Climate Change and Drought Impact on Mediterranean Agricultural Systems

by

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Drought, Aridity and Water shortage
(WMO definitions)

- Drought:
  - a natural temporary imbalance of water availability, consisting of persistent lower-than-average precipitation of uncertain frequency, duration and severity, of unpredictable occurrence with overall diminished water resources and carrying capacity of the ecosystem
- Aridity:
  - a natural permanent imbalance in the availability of water - the average annual precipitation is low
- Water shortage:
  - a human-induced temporary water imbalance and results in groundwater overdraft, reduced reservoir capacities, disturbed and reduced land use, and an altered carrying capacity.

Drought - **<u>decrease of water availability</u> in a particular period and over a particular area (Beran and Rodier, 1985)**

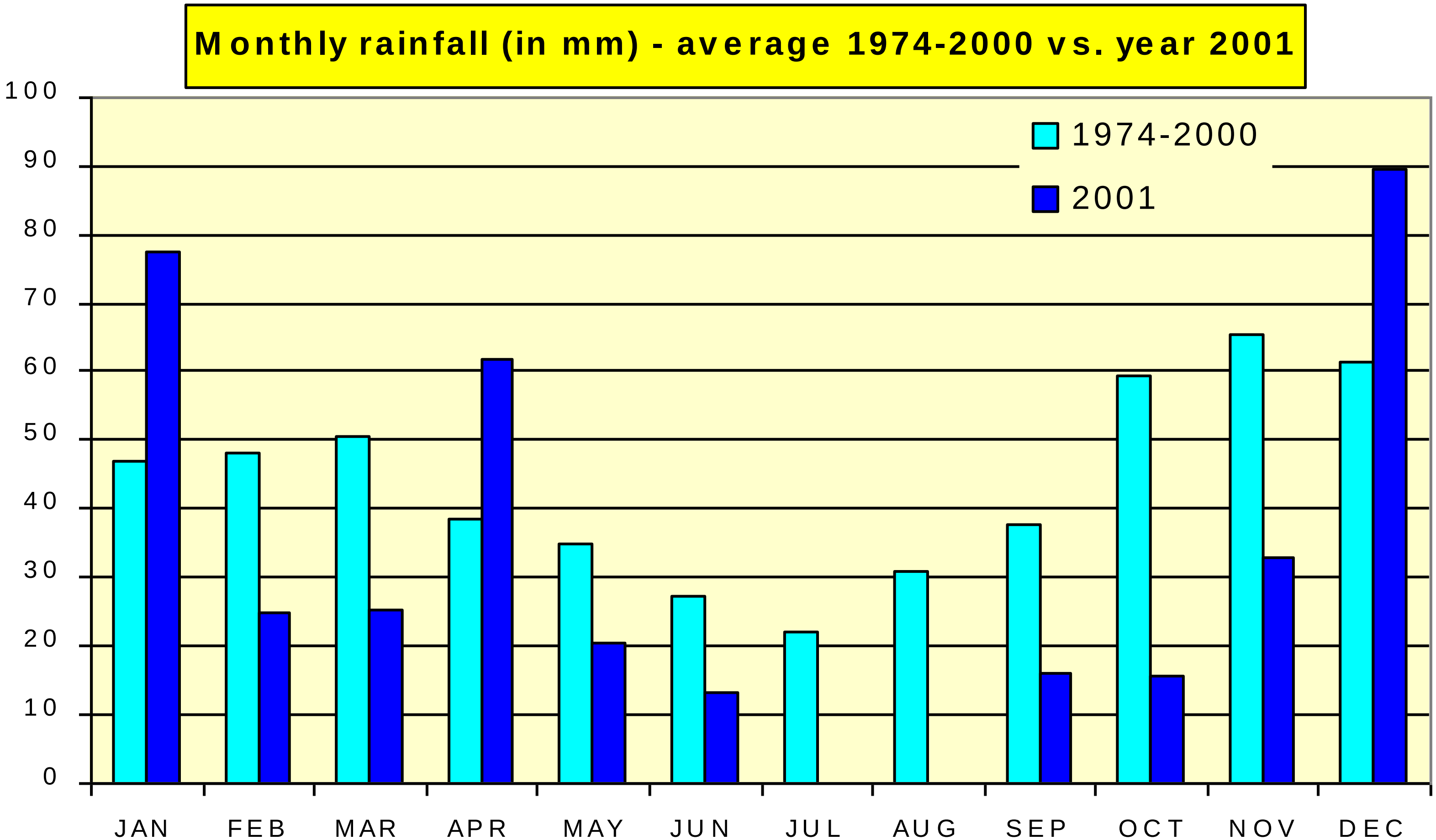
- Meteorological drought:
  - precipitation lower than average values for some time period
  - combination of precipitation and air temperature can be also used
- Agricultural drought:
  - plant (soil) available water (from P only) falls below that required during a critical growth stage
  - leads to a decrease of yield
- Hydrologic drought:
  - combination of factors such as runoff, stream flow, reservoir storage and groundwater below an average level
- Socio-economic drought:
  - loss of return (profit - economic good) from an average or expected return

Drought events in the Euro-Mediterranean area

- 1924-1926: severest and longest drought in the Mediterranean basin of Iberia
- 1933-1934: Severe drought in Eastern Mediterranean basin and worst drought in French basins
- 1945-1946: Driest and longest drought in Central Mediterranean basin and severe drought in the Mediterranean basins of Iberia
- 1973-1975: Worst drought in Eastern Mediterranean basin
- 1989-1990: Dry period in Eastern Mediterranean basin
- 1991-1995: Worst drought in western Iberian basins
- In the first decade of 21st Century, the frequency of drought events has increased 3 times in respect to the previous 20 years

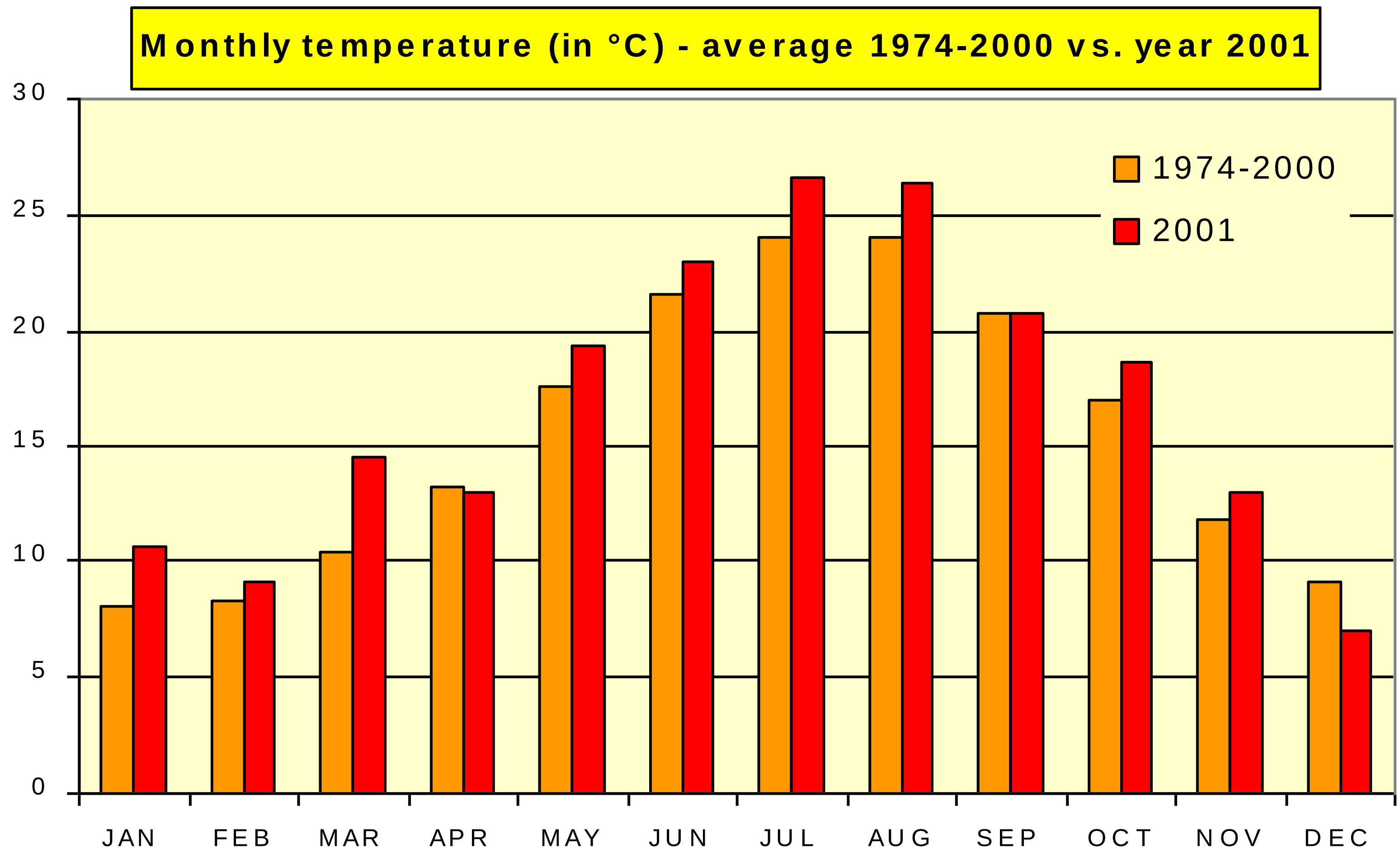
Source: various

Area of Bari - Southern Italy: an example of meteorological drought in 2001



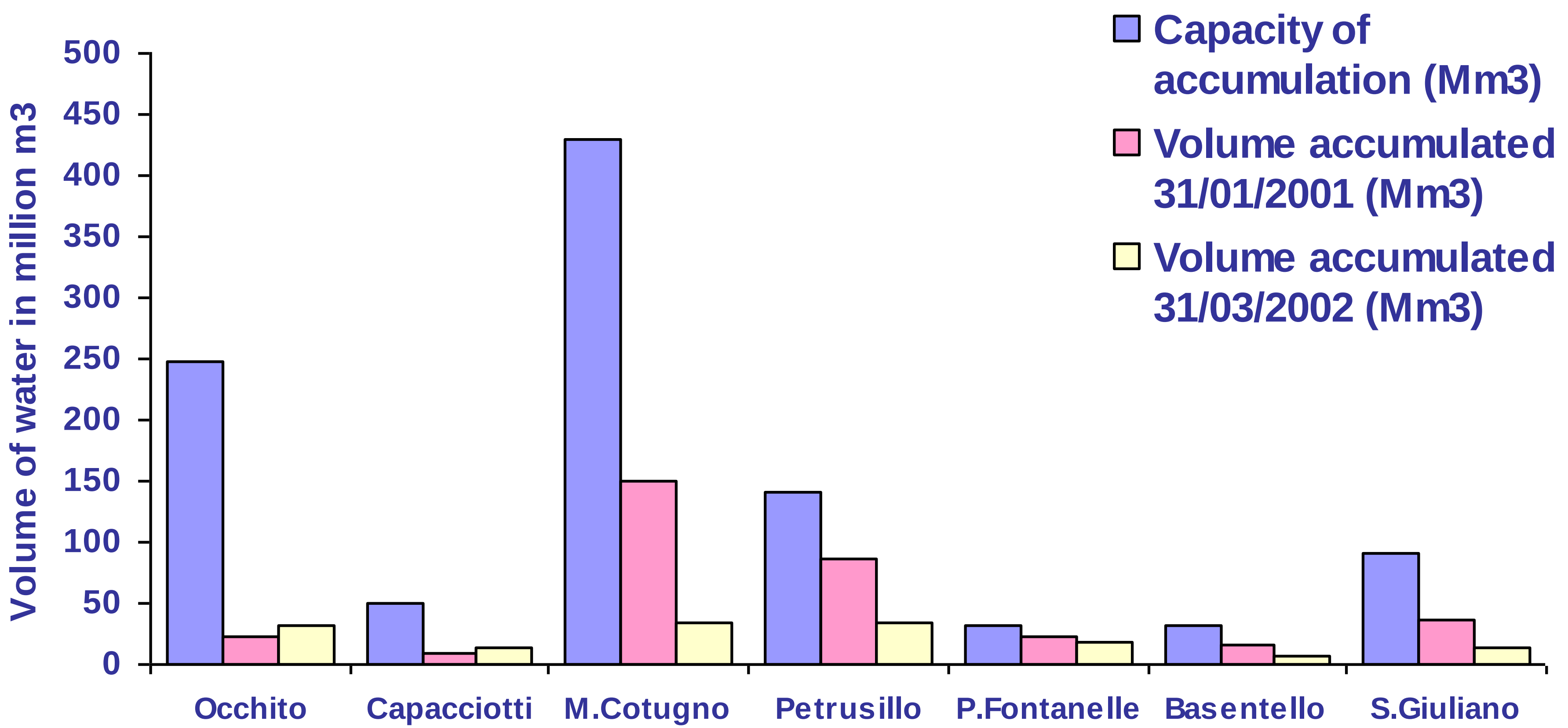
Source: CIHEAM-IAMB Agro-meteorological bulletin 29-30 (2001)

Area of Bari - Southern Italy: one more example of meteorological drought (combined with precipitation) in 2001



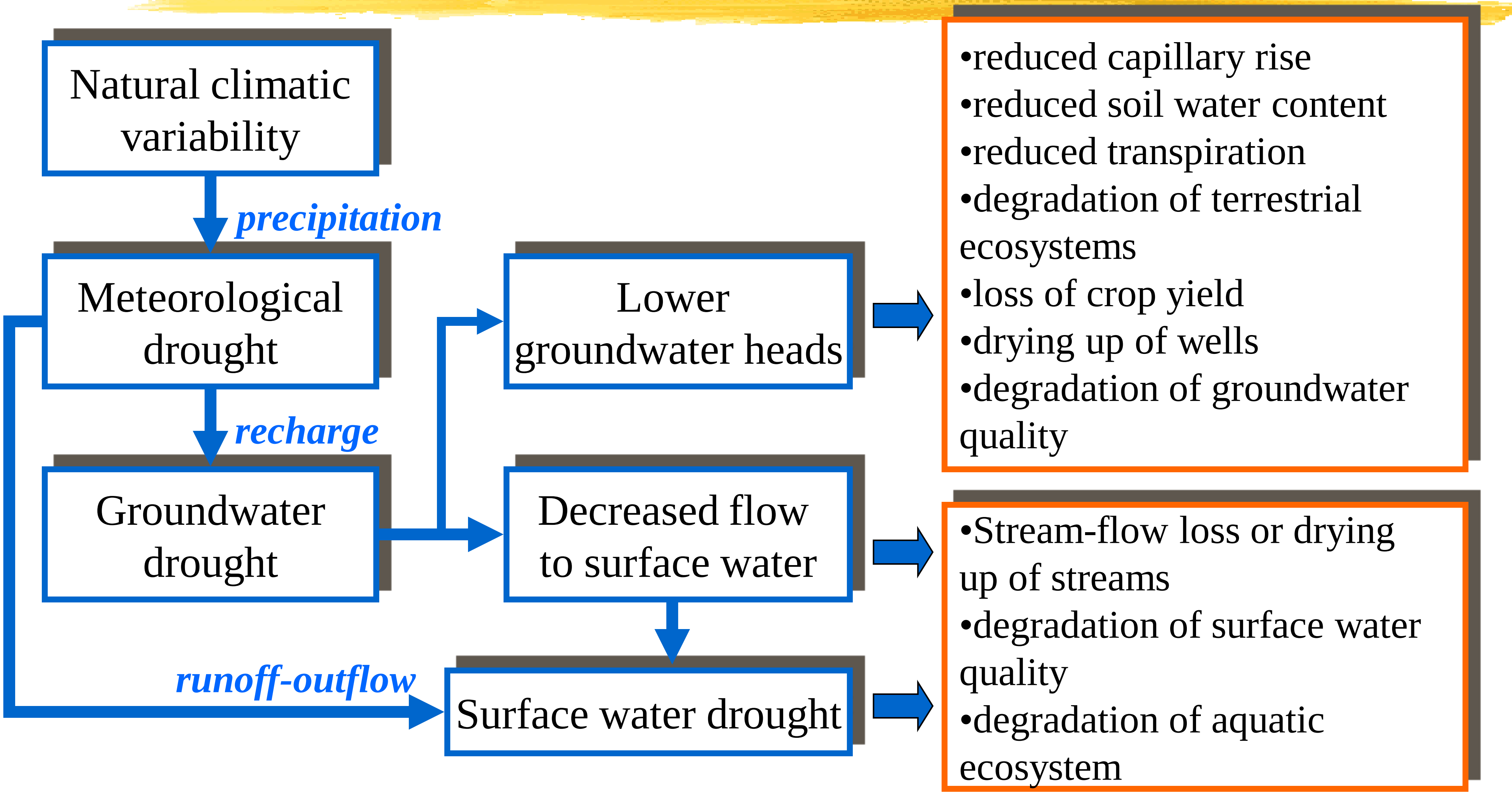
Source: CIHEAM-IAMB Agro-meteorological bulletin 29-30 (2001)

Apulia Region - Southern Italy: an example of hydrological drought (surface water) in 2001 and 2002



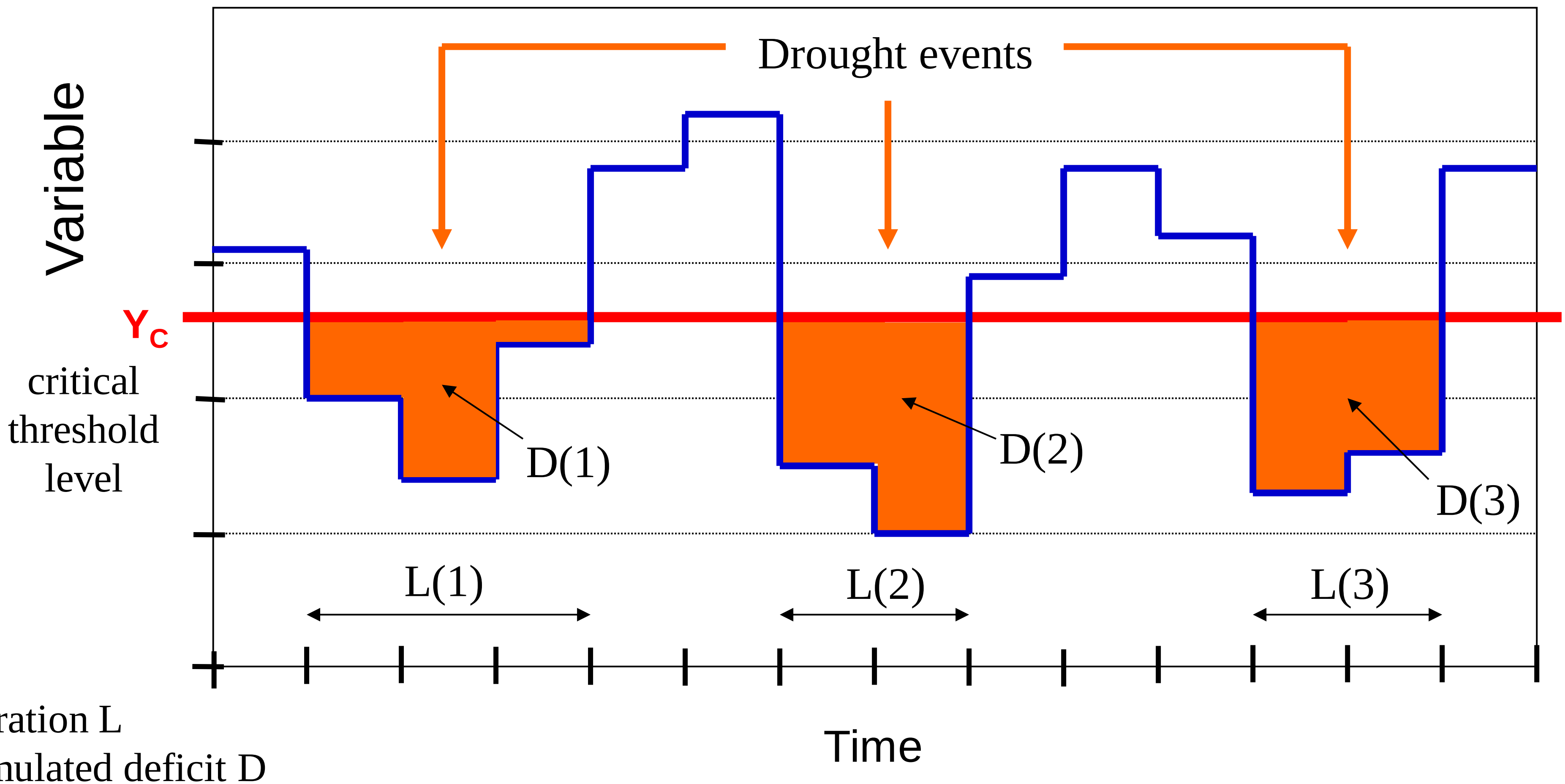
Source: Corriere della sera, April 2002

Schematic outline of drought and its consequences



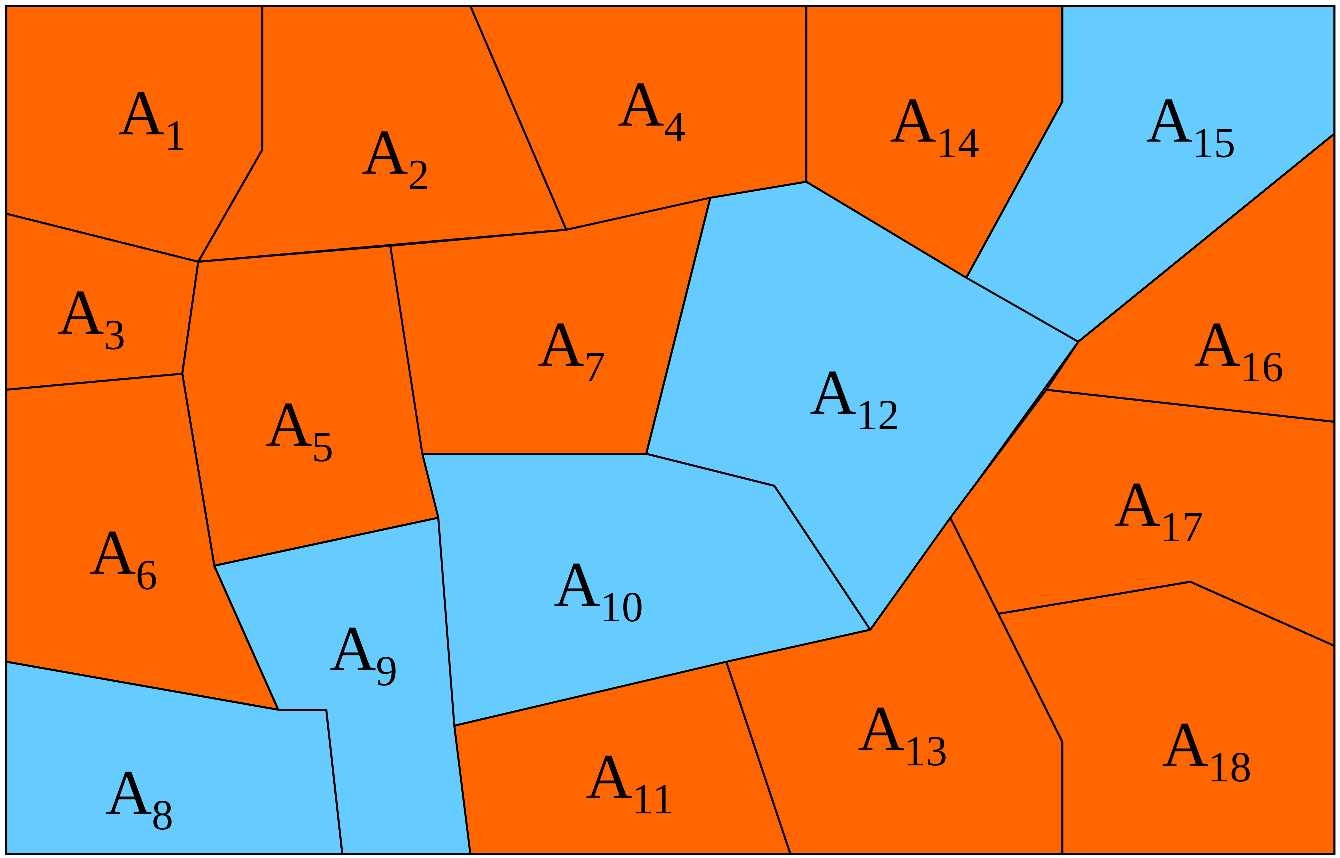
Source: adapted after ARIDE (Demuth and Stahl, 2001)

Site Drought Identification - the Theory of runs



Duration L
cumulated deficit D
Intensity = D/L

Regional Drought Identification



$\Sigma A_j \geq A_C$

Regional drought - when the sum of the areas A_j affected by local drought reaches a selected threshold A_C (percentage of the total area under consideration)

Regional Drought Identification - the Theory of runs

- The duration:
  - is the length of the consecutive time intervals in which drought affects an area that equals or exceeds the areal critical threshold established
- The cumulated areal deficit
  - is the sum of the deficits at each site, weighted by the corresponding areas of influence
- The regional drought intensity
  - is the ratio between the cumulated areal deficit and the duration
- The mean regional coverage
  - is the mean fraction of the area in the region affected by drought

Drought Indices 1

- Percent of Normal:
  - simple calculation (P_{actual}/P_{normal}*100) well suited to general audience
- Palmer Drought Severity Index (PDSI)
  - takes into consideration P, ET_{pot}, antecedent soil moisture and runoff
  - is the soil moisture algorithm based on the supply and demand concept of the water balance equation
  - works on a monthly scale and is calibrated for relatively homogeneous regions (mainly in the United States, Australia and Europe)
  - produces single numerical values between -6 (extremely dry) and +6 (extremely wet)
- Crop Moisture Index (CMI)
  - is a PDSI derivative for identifying potential agricultural drought
  - monitor short-term moisture conditions and it is based on the mean temperature and total precipitation for each week

Drought Indices 2

- Standardized Precipitation Index (SPI)
  - less complex than PDSI
  - based on the probability distribution of precipitation (gamma distribution function) for any time scale
  - requires long-time precipitation series
  - varies between -2 (extremely dry) and +2 (extremely wet)
- Surface Water Supply Index (SWSI)
  - designed to complement PDSI in the cases when the region does not have homogeneous topography (e.g. Colorado)
  - ranges between -4.2 (extremely dry) and +4.2 (extremely wet)
- Reclamation Drought Index (RDI)
  - works at river basin level and incorporates T, P, snowpack, streamflow and reservoir levels
  - ranges between -4 (extremely dry) and +4 (extremely wet)

Drought vs. Climate change

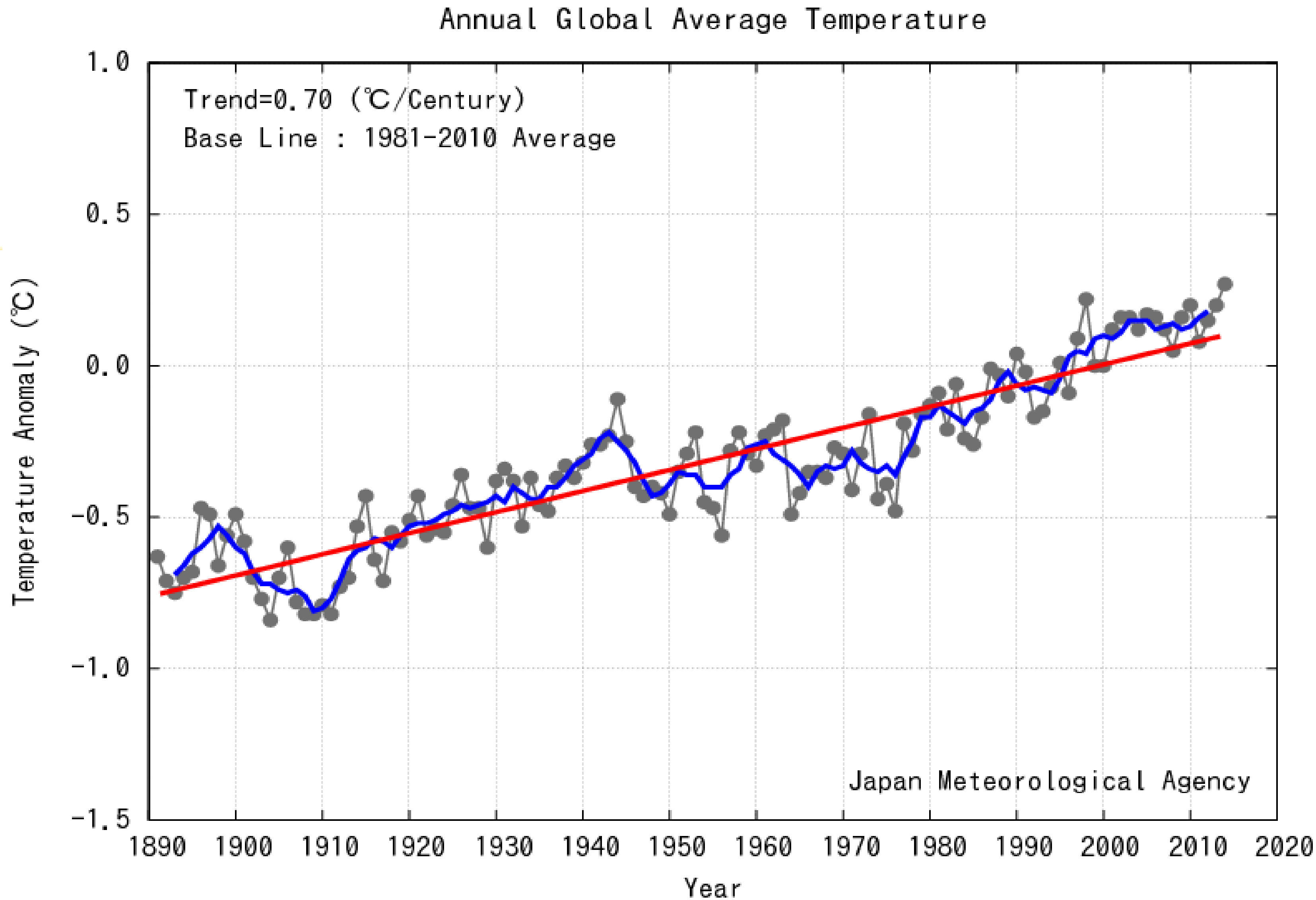
- Drought
  - is an exceptional natural event
  - “short-term” and regional-scale
  - drought may be a consequence of climate change - a decrease of precipitation in respect to an average value
  - affects both man-made and natural ecosystems
  - mitigation means water saving at local-scale with eventual involvement of larger society (water transfer)
- Climate change
  - is a natural and human-induced process
  - long-term and global-scale
  - climate change (lower frequency and higher intensity precipitation) may cause drought in some areas
  - affects both man-made and natural ecosystems
  - mitigation means consensus among different actors for integrated actions at global-scale

Climate change - a measurable long-term change in an atmospheric or oceanic physical or chemical variable attributable to natural or anthropogenic effects

- Global Climate change over the 20th Century
  - the Earth's surface temperature (land and oceans) has increased 0.6±0.2°C
  - the precipitation has increased by 0.5 to 1% per decade over the mid and high latitudes of the Northern Hemisphere and by 0.2 to 0.3% per decade over the tropical (10°N to 10°S) land areas
  - the rainfall has decreased by 0.3% per decade over the Northern sub-tropical hemisphere (10°N to 30°N)
  - for the Northern Hemisphere, the 1990's was the warmest decade and 1998 was the warmest year
  - for the Northern Hemisphere there is ~10% decrease in snow cover since the late 1960's

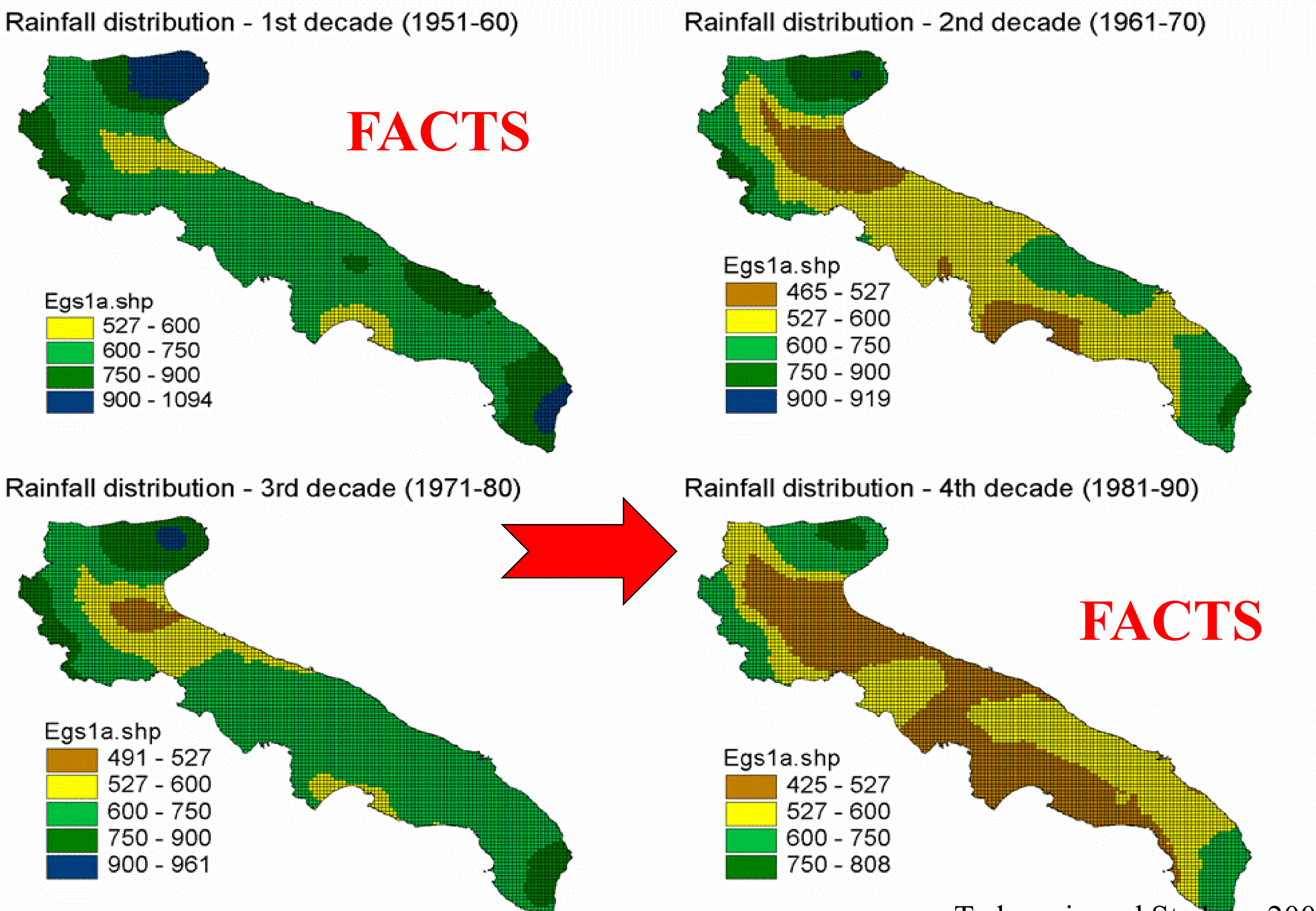
2014 Confirmed As Hottest Year On Record Globally

All 10 of the world's hottest recorded years have come since 1998, and
14 of 15 of the hottest years ever measured have all been in the 21st Century.



Anomalies are deviation from baseline (1981-2010 Average).
The black thin line indicates surface temperature anomaly of each year.
The blue line indicates their 5-year running mean.
The red line indicates the long-term linear trend.

Source: Japanese Meteorological Agency (JMA), 2015

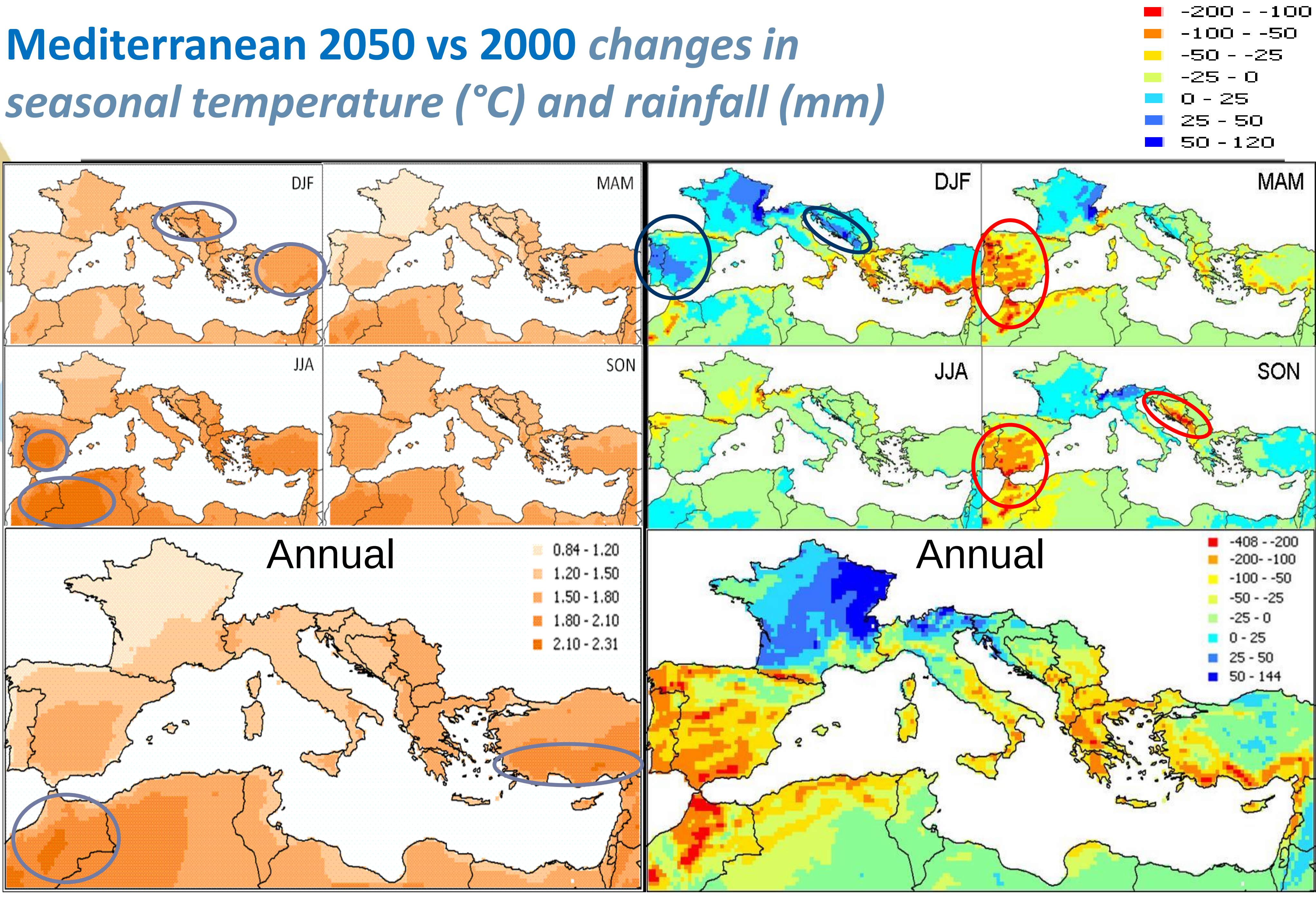


Todorovic and Steduto, 2002

Future Climate change

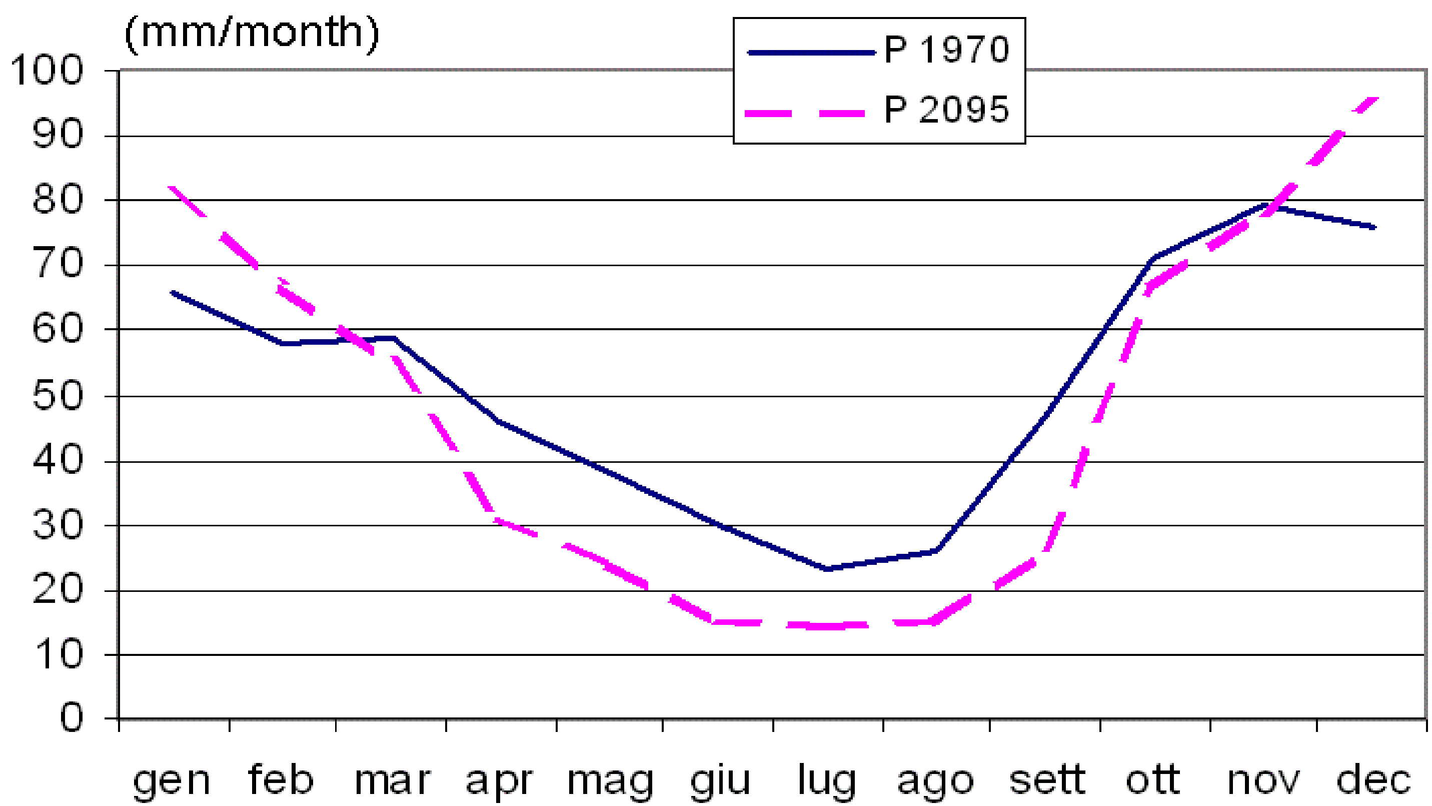
- Expected Climate change over the 21th Century
  - the Earth's surface temperature is projected to increase by 1.4 to 5.8°C (based on a number of climatic models)
  - the projected rate of warming is without precedent during at least the last 10,000 years
  - global average vapour concentration and precipitation are projected to increase
  - precipitation will have increased over Northern mid to high latitudes and Antarctica in winter.
  - At low latitudes there are both regional increases and decreases over land areas.
  - More intense precipitation events and larger year-to-year variations in precipitation are very likely over most areas (drought risk!!!)

Mediterranean 2050 vs 2000 *changes in seasonal temperature (°C) and rainfall (mm)*



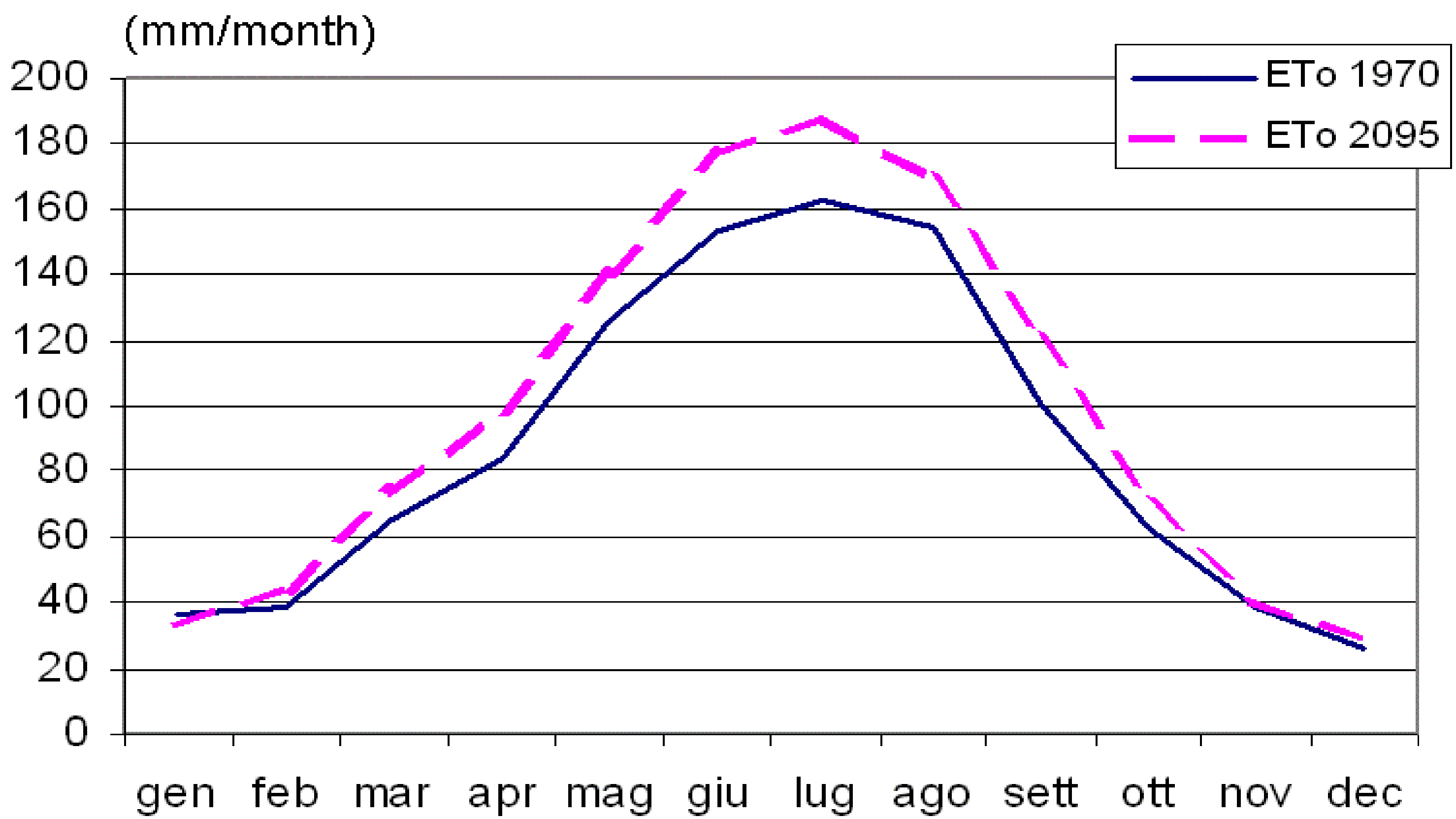
Source: WASSERMed project (EC-FP7-ENV), Saadi et al., 2015

Apulia Region (Southern Italy) - Average monthly precipitation measured in the period 1950-1990 and projected (HadCM3 - A2) for the period 2090-2100

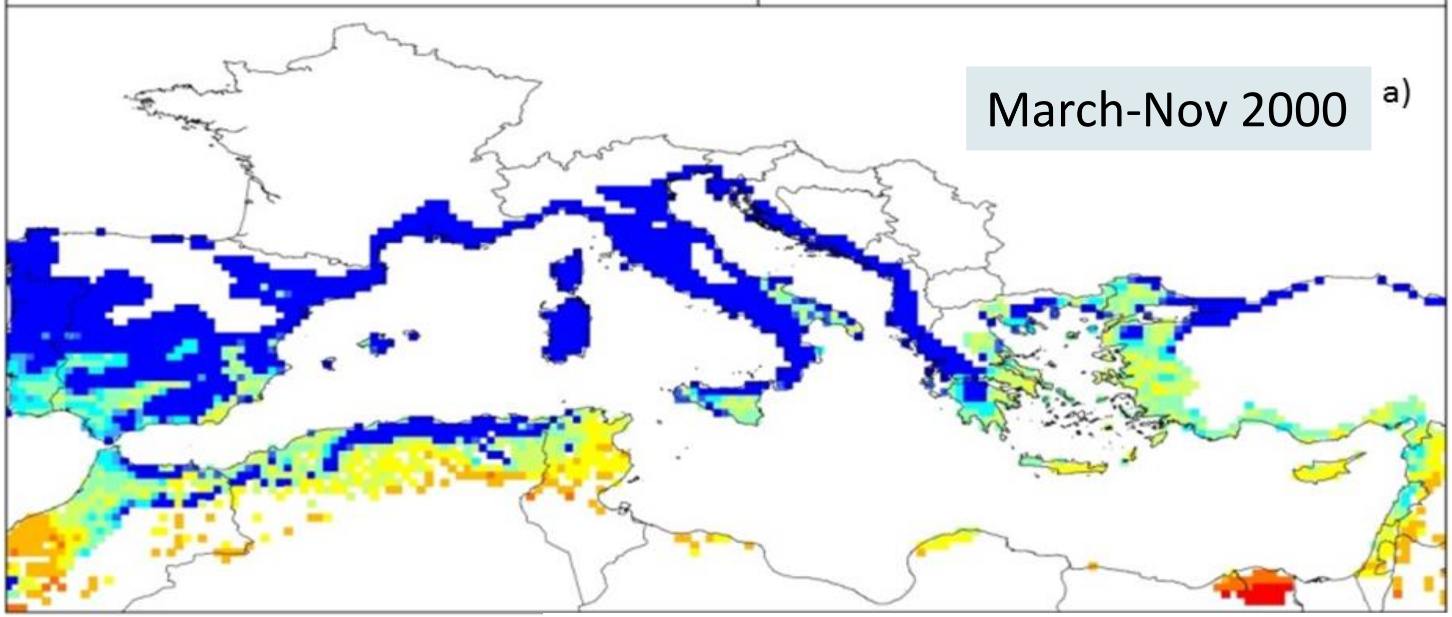


Todorovic, 2007

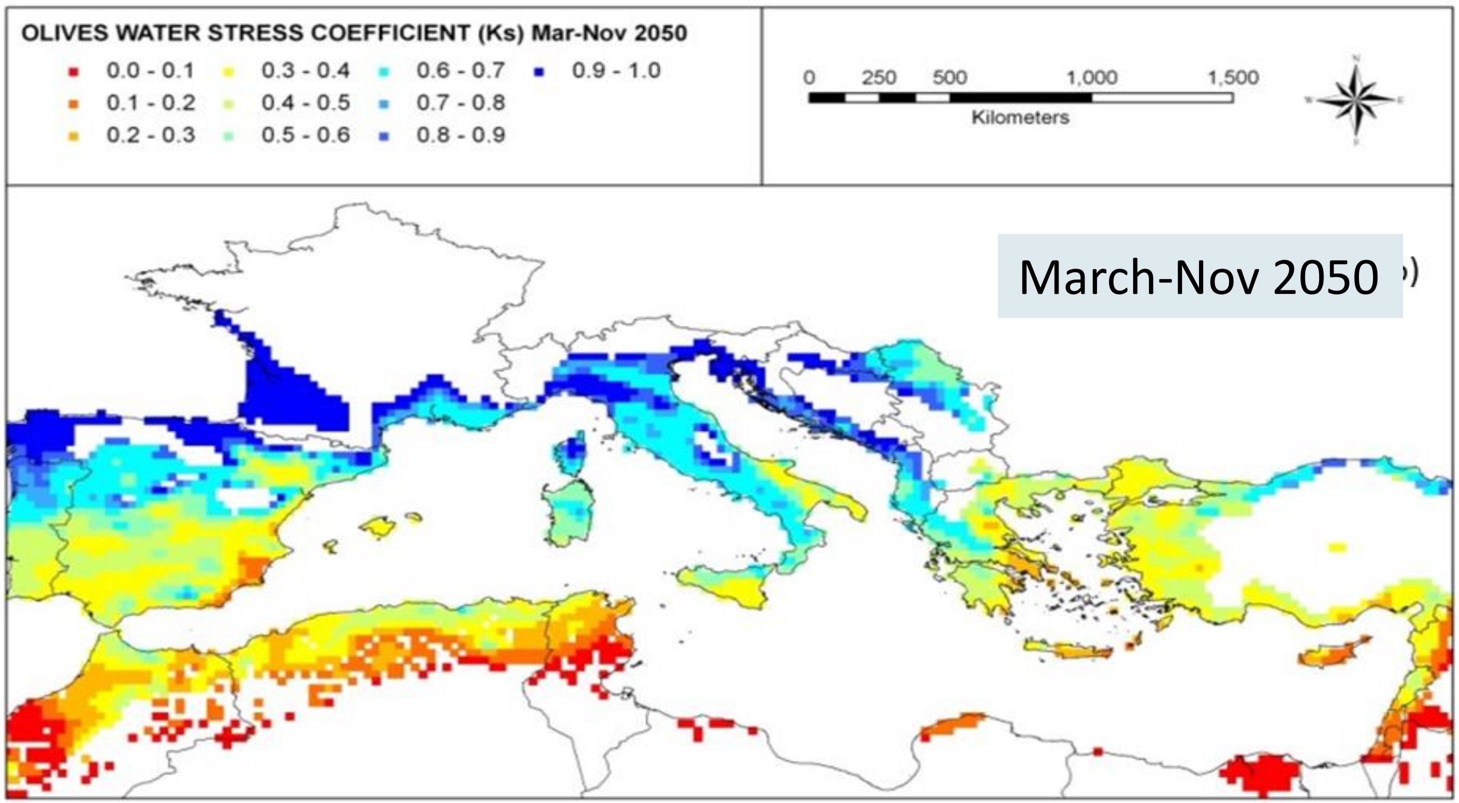
Apulia Region (Southern Italy) - Average monthly ETo measured in the period 1950-1990 and projected (HadCM3 - A2) for the period 2090-2100



Todorovic, 2007



Olive water stress coefficient under rainfed 2050 vs 2000

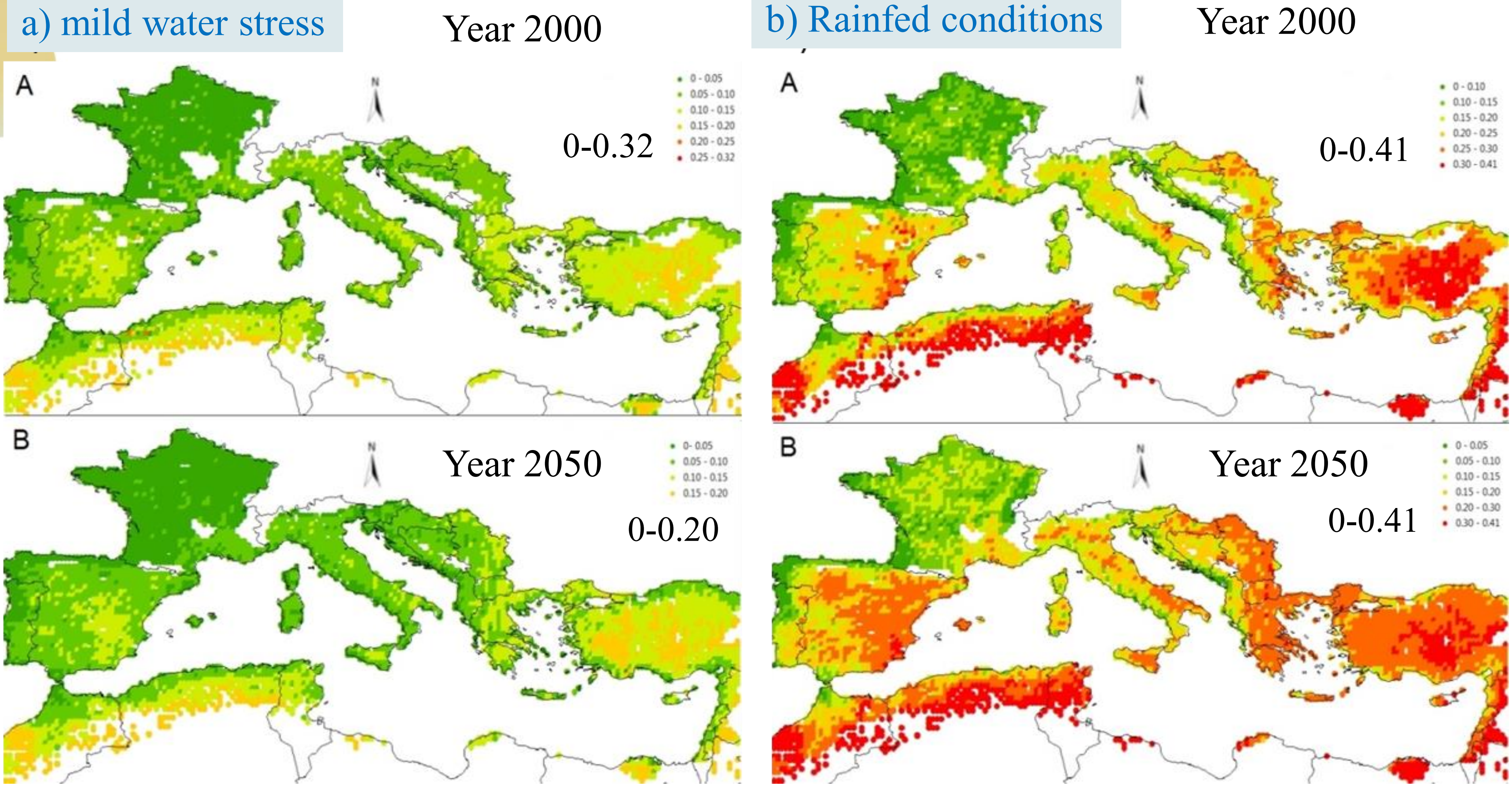


Source: Tanasijevic et al., 2014

Spatial pattern of **winter wheat** relative yield losses under a) mild deficit irrigation and b) rainfed conditions for year 2000 (A) and 2050 (B), the later including new potentially cultivable areas in the future

a) mild water stress

b) Rainfed conditions

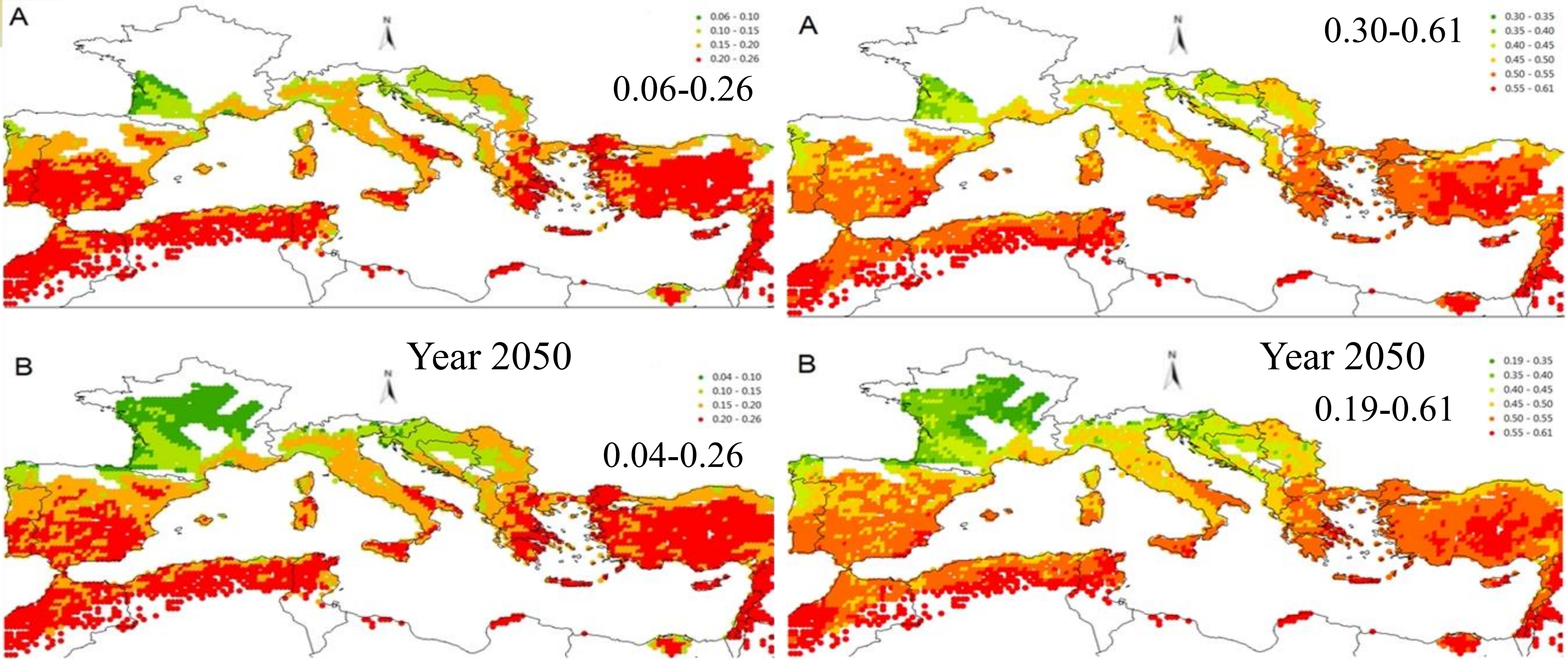


Source: Saadi et al., 2015

Spatial pattern of **tomato** relative yield losses under a) mild water stress and b) severe water stress for year 2000 (A) and 2050 (B), the later including new potentially cultivable areas in the future

a) mild water stress

b) severe water stress



Source: Saadi et al., 2015

Climate change impacts

- Hydrology and water resources
- Agricultural production and food security
- Terrestrial and fresh water ecosystem
- Coastal zones and marine ecosystem
- Human health
- Human settlements

Expected climate change impacts on crops

- Related to temperature
  - T limits crop options, warm and cool seasons, vernalization
  - temperature increase of several degrees above optimum range could reduce photosynthesis while shortening growing period and reducing yield
- Related to CO_2 (will likely double in the 21st Century)
  - photosynthesis "CO_2 fertilization effect" - increasing capacity of plants to absorb and temporally store excess carbon and increase crop productivity
  - Maximum CO_2 benefit requires an optimum environment and increased inputs of water and fertilizers to increase plant "sink capacity" for the products of photosynthesis
  - CO_2 increase causes partial closure of stomata which can decrease CWR
- Related to other factors (insects, pesticides, plant diseases, etc.)

Expected Climate change impacts on CWR

- Factors affecting ET-CWR
  - weather: radiation, air temperature, humidity and windspeed
  - crop:type, variety, development stage (height, roughness, reflection, ground cover…)
  - management and environmental conditions: soil salinity, land fertility, application of fertilizers, the presence of impenetrable soil horizons, control of diseases and pests, soil management...
  - Increase or decrease of CWR depends on the changes of various variables at regional and local scale
  - expected shifting of crop growing season and introduction of new varieties ……..

Expected climate change impacts on crops 1

- Related to temperature
  - T limits crop options - optimum temperature range for maximum yield (warm and cool season)
  - temperature increase of several degrees above optimum range could reduce photosynthesis while shortening growing period and reducing yield
  - some species require a cold period before they will produce flowers and a harvestible product (vernalization) - very narrow temperatures and duration boundaries
  - increased T has a direct effect on the mineralization of organic matter content in the soil with a negative impact on the structure, risk of erosion and decrease in fertility.

Expected climate change impacts on crops 2

- Related to CO_2 (will likely double in the 21st Century)
  - photosynthesis “CO_2 fertilization effect” - increasing capacity of plants to absorb and temporally store excess carbon and increase crop productivity
  - C3 plants (wheat, rice, potato, bean, most vegetable and fruit crops and many weed species) will benefit much more than C4 plants (maize, millet, sugarcane, sorghum, pasture grasses, etc.) because C3 photosynthetic pathway is less efficient than C4.
  - Maximum CO_2 benefit requires an optimum environment and increased inputs of water and fertilizers to increase plant “sink capacity” for the products of photosynthesis
  - CO_2 increase causes partial closure of stomata which can decrease CWR

Expected climate change impacts on crops 3

- Related to other factors
  - leaf-feeding insects often consume more foliage to survive on high CO_2-grown plants
  - natural selection would tend to favour the evolution of insect genotypes that consume more plant material more rapidly - the farmers may be required to use more pesticides
  - warmer temperatures in high latitudes areas may allow more insects to over winter
  - crop damage from plant diseases is likely to increase in temperate regions - fungal and bacterial diseases have a greater potential when temperatures are warmer and/or precipitation increases.