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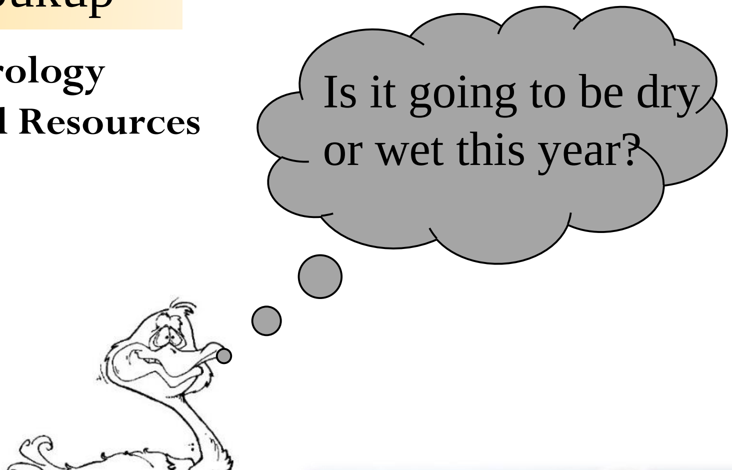
"It never failed that during the dry years the people forgot about the rich years, and during the wet years they lost all memory of the dry years.
It was always that way."

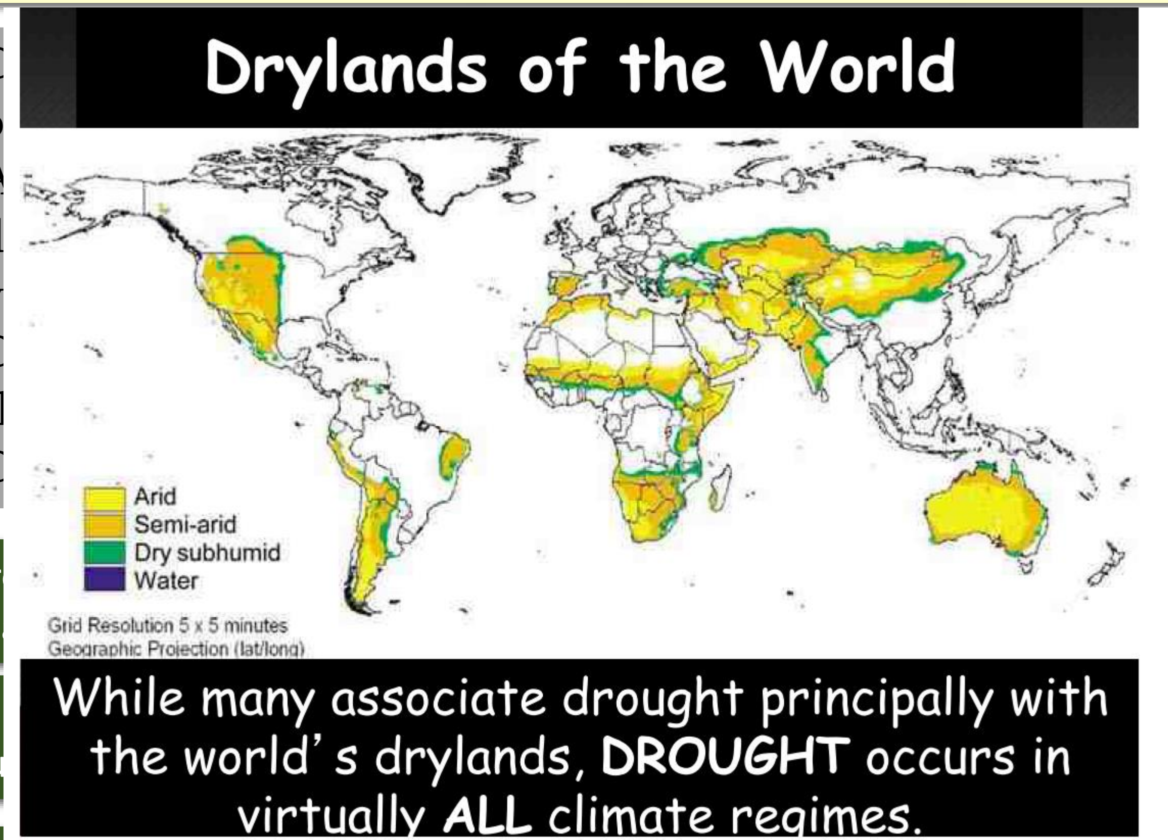
—John Steinbeck
East of Eden



What is drought?

- Drought should be understand as a natural part of a climate system under all climatic regimes since it occurs both in humid and arid areas and has a wide range of impacts and consequences.

- D ... impacts o ... ety.
- A ... nt due to d ... s during v...
- D ... e around th...
- D...



1. Dr ... vly over a subst...

2. Th ... s to the confu ... everity.

3. Impacts are poorly understood and not well documented.

4. Drought predictability is low in most cases.

5. Drought doesn't get the respect of other natural hazards.

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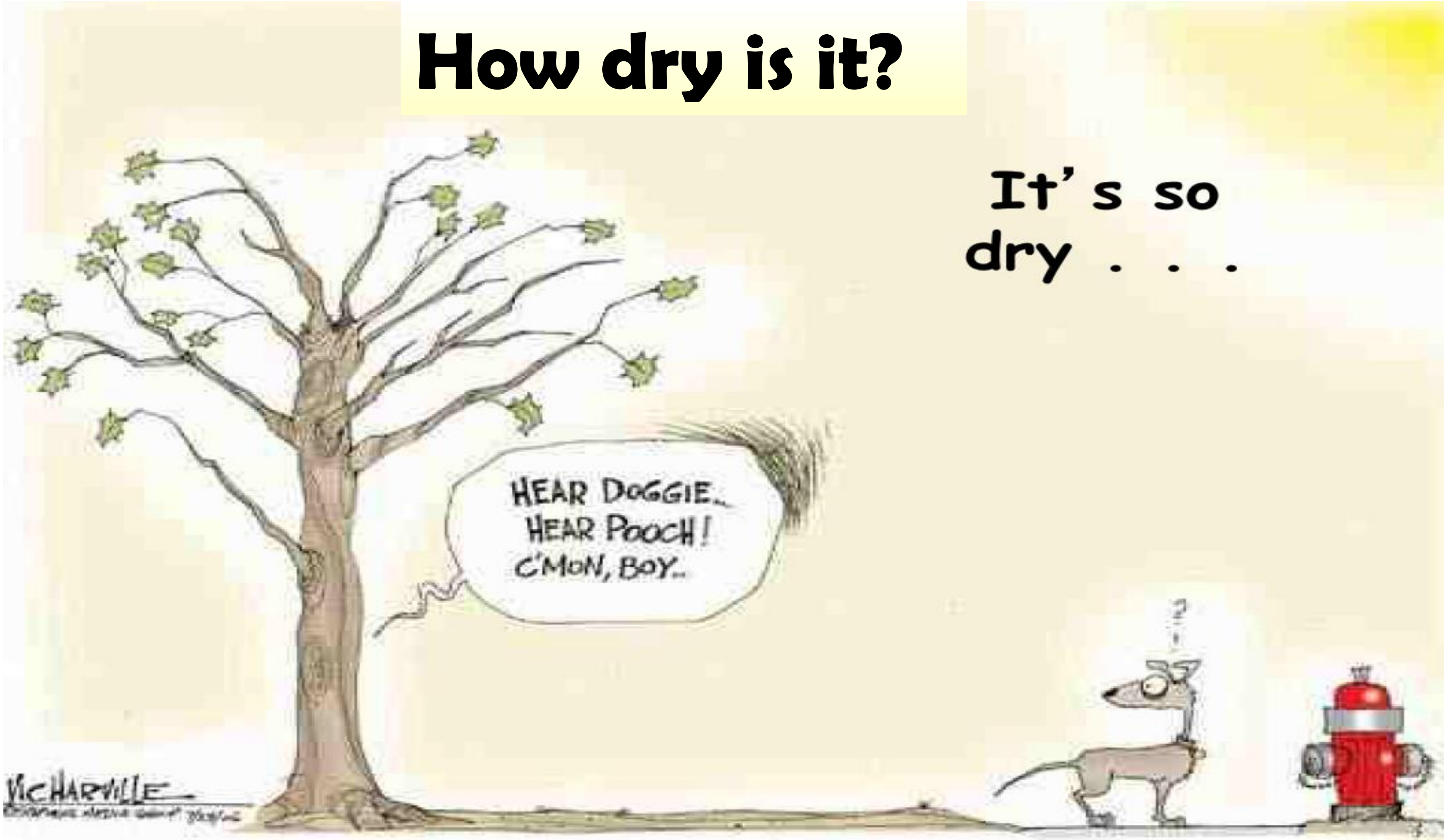
Defining Drought

Hundreds of definitions

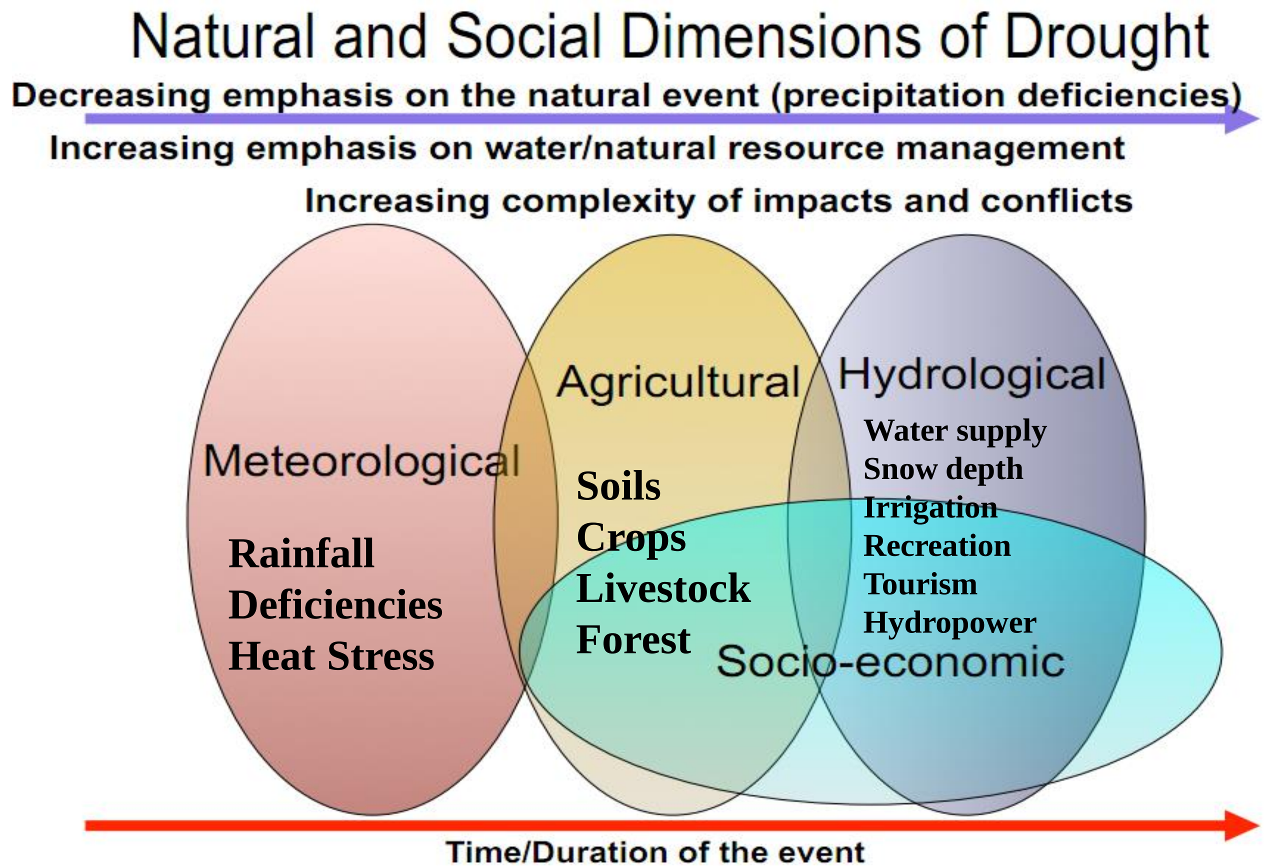
– Characteristics vary between regions;

How dry is it?



Types of drought

- It is largely accepted the drought classification into 4 types:



- It is difficult to precisely define drought because
  - meteorological drought results from precipitation deficits,
  - agricultural drought is identified based on total soil moisture deficits,
  - hydrological drought is related to a shortage of streamflow.
  - socio-economic: *result of the 3 above drought* ⇒ occurs when human activities are affected by reduced precipitation and related water availability.

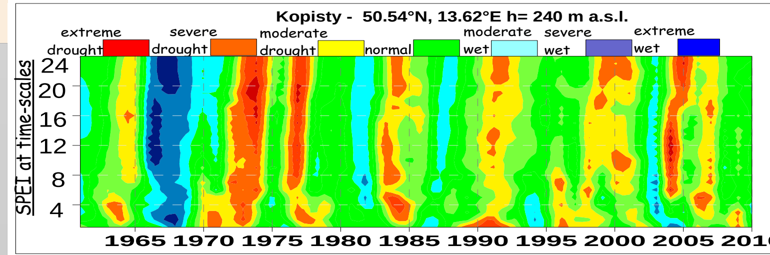
Source: Wilhite, 2011

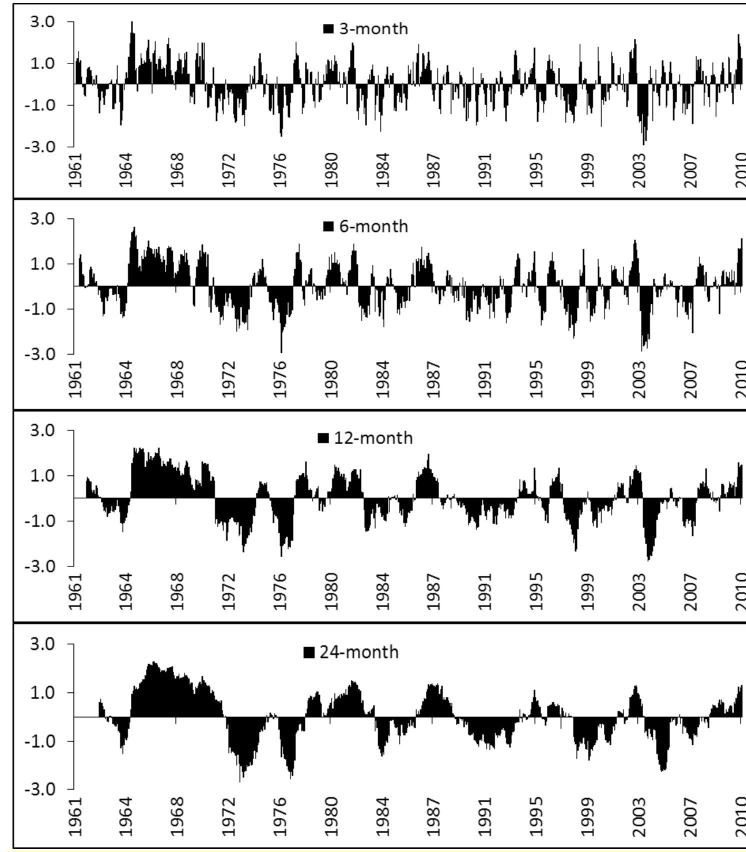
- In recent years the concept of drought **time-scale** has been widely used in drought studies (☞ Vicente-Serrano 2010, Potop *et al.* 2011, 2012, 2013).

Time scales – as new concept

the time lag that typically exists between the starting of a water shortage and the identification of its consequences.

- A single month of deficient rainfall can adversely affect rainfed crops while having virtually no impact on a large reservoir system.
- Drought impact involves the multi-scalar nature of drought because the responses of hydrological and/or agricultural systems to accumulating precipitation deficits have different response times.
- This explains why severe drought conditions can be recorded in one system, while another system in the same region displays normal conditions.
- For this reason, a drought index must be associated with specific time scales to be useful for monitoring drought.



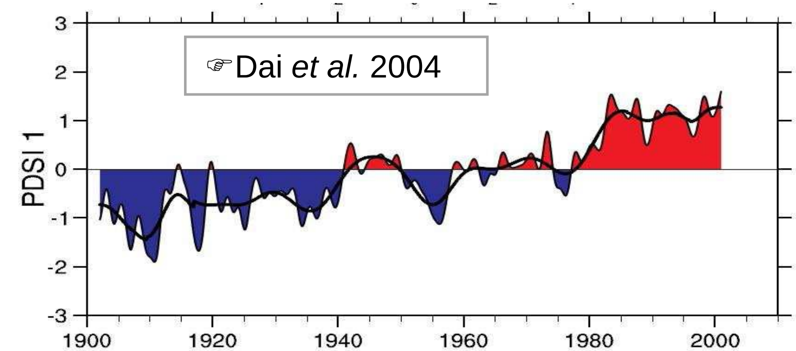


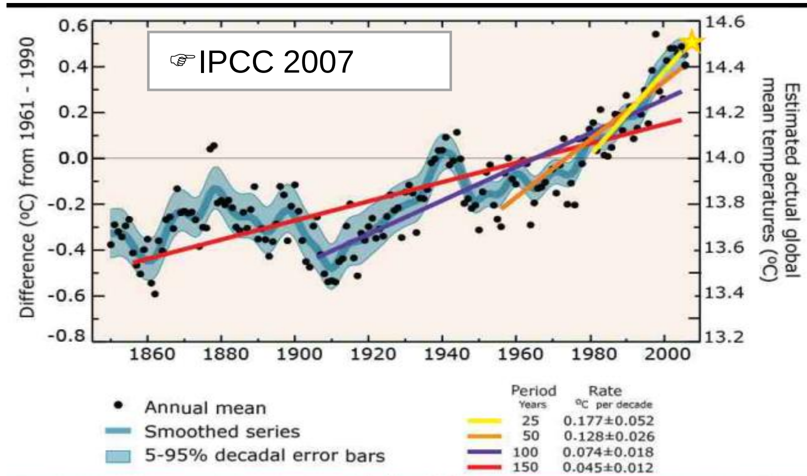
The evolution of moisture characteristics as quantified by the SPEI indicating the development of drought from 1 to 24 mo.

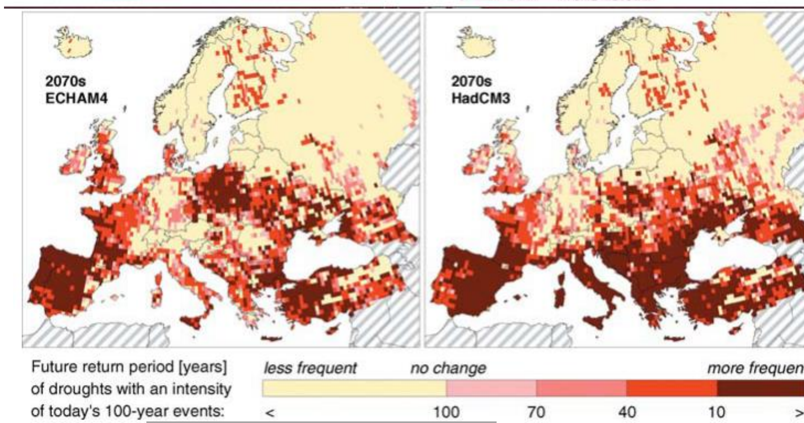
☞ Potop *et al.* 2012

Are droughts increasing in frequency, intensity and duration?

- The average global temperature has increased by +0.74°C over the past hundred years (1906 -2005).
- The average global precipitation shows a slight increase over the last century
  - increased significantly in eastern parts of North and South America, northern Europe and Asia
  - declined in the Sahel, the Mediterranean, southern Africa and Asia.
- Globally, the area affected by drought has likely increased since the 1970s.
- A large part of the recent drying is related to the shift toward more intense and frequent warm events of ENSO since the late 1970s.
- In the long-term projection for the 2070s, 100-year droughts show strong increases for large areas of southern and southeastern Europe.



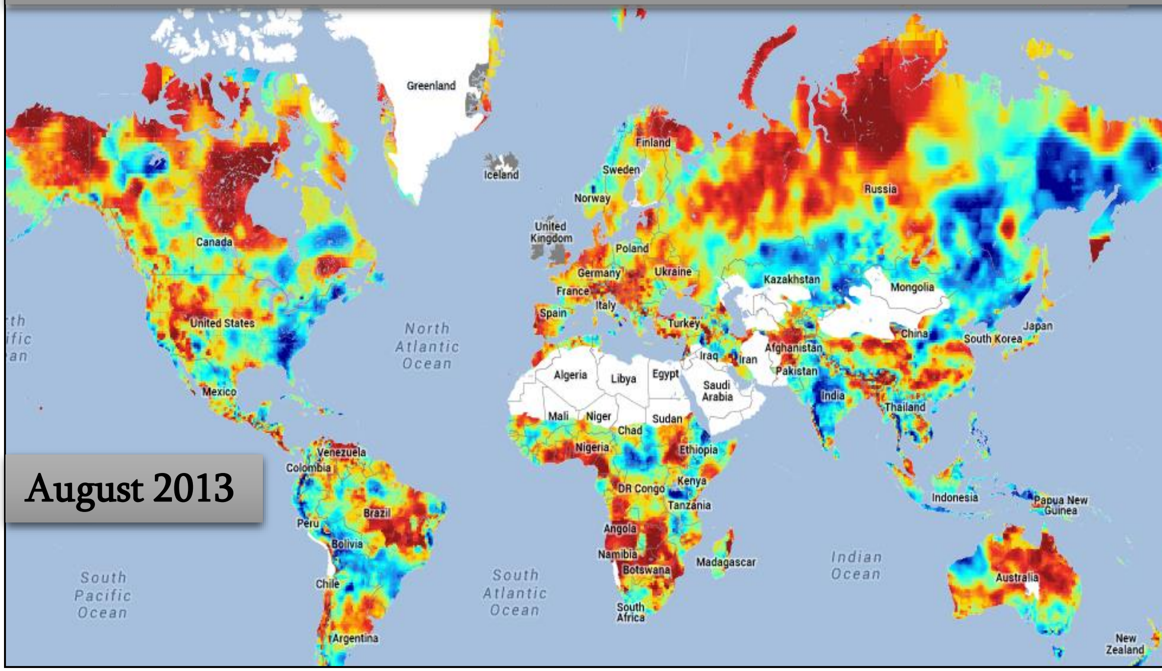




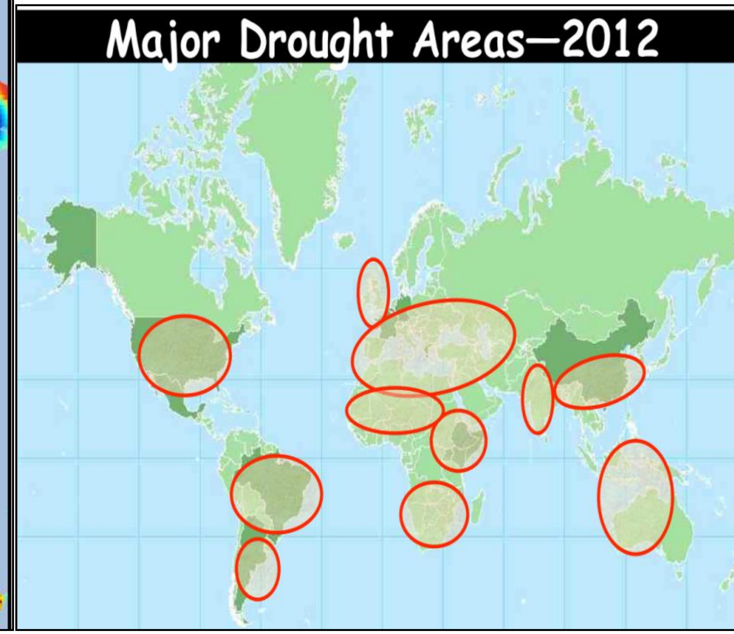
Lehner *et al.* 2006

Drought at global, regional and local scales

Standardized Precipitation Evapotranspiration Index



At global scale

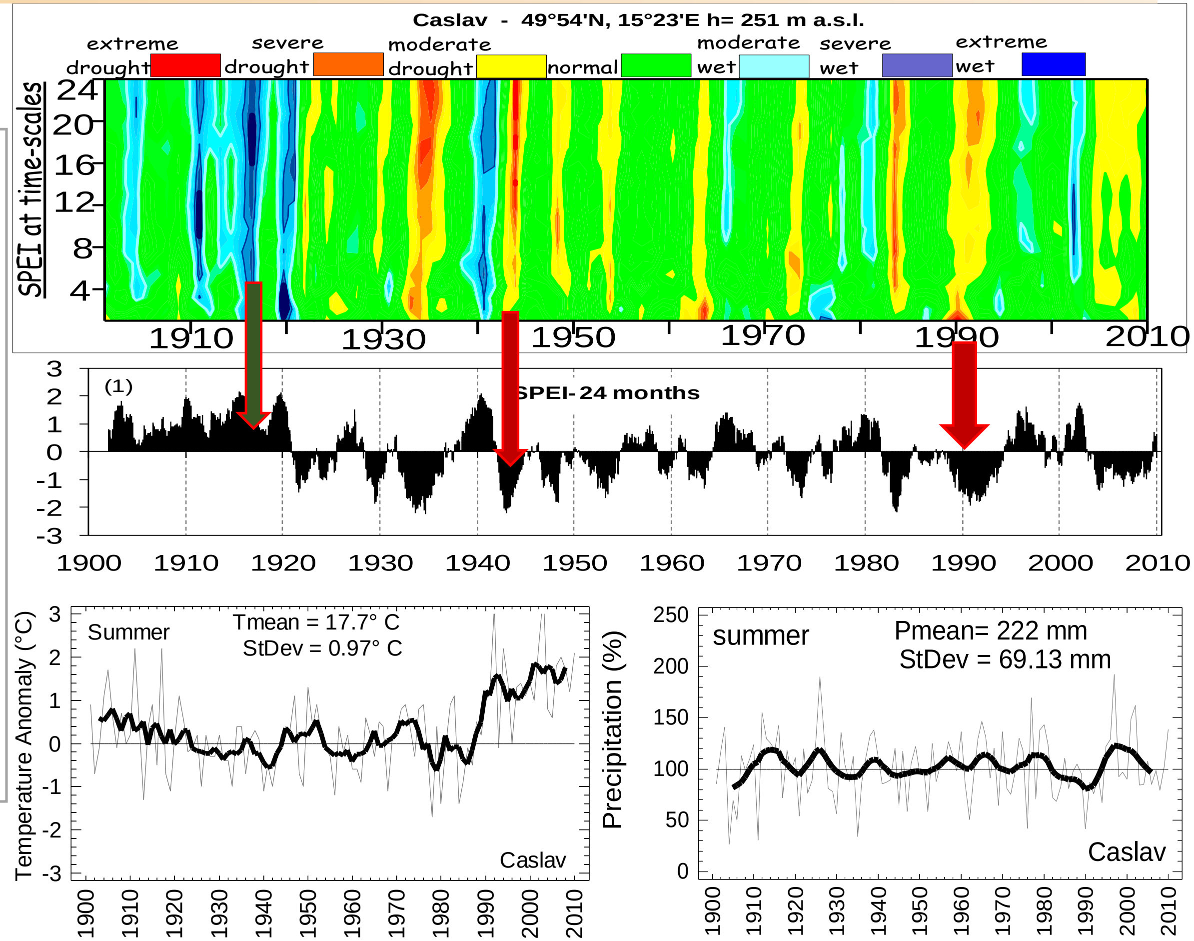


- Global warming leads to increased risk of heat waves in association with drought.
- The models project that patterns of precipitation will not change much,
    - but will result in dry areas becoming drier (generally throughout the subtropics) and wet areas becoming wetter (especially in the mid- to high latitudes).
- Wet areas get wetter and dry areas get driers, giving rise to the
    - RICH GET RICHER AND POOR GET POORER' SYNDROME !!!! ☞Dai *et al.* 2004.

Drought at global, regional and local scales

Drought conditions over Europe

- Droughts have occurred frequently over the last century in Europe (part of natural climatic cycles).
- Droughts and floods, present a strong decadal variability:
  - **very wet conditions** were found between mid 1910s and 1920s.
  - **the driest conditions** were in the mid 1940s–1950s, 1990s (☞ Potop *et al*. 2012).



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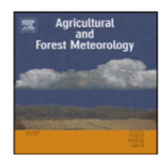


Source: Drought evolution at various time scales in the lowland regions and their impact on vegetable crops in the Czech Republic

Vera Potop[a,*], Martin Možný[b], Josef Soukup[a]

Drought at global, regional and local sc

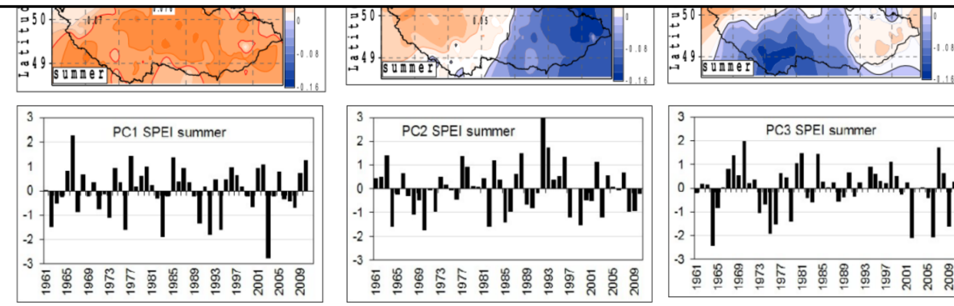
Drought conditions in Central Europe

- Central Europe is not drought-pron European context with the exception b Basin (eastern Austria and a large pa
- Only recently has the importance research of drought climatology be countries like the Czech Republic.

Percentages of explained variance of the leading EOFs of the SPEI over the growing season

Explained variance (%)					
	SPEI-1	SPEI-3	SPEI-6	SPEI-12	**SPEI-24**
EOF1	66.04	61.82	60.48	57.66	**55.56**
EOF2	6.86	7.53	8.45	10.28	**10.70**
EOF3	**4.00**	**5.15**	**5.23**	**5.78**	**6.51**

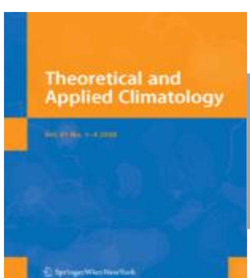
ummer SPEI



Motivation:

- Recent studies based on long-term observations point out on significant trends toward dry conditions in the CR (☞ Potop *et al*. 2010).

- To identify the principal modes of variability of drought at the various time scales, the EOF have been calculated over the CR.
- The explained variance of EOF1 of the SPEI at various lags ranges between 66 and 56% as the time scale increases from 1 to 24 mo (☞ Potop *et al*. 2013).
    - these results indicate that large-scale factors drive the drought conditions in the CR.



Potop, V., Boroneat C., Možný, M., Štěpánek, P. & Skalak, P. 2013: Observed spatio-temporal characteristics of drought on various time scales over the Czech Republic. *Theoretical and Applied Climatology*, 112, 3-4 doi: 10.1007/s00704-013-0908-y

DATA AND METHODS

- A batch script was created and used to optimise the calculation of the SPEI for the 250 stations (1961-2012).

- **Input data for SPEI:**

- the steps followed for the SPEI calculation were:

 i) the parameterization of *PET*

 ii) water balance:

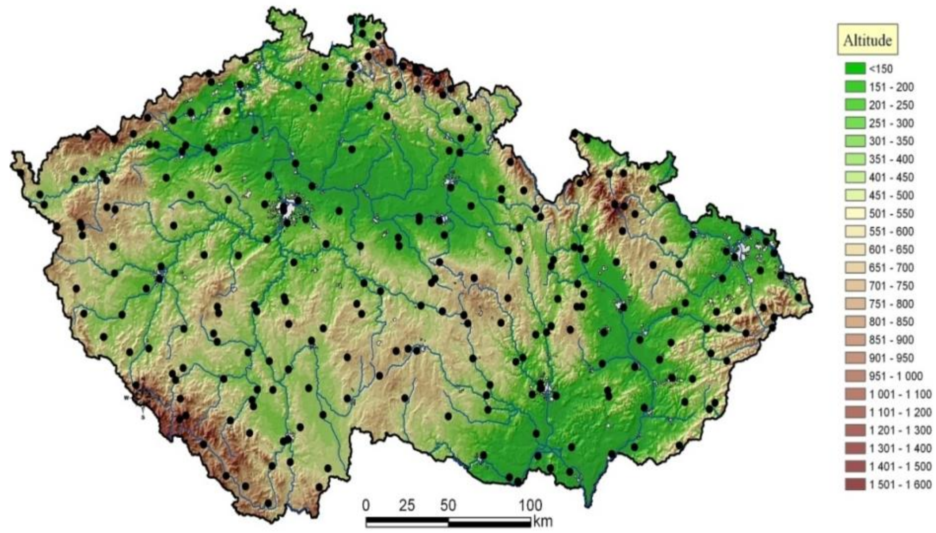
$$D_n^k = \sum_{i=0}^{k-1} P_{n-i} - PET_{n-i}$$

 iii) normalisation of the water balance into a log-logistic probability distribution to obtain the SPEI series in study area:

$$f(x) = \frac{\beta}{\alpha}\left(\frac{x-\gamma}{\alpha}\right)^{\beta-1}\left(1+\left(\frac{x-\gamma}{\alpha}\right)^{\beta}\right)^{-2}$$

- The SPEI calculated for various lags contain the "memory" of moisture conditions prior to the current month.

Location of stations used for the calculation of the SPEI drought index in the CR.



The 7 classes of SPEI category according to its value

SPEI	Drought category	Probability
≥2.0	Extreme wet	0.02
1.50 – 1.99	Severe wet	0.06
1.49 - 1.00	Moderate wet	0.10
0.99 - -0.99	Normal	0.65
-1.00 – -1.49	Moderate drought	0.10
-1.50 - -1.99	Severe drought	0.05
≤-2.00	Extreme drought	0.02

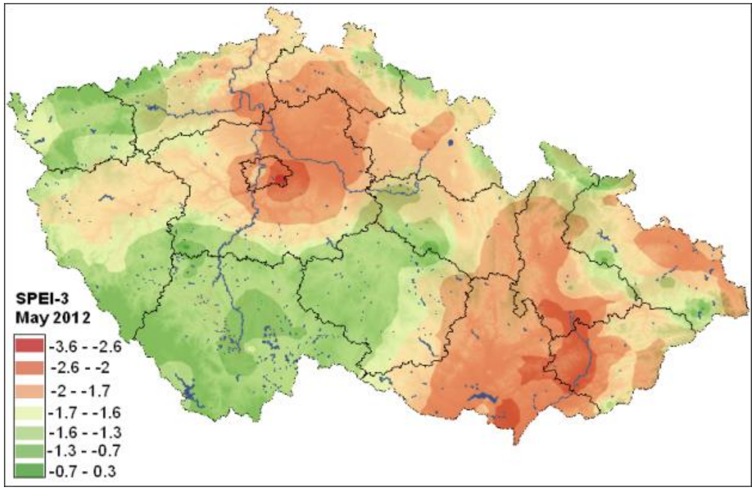
Source: More information can be explored through obtaining the SPEI at http://sac.csic.es/spei/index.html

DATA AND METHODS

- **Our objectives** are also to determine the influence of drought on crop productivity of the main agricultural crops grown in the CR and, in particular, the drought time-scales that affect the growth of agricultural crops.

- Agro-databases contain yearly regional-level yields of spring wheat, winter wheat, spring barley, winter barley, winter rye, oats, maize, sugar beet, potatoes and grapes.

- To assess to what extent the variability of productivity of crops is related to the SPEI, correlation analyses were performed between de-trended yield and de-trended monthly SPEI series.



Spatial distribution of SPEI at 3 time scales on May 2012 over the Czech Republic.

Winter-spring rye

	1	2	3	4	5	6	7	8	9	10	11	12
Dec	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.2	-0.3
Nov	0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	-0.2	-0.2	-0.1
Oct	0.0	0.0	0.1	0.1	0.2	0.1	0.1	0.3	-0.3	-0.2	-0.1	-0.2
Sep	0.0	0.0	0.1	0.0	0.0	0.0	0.3	-0.2	-0.2	0.2	-0.3	-0.3
Aug	0.0	0.0	0.2	0.0	0.1	0.2	0.0	0.1	0.1	0.0	0.1	0.1
Jul	0.0	0.0	0.0	0.2	0.2	0.2	0.0	0.2	0.1	0.0	0.1	0.0
Jun	-0.3	-0.3	-0.3	-0.2	-0.4	-0.4	0.2	0.2	0.1	0.1	0.1	0.1
May	0.2	0.2	-0.4	-0.4	-0.4	-0.4	-0.3	0.0	0.0	0.0	0.0	0.0
Apr	0.0	-0.2	-0.5	-0.6	-0.6	-0.6	-0.4	-0.2	0.0	0.0	0.0	0.0
Mar	-0.2	-0.1	0.4	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Feb	0.0	0.3	0.1	-0.1	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0
Jan	0.0	0.0	-0.2	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0

SPEI time-scales

Maize

	1	2	3	4	5	6	7	8	9	10	11	12
Dec	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nov	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oct	0.2	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sep	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.2	0.0	0.1	0.2	0.2
Aug	-0.2	-0.2	-0.5	-0.6	-0.6	-0.5	0.0	0.3	0.1	0.2	0.1	0.1
Jul	-0.2	-0.2	-0.1	-0.2	-0.1	-0.2	0.0	0.1	0.1	0.1	0.1	0.1
Jun	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.2	0.0	0.0	0.1	0.1
May	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.0	0.0	0.1	0.1	0.1
Apr	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.0	0.0	0.0	0.0
Mar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SPEI time-scales

-0.6	-0.5	-0.4	-0.3	-0.2	-0.1	0.0	0.1	0.2	0.3	0.4	0.5	0.6

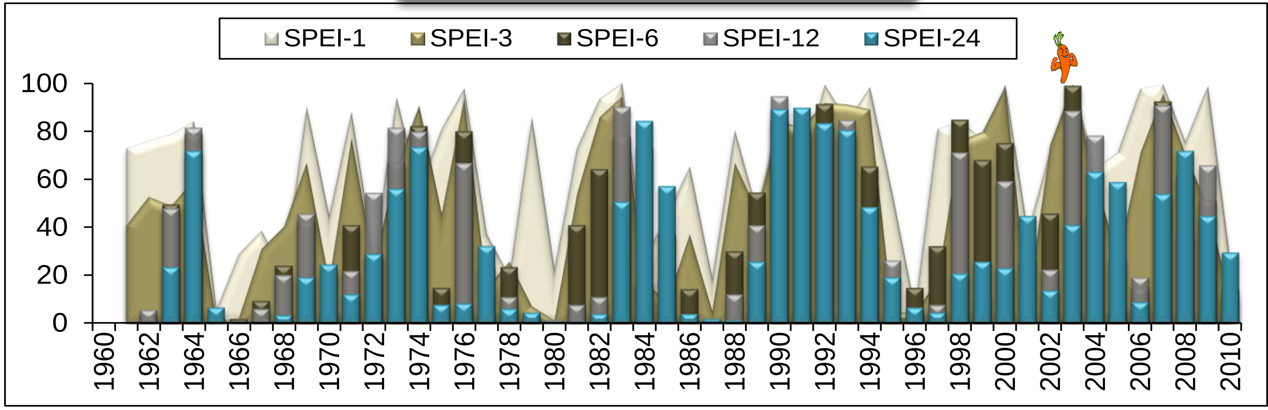
Mean Pearson correlation coefficients between monthly SPEI de-trended series at 1 to 12-month lag and de-trended yield of maize for the period of 1961-2012.

Impacts of drought at various time scales on productivity of agricultural crops

Results and discussion

Drought episodes in the CR

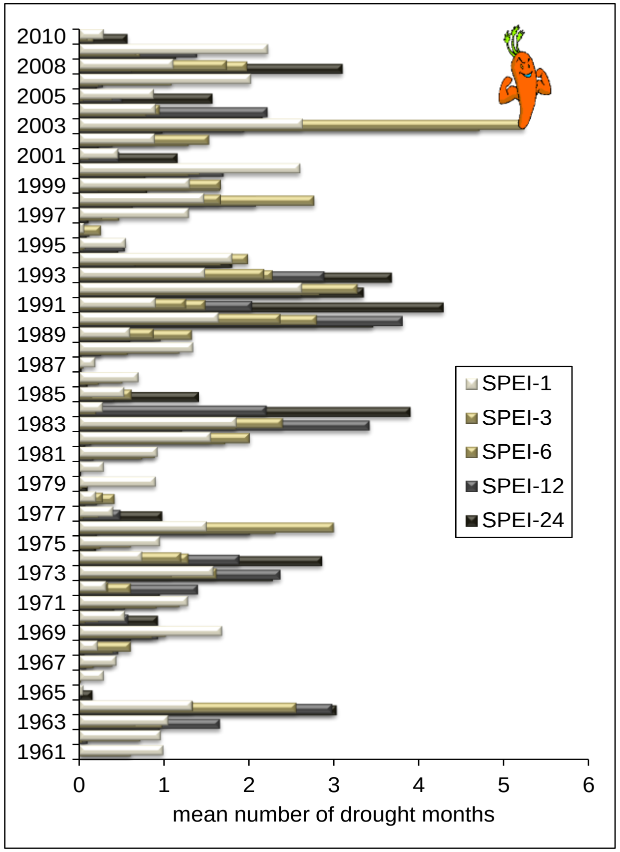
Percentage of stations (%) for the entire territory of the CR



- The most persistent agricultural drought during the growing season was in 2003 when on average 5 dry months were recorded.

- The **short-term** drought (meteorological drought) and **mid-term** drought (impacting agricultural production) occur at the whole territory of the country approximately in every three and five years, respectively.

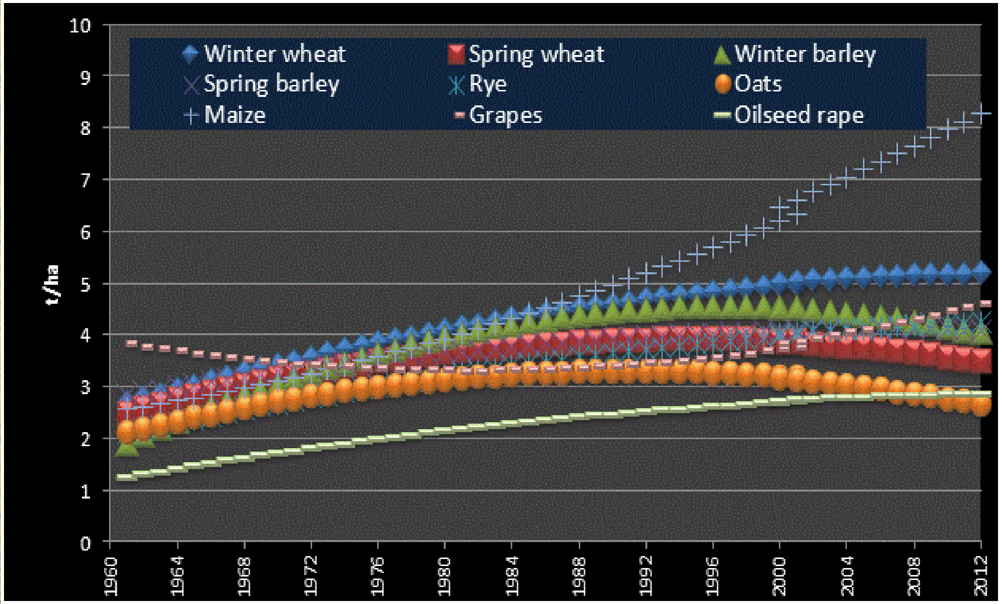
- The **long-term** drought (impacting the water system) can occur in every nine years.

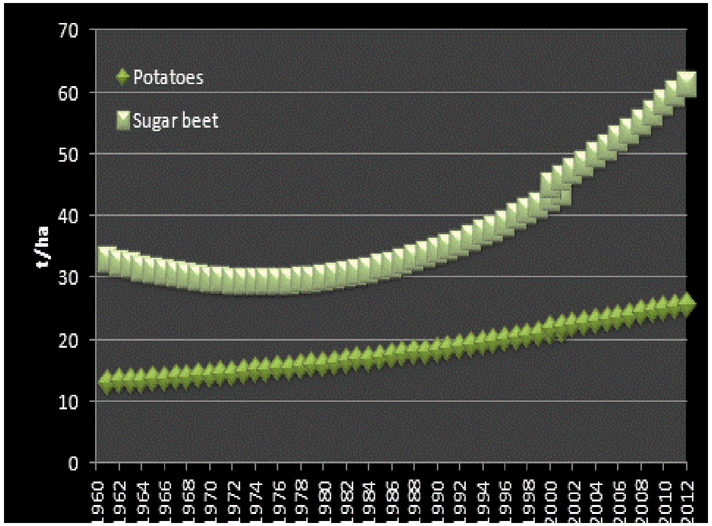


Fakulta agrobiologie, potravinových a přírodních zdrojů

Results and discussion

- The majority of agricultural crops have been pronounced increasing trend of yields in the CR.
- The largest growth rate had maize.
  - ⇨ This is mainly due to breeding performance of hybrids (since 1970s putting them into practice).
- Among the winter cereals, the fastest yield growth was found in winter wheat.
  - Winter wheat gives very high yield stability in contrast to spring wheat.
  - The difference between spring and winter cereals was 23% in favour of winter cereals.
- Grapes showed slight increase in yield.





The trend growth rate in annual yield series ($t ha^{-1}$) of crops grown in the Czech Republic (1961-2012).

Impacts of drought at various time scales on productivity of agricultural crops

- In agreement with the SPEI, the most significant losses in cereal production were recorded in years with late spring/earlier summer drought
  - more than 40% of the months can be affected by moderate/severe drought.
- However, the greatest fraction of decreases in cereals yields occurred during GS with extreme wet spells in June.
- Winter wheat was affected by a **severe drought in May-June** at 1 to 6-month lag.
- Lower yields of spring wheat/barley were registered in the years with the **mid-term spring drought**.
  - Spring barley is susceptible to drought in **May** at **short- to mid-term** lags (1 to 7 mo).
- Among the winter cereals, winter rye shows the greatest yield fluctuations due to spring drought (April-May with *r = -0.2 to -0.6*).

Winter wheat

	1	2	3	4	5	6	7	8	9	10	11	12
Dec	0.1	0.2	0.2	0.1	0.2	0.3	0.3	0.5	0.4	0.5	-0.4	-4.0
Nov	0.2	0.0	0.0	0.0	0.0	0.0	-0.3	-0.2	-0.2	-0.3	-0.4	-0.4
Oct	0.0	0.0	0.1	0.1	0.2	0.1	0.3	0.3	0.3	0.3	-0.4	-0.4
Sep	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.2	0.4	0.4	0.4	0.4
Aug	0.0	0.0	0.2	0.0	0.2	0.2	0.0	0.1	0.1	0.2	0.1	0.1
Jul	0.0	0.2	0.0	0.2	0.2	0.2	0.0	0.2	0.1	0.2	0.1	
Jun	-0.6	-0.6	-0.5	-0.5	-0.5	-0.5	-0.2	-0.4	0.0	0.4	-0.3	-0.3
May	-0.6	-0.5	-0.6	-0.5	-0.6	-0.5	-0.3	0.0	-0.4	-0.2	0.2	-0.3
Apr	-0.4	0.4	0.0	0.1	0.0	-0.1	0.2	-0.4	-0.3		-0.3	-0.3
Mar	0.3	0.3	0.4	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	-0.3
Feb	0.3	0.3	0.1	-0.1	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0
Jan	0.2	0.0	-0.2	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0

SPEI time-scales

Spring wheat

	1	2	3	4	5	6	7	8	9	10	11	12
Dec	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nov	0.2	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.2	0.1	0.1	0.0
Oct	0.0	0.0	0.1	0.1	0.2	0.1	0.3	0.3	0.3	0.3	0.1	0.0
Sep	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.2	0.2	0.1	0.2	0.2
Aug	0.0	0.0	0.2	0.0	0.2	0.2	0.0	0.1	0.1	0.2	0.1	0.1
Jul	0.0	0.2	0.0	0.2	0.2	0.2	0.0	0.2	0.1	0.2	0.1	0.0
Jun	-0.4	-0.3	-0.4	-0.3	-0.2	-0.4	0.2	0.3	0.0	0.0	0.3	0.3
May	-0.6	-0.5	-0.5	-0.4	-0.2	-0.2	0.2	0.0	0.0	0.2	0.2	0.2
Apr	-0.6	-0.6	-0.6	-0.5	-0.2	0.0	0.0	0.2	0.0	0.2	0.2	0.2
Mar	-0.4	-0.4	-0.2	-0.3	-0.3	-0.3	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Feb	0.3	0.3	0.1	-0.1	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0
Jan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SPEI time-scales

Spring barley

	1	2	3	4	5	6	7	8	9	10	11	12
Dec	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Nov	0.2	0.0	0.0	0.1	0.2	0.0	0.2	0.2	0.2	0.1	0.1	0.0
Oct	0.0	0.0	0.0	0.2	0.2	0.1	0.2	0.2	0.1	0.0	0.1	0.0
Sep	0.0	0.1	0.2	0.0	0.0	0.0	0.2	0.2	0.2	0.1	0.2	0.2
Aug	0.0	0.2	0.2	0.0	0.2	0.2	0.0	0.1	0.1	0.2	0.1	0.1
Jul	0.2	0.2	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Jun	-0.2	-0.3	-0.3	-0.1	-0.1	-0.1	0.2	0.3	0.0	0.0	0.3	0.3
May	-0.4	-0.5	-0.6	-0.6	-0.6	-0.6	0.2	0.0	0.0	0.2	0.2	0.2
Apr	-0.4	-0.6	-0.6	-0.5	-0.2	-0.4	-0.4	0.2	0.0	0.2	0.2	0.2
Mar	-0.3	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	0.1	0.1	0.2	0.1	0.0
Feb	0.1	0.2	0.2	0.1	0.0	0.1	0.2	0.2	0.0	0.0	0.0	0.0
Jan	0.2	0.1	0.2	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0

SPEI time-scales

Winter-spring rye

	1	2	3	4	5	6	7	8	9	10	11	12
Dec	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.2	-0.3
Nov	0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	-0.2	-0.2	-0.1
Oct	0.0	0.0	0.1	0.1	0.2	0.1	0.1	0.3	-0.3	-0.2	-0.1	-0.2
Sep	0.0	0.0	0.1	0.0	0.0	0.0	0.3	-0.2	-0.2	0.2	-0.3	-0.3
Aug	0.0	0.0	0.2	0.0	0.1	0.2	0.0	0.1	0.1	0.0	0.1	0.1
Jul	0.0	0.0	0.0	0.2	0.2	0.2	0.0	0.2	0.1	0.0	0.1	0.0
Jun	-0.3	-0.3	-0.3	-0.2	-0.4	-0.4	0.2	0.2	0.1	0.1	0.1	0.1
May	0.2	0.2	-0.4	-0.4	-0.4	-0.4	-0.3	0.0	0.0	0.0	0.0	0.0
Apr	0.0	-0.2	-0.5	-0.6	-0.6	-0.6	-0.4	-0.2	0.0	0.0	0.0	0.0
Mar	-0.2	-0.1	0.4	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Feb	0.0	0.3	0.1	-0.1	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0
Jan	0.0	0.0	-0.2	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0

SPEI time-scales

Oats

	1	2	3	4	5	6	7	8	9	10	11	12
Dec	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Nov	0.1	0.0	0.0	0.1	0.2	0.0	0.2	0.2	0.2	0.1	0.1	0.0
Oct	0.0	0.0	0.0	0.2	0.2	0.1	0.2	0.3	0.3	0.3	0.1	0.0
Sep	0.0	0.1	0.1	0.0	0.0	0.0	0.2	0.2	0.3	0.1	0.2	0.2
Aug	0.0	0.0	0.1	0.0	0.2	0.3	0.3	0.3	0.1	0.2	0.1	0.1
Jul	0.0	0.0	0.0	0.1	0.1	0.3	0.3	0.1	0.1	0.1	0.1	0.1
Jun	0.3	0.3	0.2	0.3	0.4	0.3	0.0	0.0	0.0	0.0	0.1	0.1
May	-0.6	-0.6	-0.6	-0.5	-0.4	-0.6	0.0	0.0	0.0	0.1	0.1	0.1
Apr	-0.1	-0.2	-0.3	-0.1	-0.1	-0.4	-0.4	0.2	0.0	0.2	0.2	0.2
Mar	0.4	0.3	0.2	0.1	0.1	-0.3	-0.2	0.1	0.1	0.2	0.1	0.0
Feb	0.0	0.0	0.0	0.1	0.2	0.1	0.2	0.2	0.0	0.0	0.0	0.0
Jan	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SPEI time-scales

-0.6	-0.5	-0.4	-0.3	-0.2	-0.1	0.0	0.1	0.2	0.3	0.4	0.5	0.6

Results and discussion

- Thus, higher yields of winter rye, maize and barley were found in the years with SPEI normal and moderately wet categories.
- **A negative correlation** (*i.e.* damaging effects) was observed between the de-trended yield of sugar beet and SPEI at time scales from 1 to 5 months during May, July, and August ($r = -0.37$ to -0.55).
- **Negative correlations** were found between the yield of potatoes and SPEI in June ($r = -0.31$),
  - but **positive correlation** in July ($r = 0.51$) and August ($r = 0.38$) at short-term (1 to 3-month) lags.
- Grape vines do not show strong associations between de-trended yield and the SPEI.
  - The lowest grape yields were recorded in years with severe winters and late spring frosts.

Maize

	1	2	3	4	5	6	7	8	9	10	11	12
Dec	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nov	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oct	0.2	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sep	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.2	0.0	0.1	0.2	0.2
Aug	-0.2	-0.2	-0.5	-0.6	-0.6	-0.5	0.0	0.3	0.1	0.2	0.1	0.1
Jul	-0.2	-0.2	-0.1	-0.2	-0.1	-0.2	0.0	0.1	0.1	0.1	0.1	0.1
Jun	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.2	0.0	0.0	0.1	0.1
May	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.0	0.0	0.1	0.1	0.1
Apr	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.0	0.0	0.0	0.0
Mar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SPEI time-scales

Sugar beets

	1	2	3	4	5	6	7	8	9	10	11	12
Dec	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nov	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oct	0.2	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Sep	0.2	0.2	0.2	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Aug	-0.4	-0.4	-0.5	-0.5	-0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jul	-0.3	-0.3	-0.2	-0.2	-0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Jun	0.4	0.4	0.3	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.1	0.1
May	-0.1	-0.1	-0.2	-0.2	-0.2	-0.1	0.0	0.0	0.0	0.0	0.0	0.0
Apr	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SPEI time-scales

Potatoes

	1	2	3	4	5	6	7	8	9	10	11	12
Dec	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nov	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oct	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sep	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aug	0.4	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jul	0.5	0.4	0.5	0.2	0.2	0.1	0.0	0.1	0.1	0.1	0.1	0.1
Jun	-0.3	-0.3	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
May	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Apr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SPEI time-scales

-0.6	-0.5	-0.4	-0.3	-0.2	-0.1	0.0	0.1	0.2	0.3	0.4	0.5	0.6

Grapevine

	1	2	3	4	5	6	7	8	9	10	11	12
Dec	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nov	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oct	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sep	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.4	0.4	0.3	0.3	0.3
Aug	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.4	0.4	0.3	0.3	0.3
Jul	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Jun	0.2	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1
May	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Apr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SPEI time-scales

Conclusions

- Droughts affect agricultural production but their time-scales are also a critical factor.
- The response of crops to drought depends on the timing of the drought as well as its severity.
- Yield-response to drought varied among crops: the greatest yield-drought correlation being for cereals, the least for grapes.
- The use of multi- scalar drought indices, such as the SPEI, was useful for determining and quantifying the drought effect on crops.

Thanks for your attention!

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