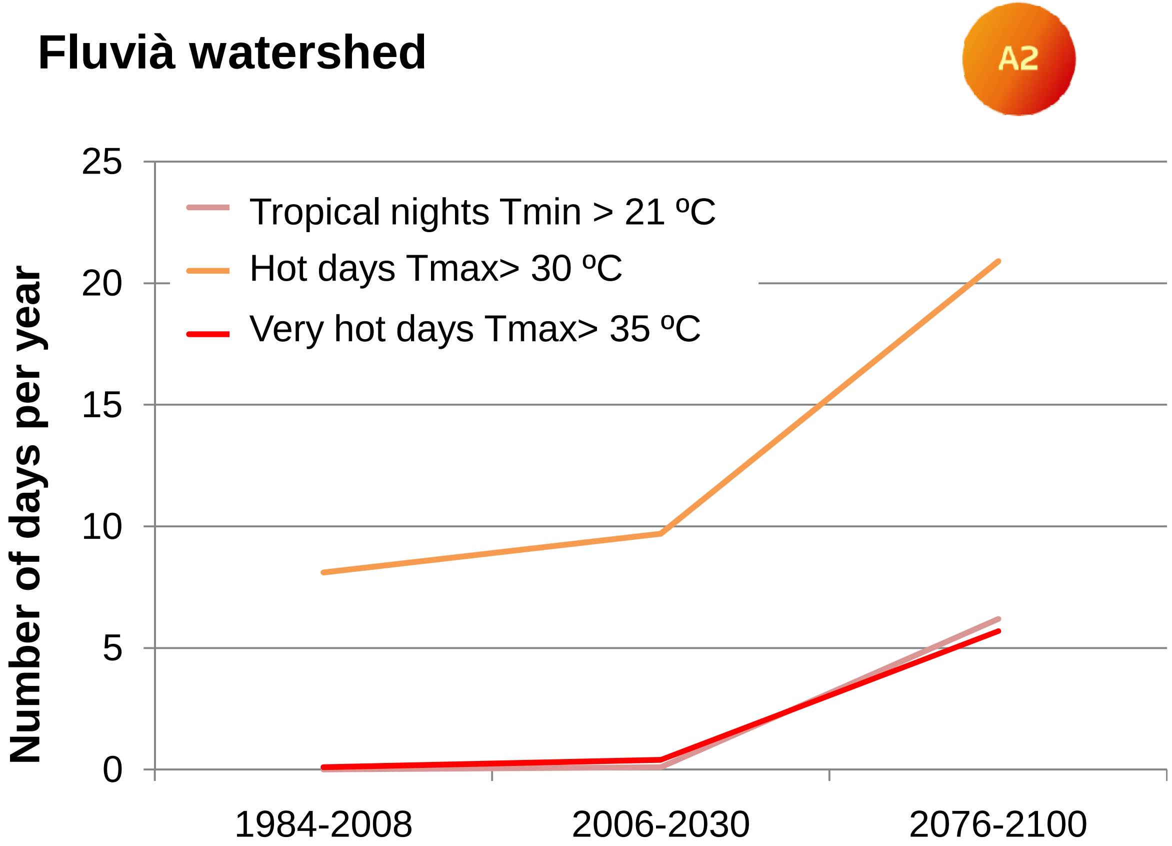


Heat wave in France. **Summer 2003**



Impacts on population

Population vulnerability to climate change



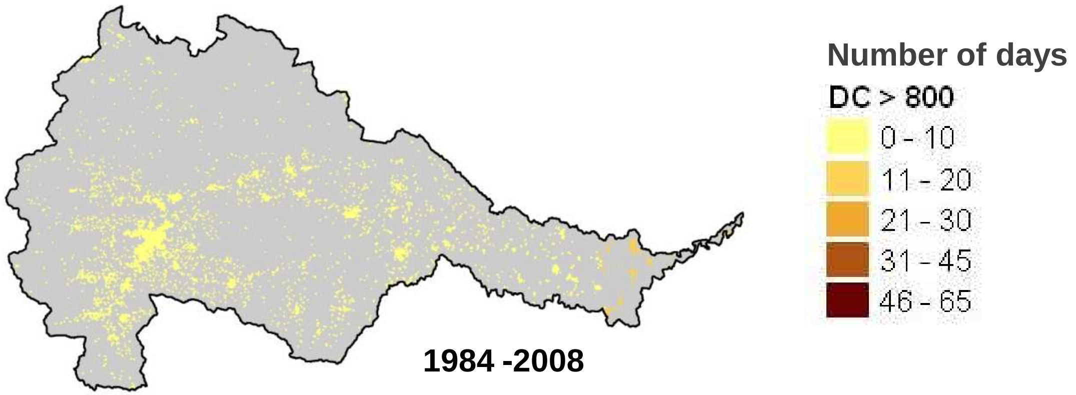
At the end of the Century, there will be **6** days more of **tropical nights** and **13** and **6** days more of **hot** and **very hot days** per year

Source: ACCUA from SMC 2010 projections

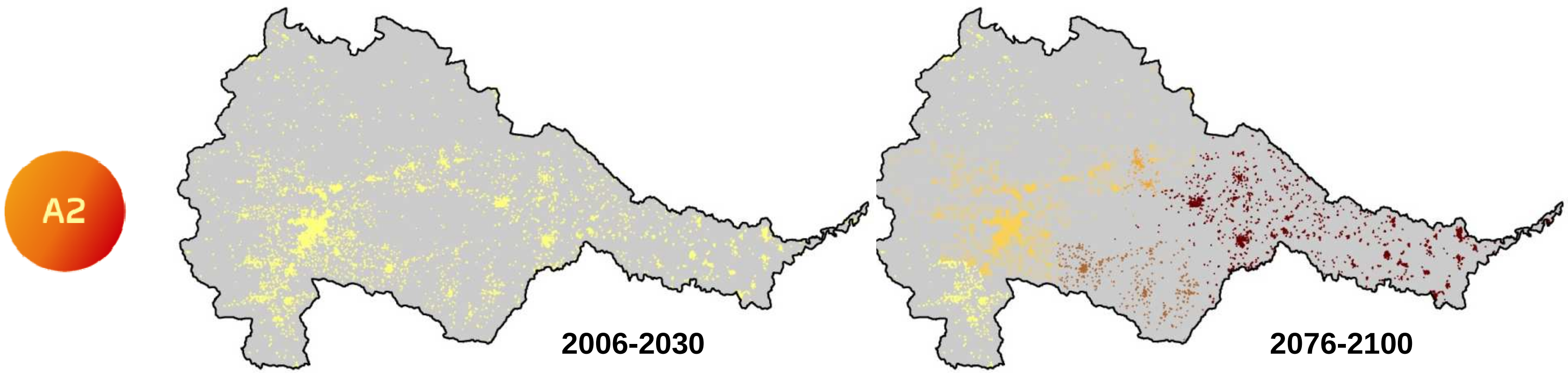
Impacts on population

Forest fire risk for goods and persons

NUMBER OF DAYS PER YEAR WITH DC > 800 (EXTREME RISK)



At the end of the Century, **urban areas** next to forest with **extreme** fire risk **could increase**, specially in the lower part of the watershed



Impacts on population
Conclusions

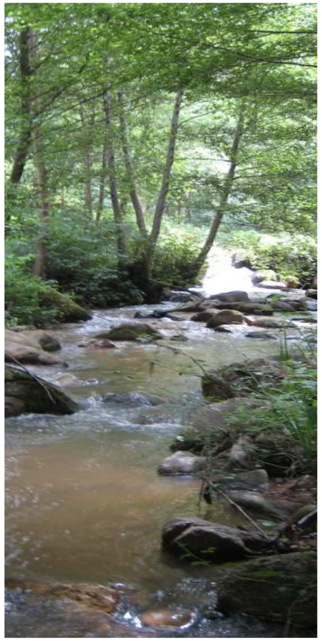
- **Human wellfare, health** and **security** could be affected by the changes in environmental conditions.

Adaptive measures

Adaptive measures

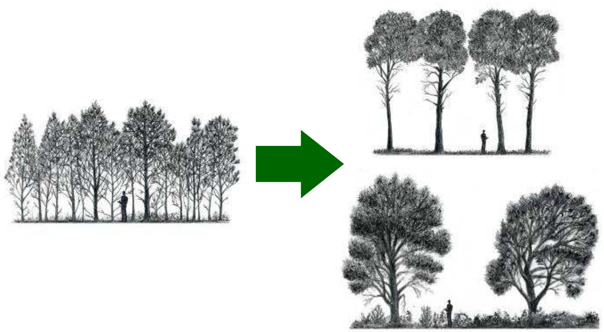
Water bodies

- **Improvement** of the **integral management** of water resources:
  - **Planning** of the **future land uses** depending on water availability.
  - Application of **saving measures** that promote the **resources optimal uses** and its **reutilization**.
  - Application of action plans to **protect** the **Empordà wetlands** and prevent from **fragmentation**



Adaptive measures
Forests and shrublands

- **Forest management** promoting health forest structures, fire and water stress resistance: **Reduction of trees density** and promotion of **big trees**



- Identification of **more vulnerable** species to global change in order to **manage** and **guaranty** its viability:
  - **Oak** in low altitude areas
- Promotion of trees and shrublands species **more adapted** to future **new conditions.**
- Recovery and maintenance of the **agro-forest mosaic**

Adaptive measures

Forest management results in Catalan forests

Prades Mountains

Adaptive measures

Crops

- **Agronomic techniques** might help more vulnerable species through:
  - **changes** in **varieties** and **sowing season dates**,
  - **reduction** of plantation **density**,
  - crops **orientation**,
  - increase of soil water **storage capacity**,
  - increase **water use efficiency**, also in irrigated crops
  - use **regenerated water** if possible.

- **Agro-forest mosaic** balance (crops–forests–shrublands–pastures) :
  - **flux regulation** of carbon, nitrogen, phosphor, water, …,
  - improvement of **biodiversity** and **connectivity**
  - thermal regulation and wind protection.

Adaptive measures
Urban uses

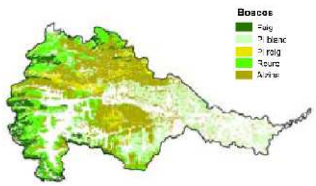
- Water use **optimization**. **Water saving** through incentives that promote **optimal** water **use** and reutilization
- **Territorial and strategic planning**: Introduce sustainability criteria in urban planning. Promotion of **compact cities**
- Promotion of **housing energetic efficiency** and the use of **renewable energies**
- Identification of **sensitive population** to extreme climatic events and development of **emergency plans**

ACCUA summary sheet: a tool supporting adaptive management

FLUVIÀ
Boscos
escenari climàtic
A2 smc
sense escenari
socioeconòmic

Cobertes arbòries de la conca

El **77.3%** de la conca del **Fluvià** està ocupat per **boscos** (MCSC 2005)



1 Pressions

Temperatura mitjana

Precipitació anual

Variació espacial de la precipitació

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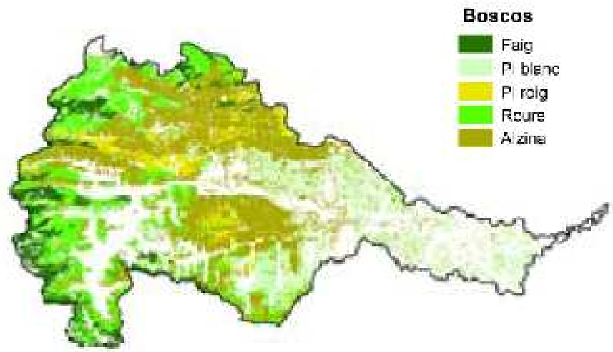
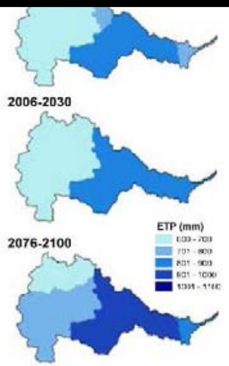
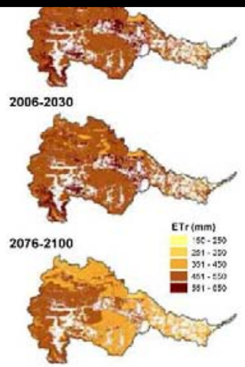






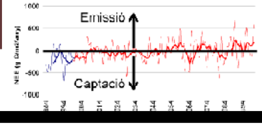
L'augment de la temperatura provoca un increment en la demanda evaporativa de les plantes.

La disminució de la precipitació té un efecte directe sobre la quantitat d'aigua disponible al sòl.

L'evapotranspiració real, definida com la quantitat d'aigua que realment s'evapora en condicions normals i que depèn de l'aigua disponible al sòl i de la coberta vegetal, disminueix a mesura que hi ha menys aigua al sòl.

3 Vulnerabilitats

Intercanvi de carboni als boscos. **Comportament previst: Període 2006-2030:** Els boscos seguiran actuant com a **captadors** de carboni. **Període 2076-2100:** Alguns boscos podrien actuar com a **emissors de carboni**, especialment



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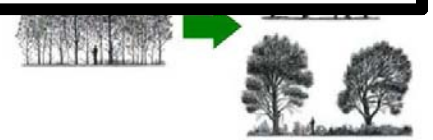
1. Espècies **més vulnerables** que s'haurien de **gestionar prioritàriament** per garantir la seva viabilitat:
   - Castanyer i faig als trams mitjos i baixos
   - Roure i castanyer als trams baixos
2. **Reduir densitats** i potenciar estructures amb **arbres grans** a través de la gestió
3. Desprès d'una pertorbació, identificar espècies sensibles i **potenciar** aquelles **espècies més resistents a les noves condicions.**
4. Recuperació i manteniment del **mosaic agroforestal**



5 Incerteses

Aquestes anàlisis no tenen en compte l'efecte de situacions extremes i les seves sinèrgies: episodis de sequeres, ventades, nevades, ... Els resultats reflecteixen els efectes de canvis graduals més que no pas esdeveniments extrems.

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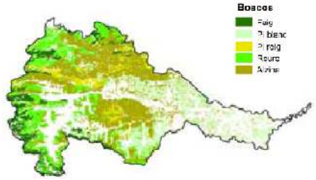

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Risc d'incendi

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1 Pressions

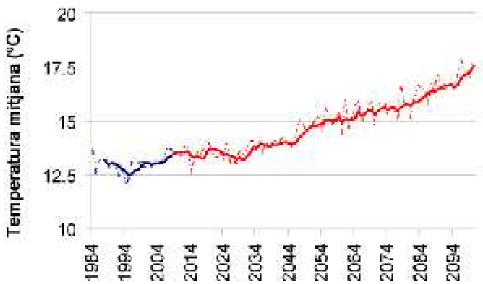
1 Pressions

Temperatura mitjana

Increments previstos:

Període 2006-2030: **0.5°C**

Període 2076-2100: **3.5°C**

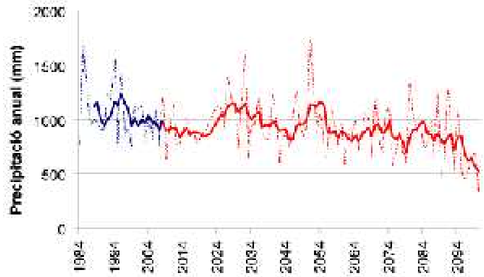


Precipitació anual

Reduccions previstes:

Període 2006-2030: **-9.6%**

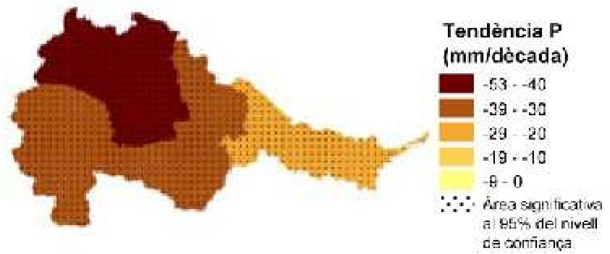
Període 2076-2100: **-28.1%**

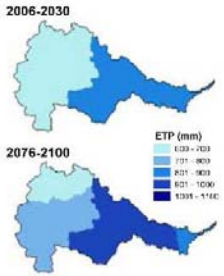


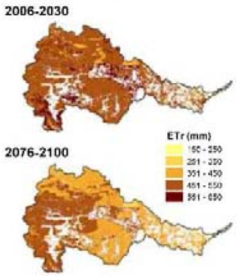
Variació espacial de la precipitació

Previsions per al s. XXI (mm/dècada):

Les reduccions de precipitació més severes i significatives s'esperen a la **capçalera**







un increment en la demanda evaporativa de les plantes.

La disminució de la precipitació té un efecte directe sobre la quantitat d'aigua disponible al sòl.

L'evapotranspiració real, definida com la quantitat d'aigua que realment s'evapora en condicions normals i que depèn de l'aigua disponible al sòl i de la coberta vegetal, disminueix a mesura que hi ha menys aigua al sòl.

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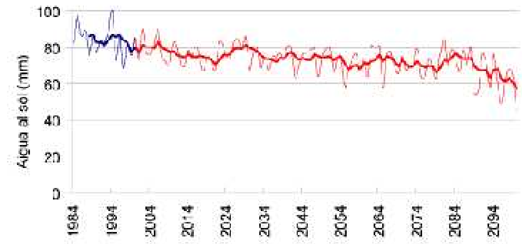
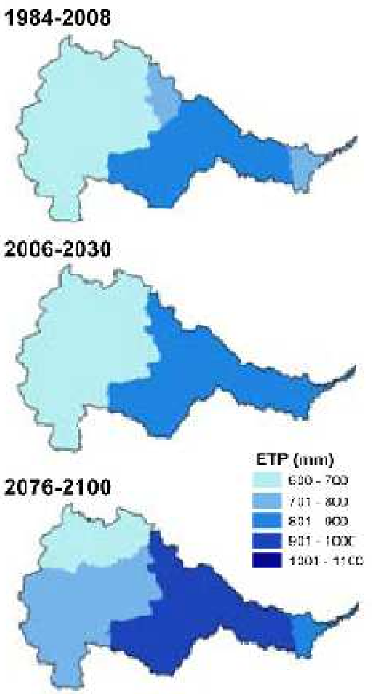
2 Impactes

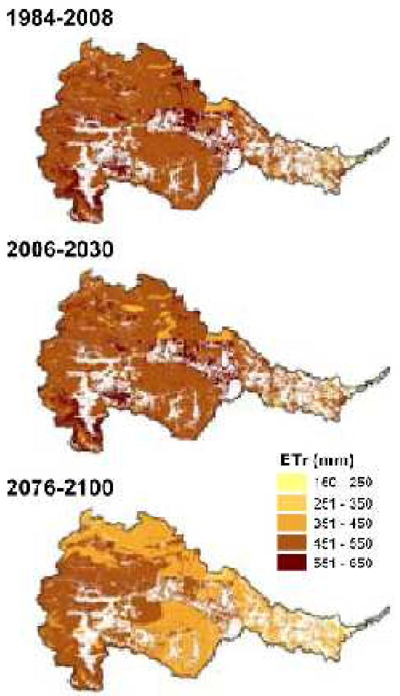
Demanda evaporativa mitjana (ETP)
Període 1984-2008: **734.4 mm**
Increments previstos:
Període 2006-2030: **2.5%**
Període 2076-2100: **16.8%**

Evapotranspiració real (ETr)
Període 1984-2008: **527.5 mm**
Reduccions previstes:
Període 2006-2030: **-1.7%**
Període 2076-2100: **-12.6%**

Quantitat d'aigua al sòl
Reduccions previstes:
Període 2006-2030: **-7.1%**
Període 2076-2100: **-17.9%**







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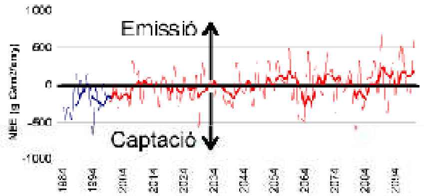

Producció de fusta

Comportament previst: Elevada variabilitat futura, altament dependent de la precipitació, però amb **tendència al decreixement.**

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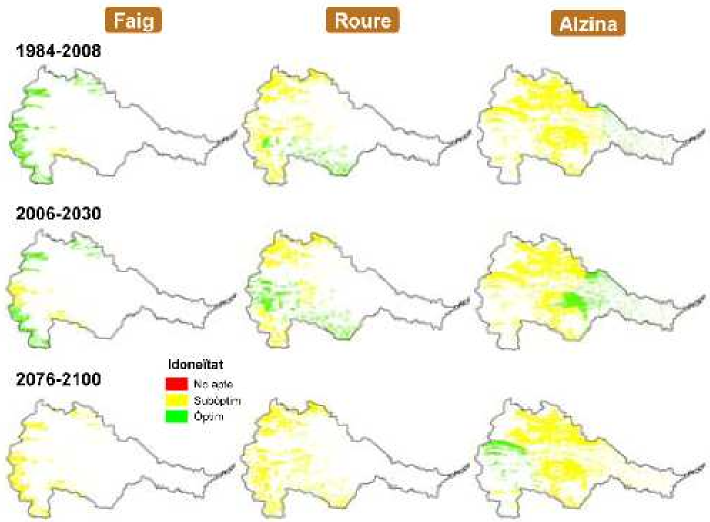

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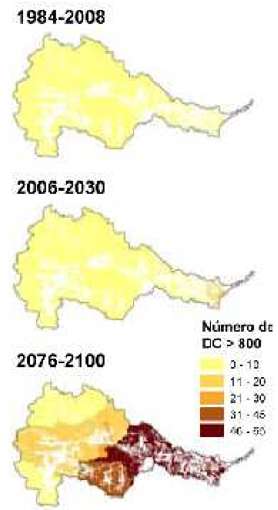

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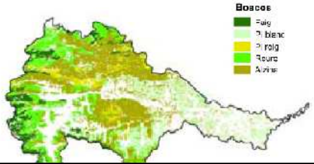

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Risc d'incendi Període 1984-2008: uniforme Comportament previst: **Període 2006-2030:** Es duplica el nombre de

4 Adaptacions

Gestió forestal orientada cap a estructures més sanes, més resistents al foc i amb menys estrès hídric

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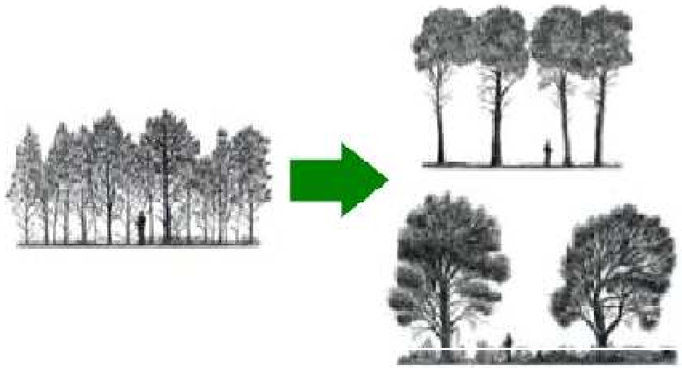

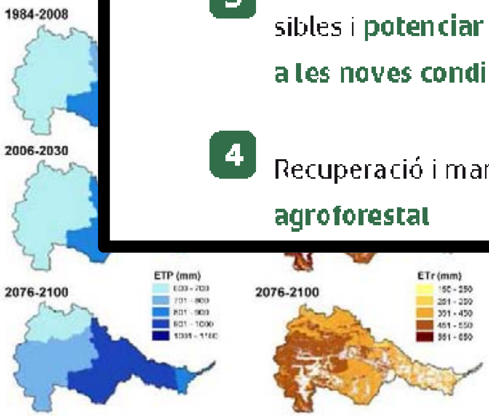

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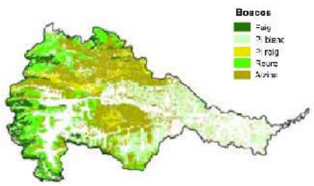
4 Recuperació i manteniment del mosaic agroforestal

Aquestes anàlisis no tenen en compte l'efecte de situacions extremes i les seves sinèrgies: episodis de sequeres, ventades, nevades, ... Els resultats reflecteixen els efectes de canvis graduals més que no pas esdeveniments extrems.

FLUVIÀ
Boscos
escenari climàtic
A2 smc
sense escenari
socioeconòmic

Cobertes arbòries de la conca

El 77.3% de la conca del Fluvià està ocupat per boscos (MCSC 2005)

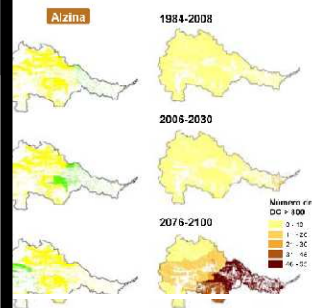


3 Vulnerabilitats

Intercanvi de carboni als boscos. Comportament previst: **Període 2006-2030:** Els boscos seguiran actuant com a captadors de carboni. **Període 2076-2100:** Alguns boscos podrien actuar com a emissors de carboni, especialment …

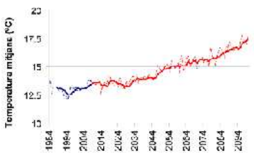
Idoneïtat climàtica de les espècies
Comportament previst: **Període 2006-2030:** Els caducifolis (faig, roure, ...) es mantenen en zones òptimes i s'estenen cap a zones més elevades. Les esclerofil·les i perennifòlies (sureda, alzina,...) estenen el seu òptim cap a zones més elevades. **Període 2076-2100:** Les zones òptimes dels caducifolis tendeixen cap … -les i … cap a …

Risc d'incendi
Període 1984-2008: uniforme. Comportament previst: **Període 2006-2030:** Es duplica el nombre de dies amb risc extrem a la part baixa del Fluvià. **Període 2076-2100:** Fins a 64 dies anuals amb risc extrem a la part final del Fluvià.

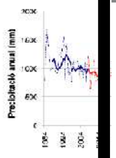


1 Pressions

Temperatura mitjana
Increments previstos:
Període 2006-2030: 0.5ºC
Període 2076-2100: 3.5ºC



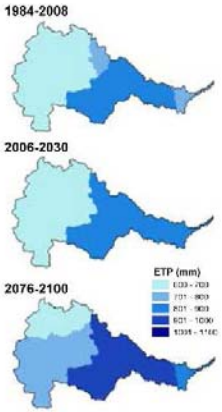
Precipitaci…
Reduccions …
Període 200…
Període 207…

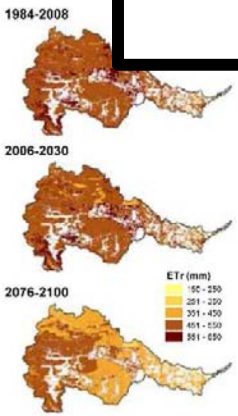


2 Impactes

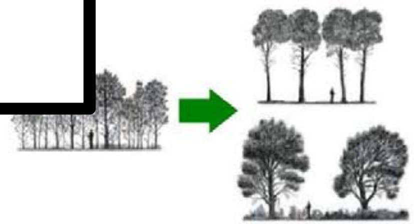
Demanda evaporativa mitjana (ETP)
Període 1984-2008: 734.4 mm
Increments previstos:
Període 2006-2030: 2.5%
Període 2076-2100: 16.8%

Evapotran… real (ETr)
Període 198…
Reduccions …
Període 200…
Període 207…





L'augment de la temperatura provoca un increment en la demanda evaporativa de les plantes.
La disminució de la precipitació té un efecte directe sobre la quantitat d'aigua disponible al sòl.
L'evapotranspiració real, definida com la quantitat d'aigua que realment s'evapora en condicions normals i que depèn de l'aigua disponible al sòl i de la coberta vegetal, disminueix a mesura que hi ha menys aigua al sòl.



1. Espècies **més vulnerables** que s'haurien de **gestionar prioritàriament** per garantir la seva viabilitat:
   - Castanyer i faig als trams mitjos i baixos
   - Roure i castanyer als trams baixos
2. **Reduir densitats** i potenciar estructures amb **arbres grans** a través de la gestió
3. Després d'una pertorbació, identificar espècies sensibles i **potenciar** aquelles **espècies més resistents a les noves condicions.**
4. Recuperació i manteniment del **mosaic agroforestal**

5 Incerteses

Aquestes anàlisis no tenen en compte l'efecte de situacions extremes i les seves sinèrgies: episodis de sequeres, ventades, nevades, ... Els resultats reflecteixen els efectes de canvis graduals més que no pas esdeveniments extrems.

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