“Climate Change and Extreme Events: Early Warning Systems for extreme events impact. Face with drought for a sustainable development”

Training seminar
03-14 July 2006
FLORENCE - ITALY

DROUGHT DEFINITIONS INDICES AND MAPPING

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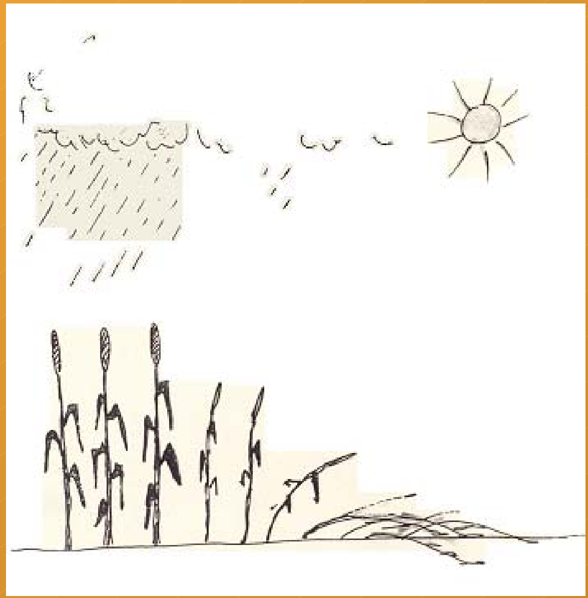
AGROMETEOROLOGICAL ANALYSIS

The availability of food depends on the agricultural production.

Yearly-seasonal and geographical crop yield variability depends on the space and time rainfall distribution.



A reduction of precipitations due to climate changes has several and important impacts on human activities and the environment.

DROUGHT DEFINITION

“Although many erroneously consider drought a rare and random event, it is a normal, recurrent feature of climate. It occurs in virtually all climatic zones, although its characteristics vary significantly from one region to another. Drought is a temporary aberration and differs from aridity since the latter is restricted to low rainfall regions and is a permanent feature of climate.” (National Center of Drought of Australia)

The severity of drought event depend on the degree of soil moisture deficit, on the duration of the event and on the extent of the affected area.

CHARACTERISTICS OF DROUGHT PHENOMENON

- **Drought is a "crawling" phenomenon**
- **It has a general and ambiguous definition**
- **Economic, social and environmental impacts are complexes and varying in space and time**
- **Prevention and management of drought are based on technical and economic measures**

One rain doesn't necessarily end a drought. It can take months of below-normal precipitation to create a drought, and it often takes more than one good rainfall to catch up.

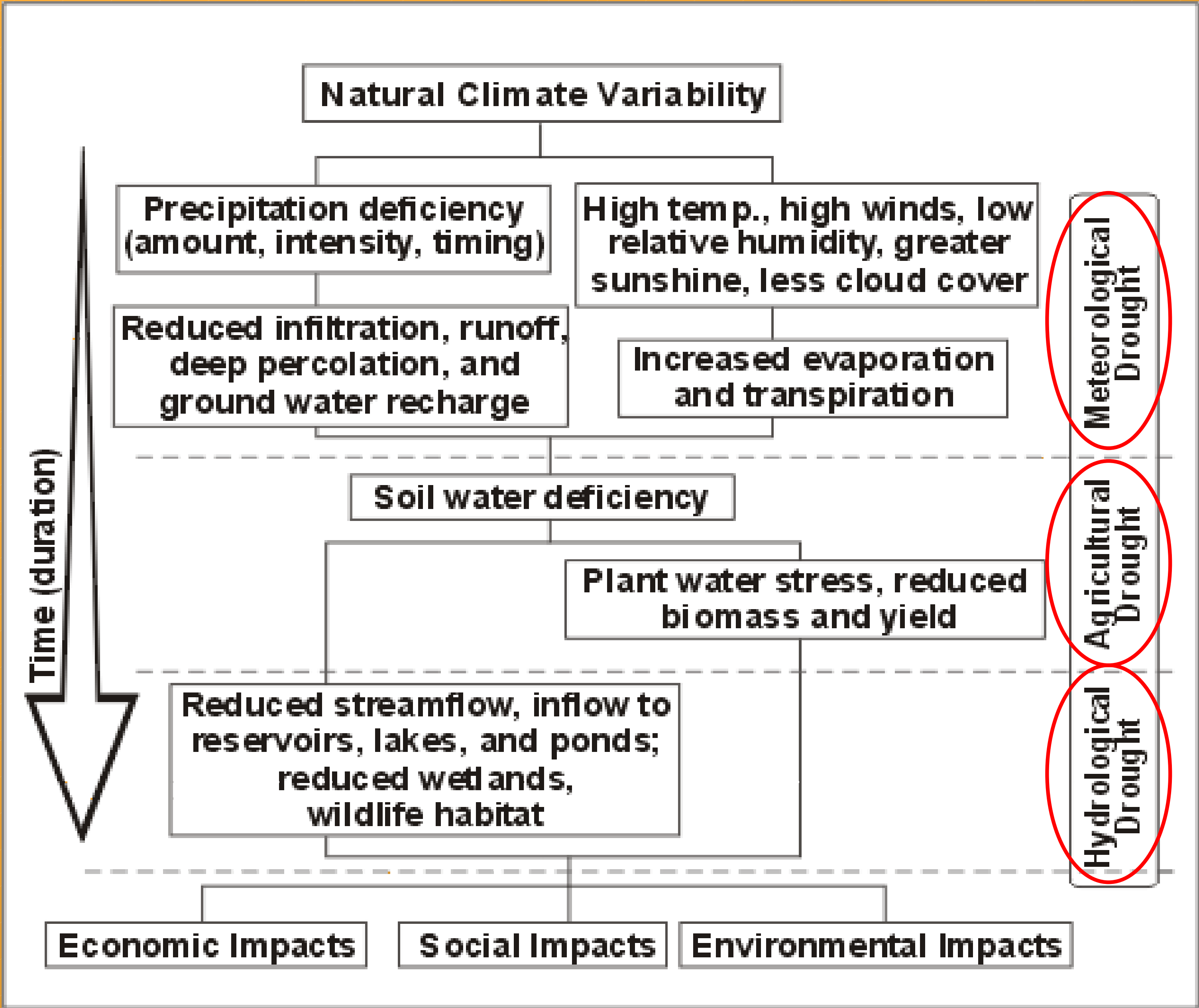
DROUGHT

Precipitations are the main factor controlling formation and persistence of drought conditions.

Anomalies in rainfall produce temporary water deficit of different duration (from month to decades), that have different impacts on society.

These impacts result from the interplay between a natural event (drought) and the demand people place on water supply.

DROUGHT TYPES



National Drought Mitigation Center, USA, Drought Watch

METEOROLOGICAL DROUGHT

Meteorological drought is usually based on precipitation's departure from normal over some period of time (usually 30 years at least).

These definitions are usually region-specific and presumably based on a thorough understanding of regional climatology.
Normally, meteorological measurements are the first indicators of drought.

A prolonged *meteorological drought* can develop quickly and end abruptly.

Drought periods often are identified through the number of days with precipitation lower than given thresholds.

AGRICULTURAL DROUGHT

"Sufficient moisture not available in the root zone for plant growth and development." (Van Havel and Carriker, 1975)

Agricultural drought occurs when there isn't enough soil moisture to meet the needs of a particular crop at a particular critical time during the growing season. Agricultural drought is typically evident after meteorological drought but before a hydrological drought.

Agricultural drought can severely reduce crop yields, even though deeper soil levels may be saturated.

Hot temperatures, low relative humidity, and desiccating winds often add to the impact of the lack of rainfall.

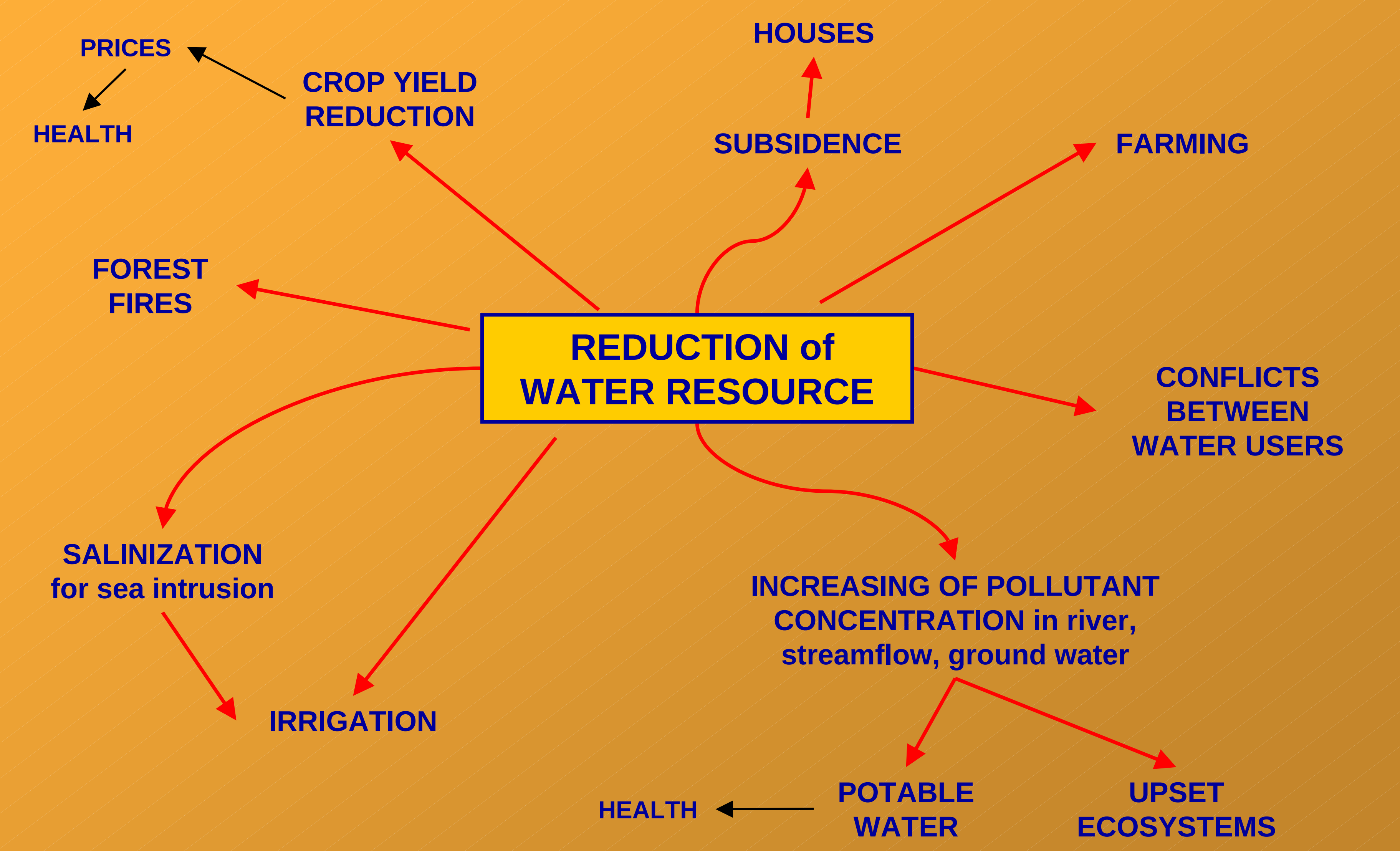
HYDROLOGICAL DROUGHT

Hydrological drought refers to <u>deficiencies in surface and subsurface water supplies</u>, due to precipitation deficit over a prolonged period.
It is measured as streamflow, and as lake, reservoir, and ground water levels.

There is a time lag between lack of rain or snow and less water in streams, rivers, lakes, and reservoirs, so hydrological measurements are not the earliest indicators of drought.

Hydrological drought will persist long after a meteorological drought has ended.

SOCIAL, ENVIRONMENTAL AND ECONOMICAL IMPACTS



DROUGHT INDICES

There are several indices that measure how much precipitation, for a given period of time, has deviated from historically normal value. Indices developed for one region may not be applicable in other regions because the meteorological conditions that result in drought are highly variable around the world.

Although none of the major indices is inherently superior to the rest in all circumstances, some indices are better suited than others for certain uses:

- **topography**

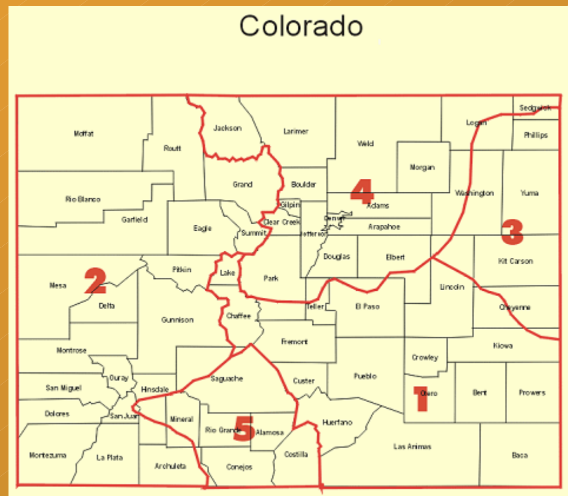
- **time and spatial scales**

- **availability of other parameters (T°, soil moisture, snowpack, etc.)**

PALMER DROUGHT SEVERITY INDEX - PDSI (1)

The Palmer Drought Severity Index - PDSI (Palmer, 1965) is a soil moisture algorithm, which uses:

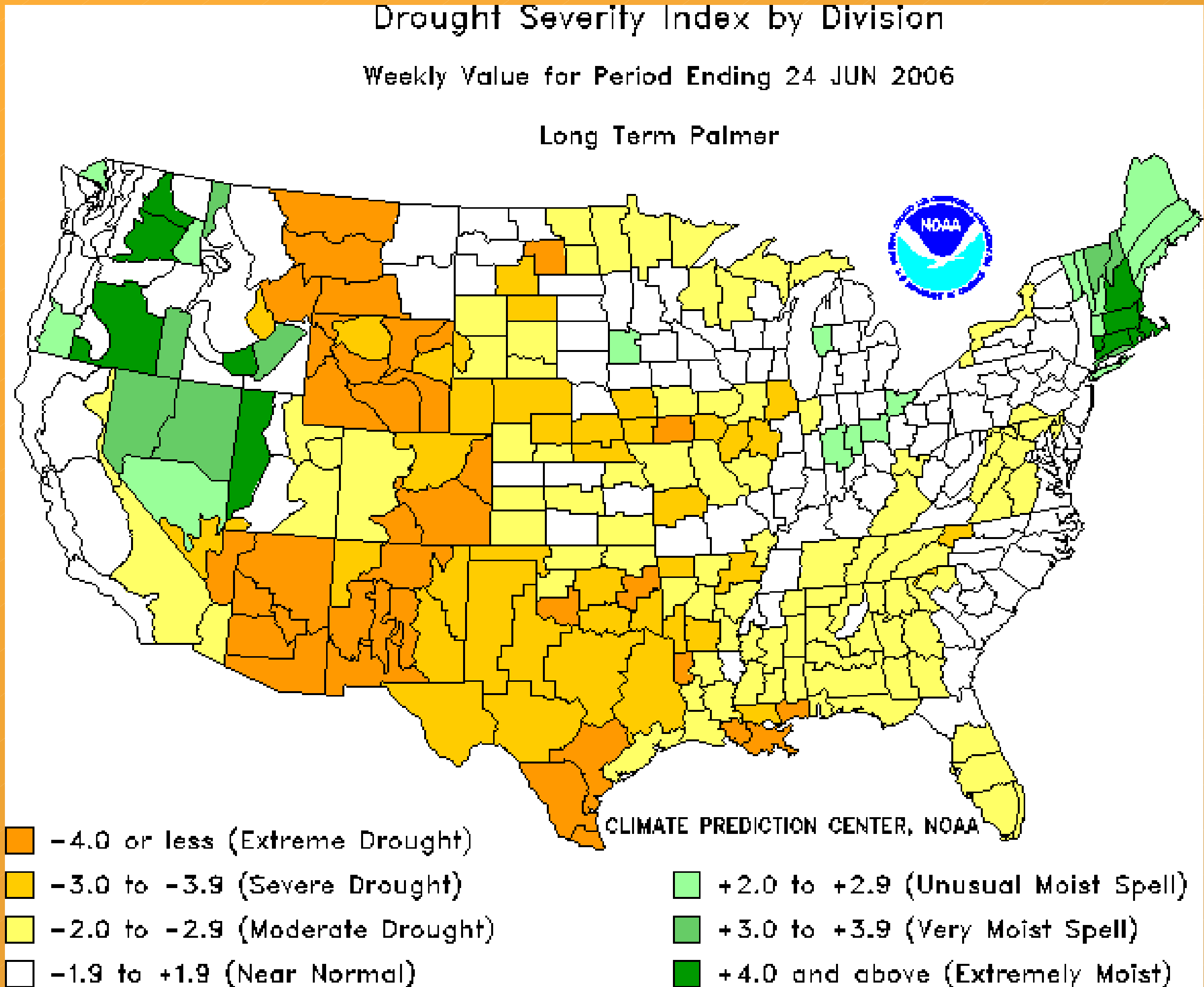
1. precipitation data;
2. temperature data;
3. local Available Water Content (AWC) of the soil.



Time scale: *monthly* (also *weekly* for US climate division during growing season).

From the inputs, all the basic terms of the water balance equation can be determined, including evapotranspiration, soil recharge, runoff, and moisture loss from the surface layer.

PALMER DROUGHT SEVERITY INDEX - PDSI (2)



PDSI monitors <u>long-term</u> meteorological wet and dry spells.

Palmer Drought Severity Index Values	
4.0 or More	Extremely Wet
3.0 to 3.99	Very Wet
2.0 to 2.99	Moderately Wet
1.0 to 1.99	Slightly Wet
0.5 to 0.99	Incipient Wet Spell
0.49 to -0.49	Near Normal
-0.5 to -0.99	Incipient Dry Spell
-1.0 to -1.99	Mild Drought
-2.0 to -2.99	Moderate Drought
-3.0 to -3.99	Severe Drought
-4.0 to -4.99	Extreme Drought

PALMER DROUGHT SEVERITY INDEX - PDSI (3)

Long-term meteorological drought

$$PDSI_i = 0.897*PDSI_{i-1} + Z_i/3$$

$PDSI_i$ = Palmer index for *i*th month

$PDSI_{i-1}$ = Drought severity

$$X = Z/(2.691 + 0.309i)$$

Short-term drought

Z = soil moisture anomaly Index

$$Z = Kd$$

K = weighting factor

$$d = P - (\alpha PE + \beta PR + \gamma PRO - \delta PL)$$

P = Precipitation

PE = Potential Evapotranspiration (Thornthwaite)

PR = Potential water Recharge of the soil

PRO = Potential Run Off

PL = Potential water Losses from the soil

$\alpha = ET_{avg}/PE_{avg}$

$\beta = R_{avg}/PR_{avg}$

$\gamma = RO_{avg}/PRO_{avg}$

$\delta = L_{avg}/PL_{avg}$

PALMER DROUGHT SEVERITY INDEX - PDSI (4)

Pros:

- Calculations result in an index, which indicates standardized moisture conditions and allows comparisons to be made between locations and months (K weighting factor);
- Palmer Index is a comprehensive drought index.

Cons:

- Often values of AWC are not always available;
- Palmer values may lag emerging droughts by several months;
- Sensitive to the AWC of a soil type;
- It is calibrated for regions relatively homogeneous and is less well-suited for mountainous land or areas with frequent climatic extremes;
- Palmer index is not particularly suitable for droughts associated with water management systems, because they exclude water storage, snowfall, and other supplies. Human impacts on the water balance, such as irrigation, are also not considered.

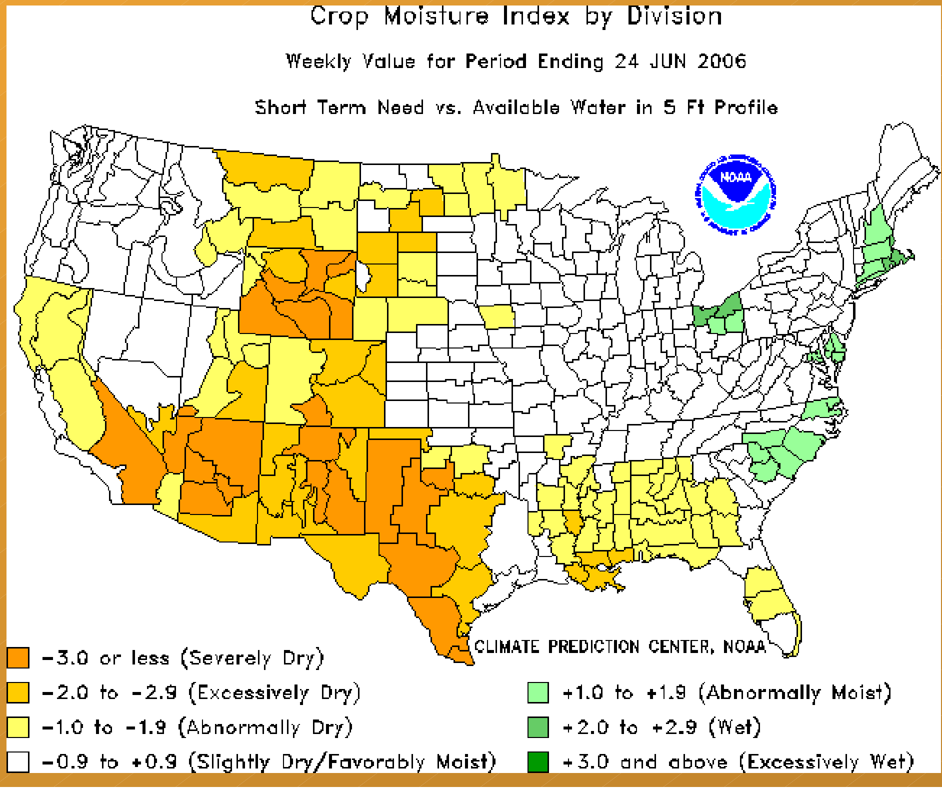
CROP MOISTURE INDEX - CMI (1)

Crop Moistire Index (Palmer, 1968) is a complement of the PDSI.
It was designed to evaluate short-term moisture conditions across major crop-producing regions.
It measures the degree to which crop moisture requirements are met; responds rapidly to changing conditions, and it is weighted by location and time.

CMI is based on:

1. Mean temperature
2. Total precipitation

It is calculated with a weekly time step.



CROP MOISTURE INDEX - CMI (2)

The CMI's rapid response to changing short-term conditions may provide misleading information about long-term conditions (a beneficial rainfall during a drought may allow the CMI value to indicate adequate moisture conditions, while the long-term drought at that location persists).

Another limit: the CMI typically begins and ends each growing season near zero. This limitation prevents the CMI from being used to monitor moisture conditions outside the general growing season, especially in droughts that extend over several years.

Example of PSDI and CMI data

Indirizzo http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/cdus/palmer_drought/wpdcentr.txt

WEEKLY PALMER DROUGHT AND CROP MOISTURE DATA FOR THE CLIMATE DIVISIONS IN THE CENTRAL REGION
CLIMATE PREDICTION CENTER, NCEP, NWS, NOAA
WEEK 17 OF THE 2006 GROWING SEASON IS THE WEEK ENDING 24 JUN 2006

ST	CD	CLIMATE DIVISION	TEMP (F)	PCPN (IN)	SOIL MOISTURE UPPER LAYER (IN)	SOIL MOISTURE LOWER LAYER (IN)	PCT FIELD CAP. END WEEK	POT EVAP (IN)	RUN OFF (IN)	CROP MOIST INDEX	CHANGE FROM PREV WEEK	MONTH MOIST ANOM (Z) INDEX	PRELIM-P FINAL -F PALMER DROUGHT INDEX	PRECIP NEEDED TO END DROUGHT (IN)
CO	1	AR DRAINAGE BASIN	68.5	0.45	0.00	0.25	3.6	1.11	0.00	-2.90	0.34	-4.70	-5.34 F	7.14
CO	2	CO DRAINAGE BASIN	64.4	0.03	0.00	3.10	44.2	1.03	0.00	-1.28	-0.39	-3.18	-2.17 P	1.63
CO	3	KS DRAINAGE BASIN	71.5	0.98	0.00	0.77	9.6	1.23	0.00	-1.96	0.93	-3.75	-4.75 F	7.83
CO	4	PLATTE DRNG. BASIN	65.6	0.28	0.00	1.75	25.0	1.05	0.00	-2.32	-0.07	-5.28	-3.58 F	5.08
CO	5	RIO GRANDE DRNG. B.	58.4	0.00	0.00	0.21	3.0	0.89	0.00	-3.08	-0.27	-5.18	-6.44 F	7.18
IL	1	NORTHWEST	71.6	0.97	0.00	7.76	77.6	1.24	0.00	-0.19	-0.01	-2.67	-2.83 P	5.78
IL	2	NORTHEAST	70.6	0.51	0.00	8.12	81.2	1.20	0.00	-0.14	-0.12	-2.23	-3.14 F	6.37
IL	3	WEST	74.9	0.58	0.00	6.87	68.7	1.33	0.00	-0.56	-0.19	-2.53	-3.93 F	10.15
IL	4	CENTRAL	75.1	0.60	0.00	6.90	69.0	1.33	0.00	-0.54	-0.18	-3.27	-3.17 F	7.77
IL	5	EAST	74.6	0.65	0.00	7.84	78.4	1.33	0.00	-0.21	-0.13	-2.28	-1.59 P	3.01
IL	6	WEST SOUTHWEST	76.9	0.60	0.00	7.08	70.8	1.40	0.00	-0.46	-0.20	-2.04	-2.51 F	6.56
IL	7	EAST SOUTHEAST	76.0	1.60	0.25	7.32	84.1	1.35	0.00	0.19	0.29	-1.18	-0.81 P	1.08
IL	8	SOUTHWEST	78.3	0.72	0.00	6.61	73.4	1.46	0.00	-0.30	-0.16	-1.69	-1.41 F	3.14
IL	9	SOUTHEAST	77.8	0.96	0.00	6.93	77.0	1.43	0.00	-0.17	-0.07	-1.37	-1.40 F	3.10

STANDARDIZED PRECIPITATION INDEX - SPI (1)

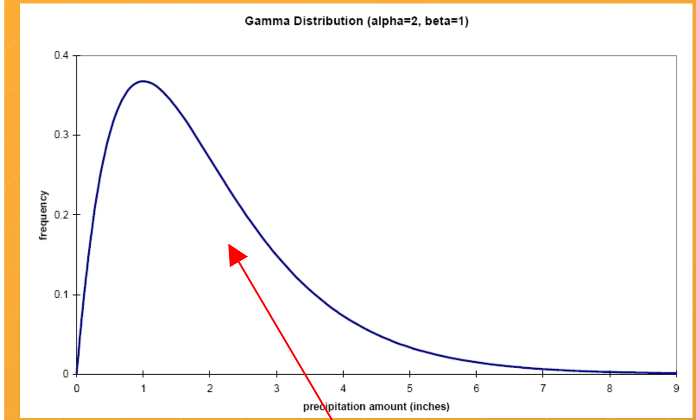
The SPI quantifies the precipitation deficit for *multiple time scales* (1, 3, 6, 12, 24, 48 months).
The use of different time scales allows to assess the effects of a drought event on different water-resources components (soil moisture, groundwater, reservoir storage, streamflow).

Pros:
- Less complex than PDSI (only precipitation)
- Help to assess drought severity
- Standardization permits a comparison between gauges climatically different
- Not negatively influenced from topography

Cons:
- Long-term precipitation record (30 years at least)
- Misleading high values (positive or negative) in areas with low amount of seasonal rainfall for short time scales (1, 3 months)

STANDARDIZED PRECIPITATION INDEX - SPI (2)

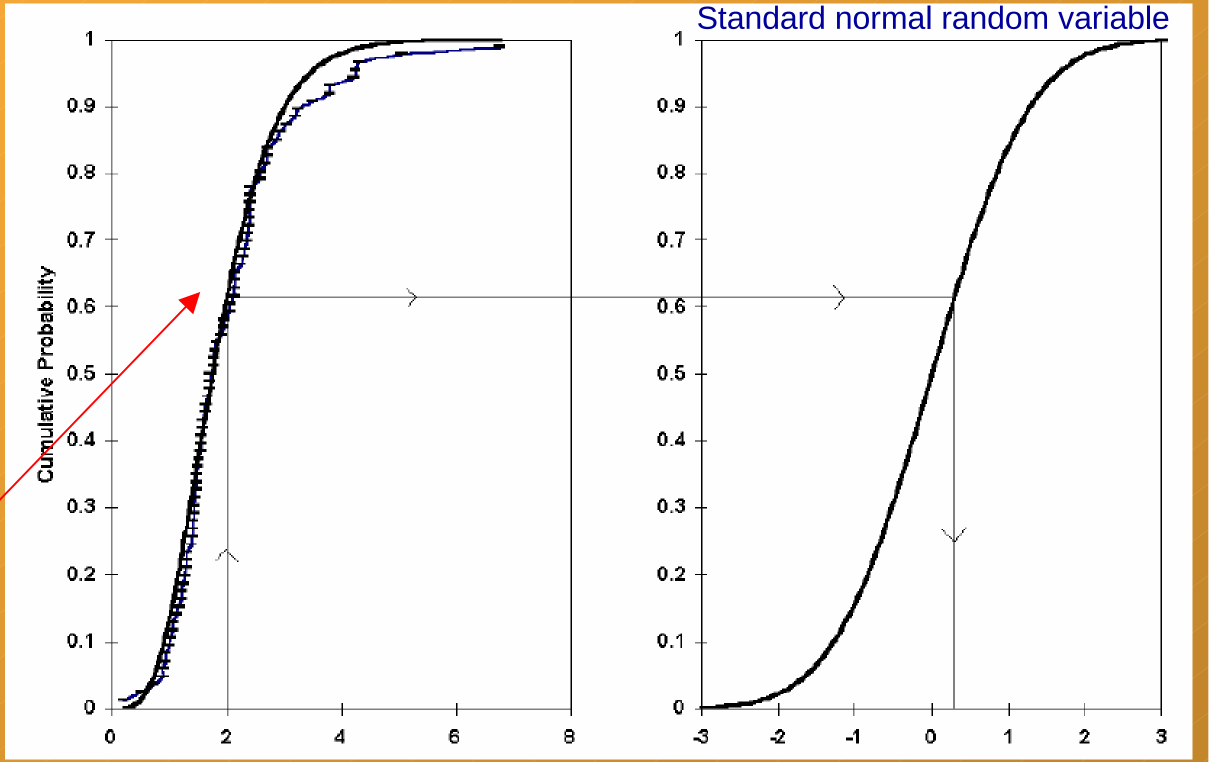
A long-term precipitation record (30 years at least) is fitted to a probability distribution (gamma distribution), that is then transformed into a normal distribution, with a mean of zero and standard deviation of one.



$$G(x) = \int_0^x g(x)dx = \frac{1}{\hat{\beta}^{\hat{\alpha}}\Gamma(\hat{\alpha})}\int_0^x x^{\hat{\alpha}-1}e^{-x/\hat{\beta}}dx$$

$$H(x) = q + (1-q)G(x)$$

q = probability of zero



STANDARDIZED PRECIPITATION INDEX - SPI (2)

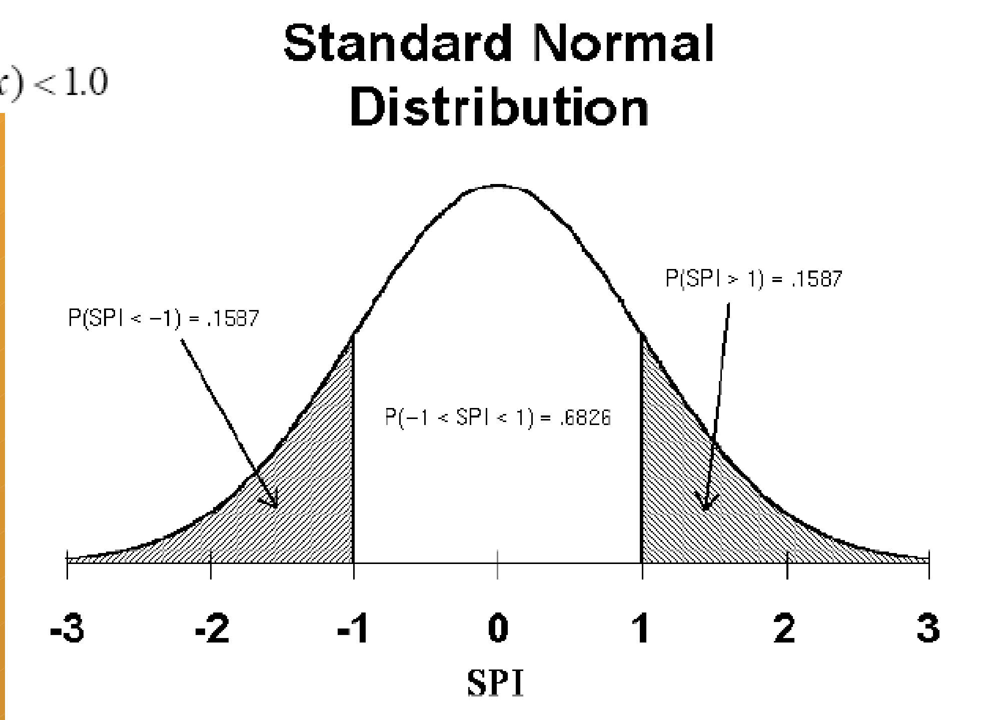
Hence the SPI represents a z-score, or the number of standard deviations above or below that an event is from the mean.

$$Z = SPI = -\left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}\right) \quad \text{for } 0 < H(x) \le 0.5$$

$$Z = SPI = +\left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}\right) \quad \text{for } 0.5 < H(x) < 1.0$$

$$t = \sqrt{\ln\left(\frac{1}{(H(x))^2}\right)} \quad \text{for } 0 < H(x) \le 0.5$$

$$t = \sqrt{\ln\left(\frac{1}{(1.0 - H(x))^2}\right)} \quad \text{for } 0.5 < H(x) < 1.0$$



STANDARDIZED PRECIPITATION INDEX - SPI (3)

SPI Values	
2.0 +	extremely wet
1.5 to 1.99	very wet
1.0 to 1.49	moderately wet
-.99 to .99	near normal
-1.0 to -1.49	moderately dry
-1.5 to -1.99	severely dry
-2.0 and less	extremely dry

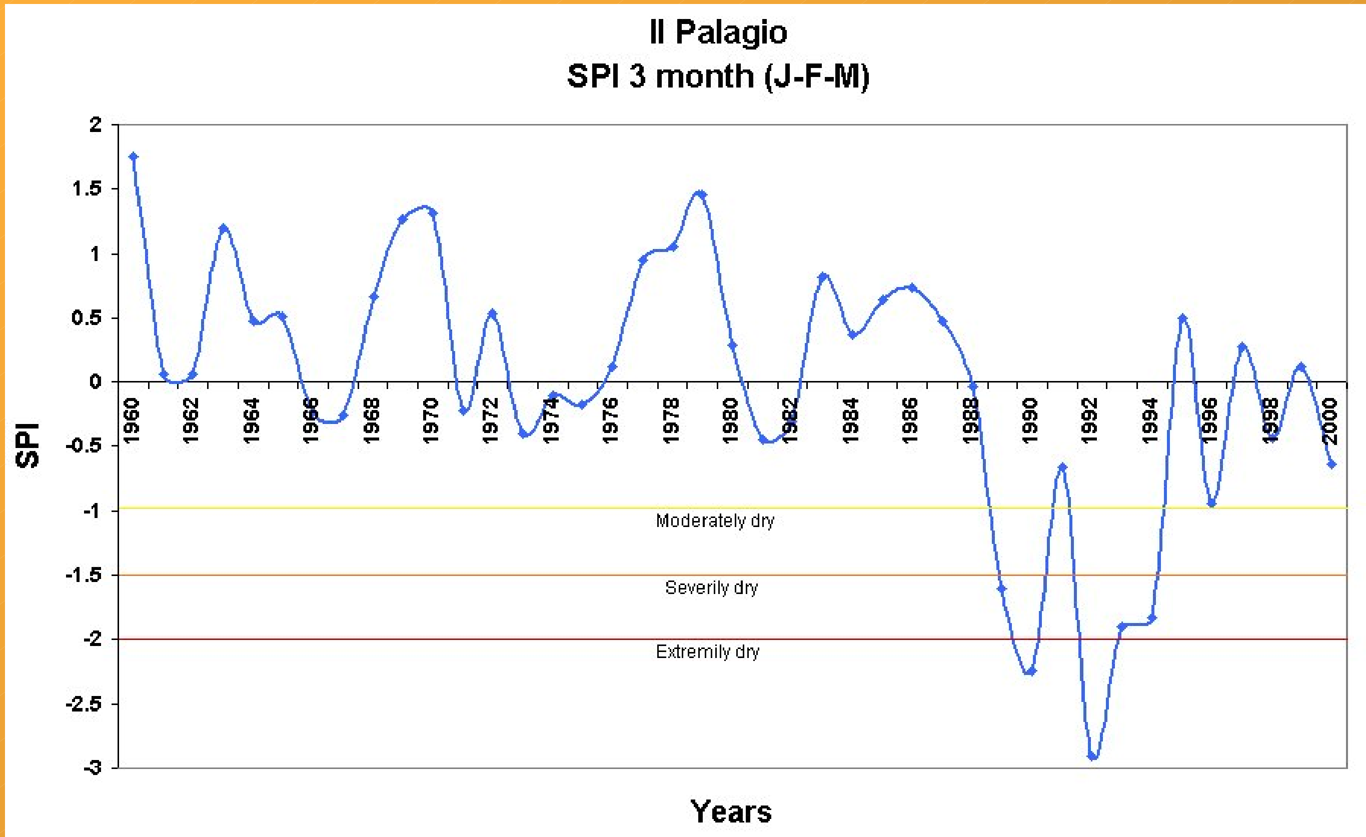
Similarly to the PDSI, SPI may be used for monitoring both dry and wet conditions.

A *drought event* start when SPI value reaches -1.0 and ends when SPI becomes positive again.

The positive sum of the SPI for all the months within a drought event is referred to as "*drought magnitude*".

STANDARDIZED PRECIPITATION INDEX - SPI (4)

When the time periods are small (3 or 6 months), the SPI moves frequently above and below zero.



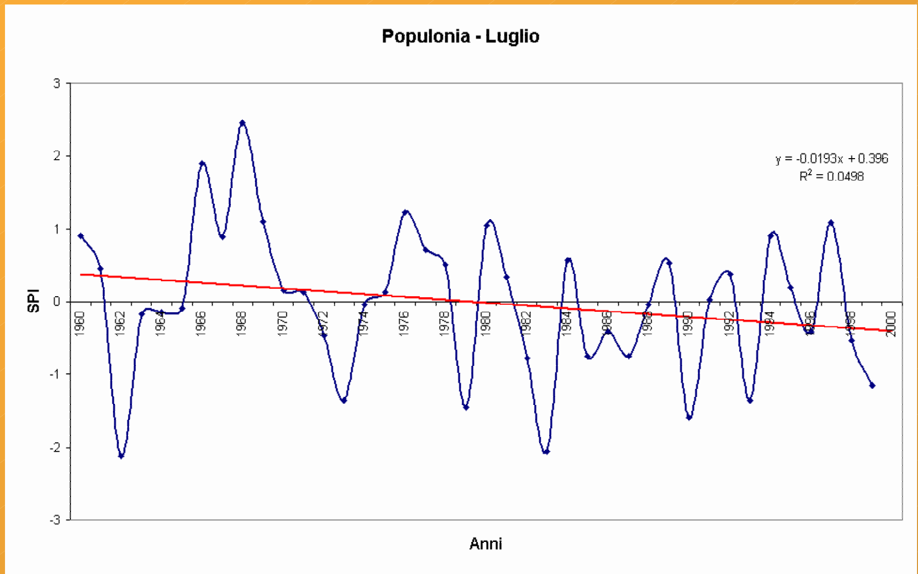
As the time period is lengthened to 12, 24 and 48 months, the SPI responds more slowly to changes in precipitation. Periods with the SPI negative and positive become fewer in number but longer in duration.

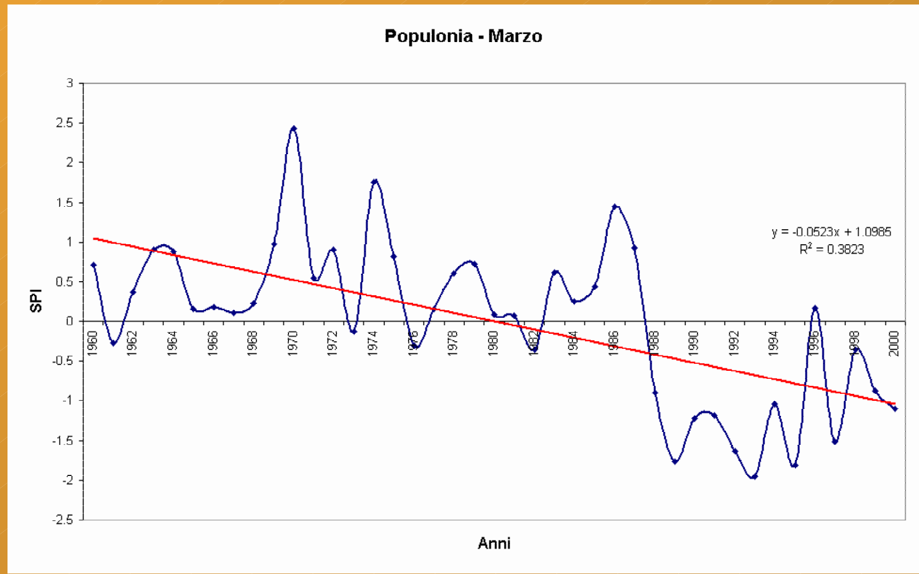
A STUDY CASE: DROUGHT IN TUSCANY

Agricultural drought events

Not unusual during <u>hottest season</u>

In the last decade great increase in <u>winter</u>





Not rarely climatic critical areas usually present a contemporary strong human pressure

SURFACE WATER SUPPLY INDEX - SWSI (1)

Surface Water Supply Index (Shafer and Dezman, 1982) is "*mountain water dependent*" because is adopted where snow forms a large component of the water balance .

SWSI integrates reservoir storage, streamflow, precipitation and snow at high elevations into a single index number.

Calculation are performed with a monthly time step.

$$SWSI = \frac{aP_{snow} + bP_{prec} + cP_{strm} + dP_{resv} - 50}{12}$$

a, *b*, *c* and *d* = weights for snow, rain, streamflow and reservoir storage (a+b+c+d=1);

P = the probability (%) of non-exceedence for each of the 4 water-balance components.

In *winter* months, SWSI is computed using snowpack, precipitation and reservoir storage.

In *summer*, streamflow, precipitation and reservoir storage data are used.

SURFACE WATER SUPPLY INDEX - SWSI (2)

Problems:

1. Limited lengths of historical hydrometeorological time series

2. For large regions with significant spatial hydrological variability the weights may differ substantially from one part of the region to another

3. If the measurements at any station are discontinued, observation on one or more components are interrupted and new frequency distributions need to be calculated

4. New dams or divisions in the basin/region will require modification of weights for each water-balance components

5. If extreme events have not been recorded previously, a frequency distribution of a relevant component needs to be revisited

6. Index is unique to each basin, which limits interbasin comparisons

DECILES

Monthly precipitation totals from a long-term record are first ranked from highest to lowest to construct a cumulative frequency distribution (Gibbs and Maher, 1967).

The distribution is then split in to 10 parts (tenth of distribution or deciles).

Any precipitation value can be compared with and interpreted in terms of these deciles.

Decile Indices are grouped into five classes, two deciles per class:

Decile classification for dry and wet periods		
Deciles 1 - 2	Lowest 20%	Much below normal
Deciles 3 - 4	Next lowest 20%	Below normal
Deciles 5 - 6	Middle 20%	Near normal
Deciles 7 - 8	Next highest 20%	Above normal
Deciles 9 - 10	Highest 20%	Much above normal

A long precipitation record (30 years at least) is required.

PERCENT OF NORMAL

Normal may be set to a long-term mean or median precipitation value.

It is calculated by dividing actual precipitation by normal precipitation (typically 30 year mean) and multiplying by 100 to get percentage.

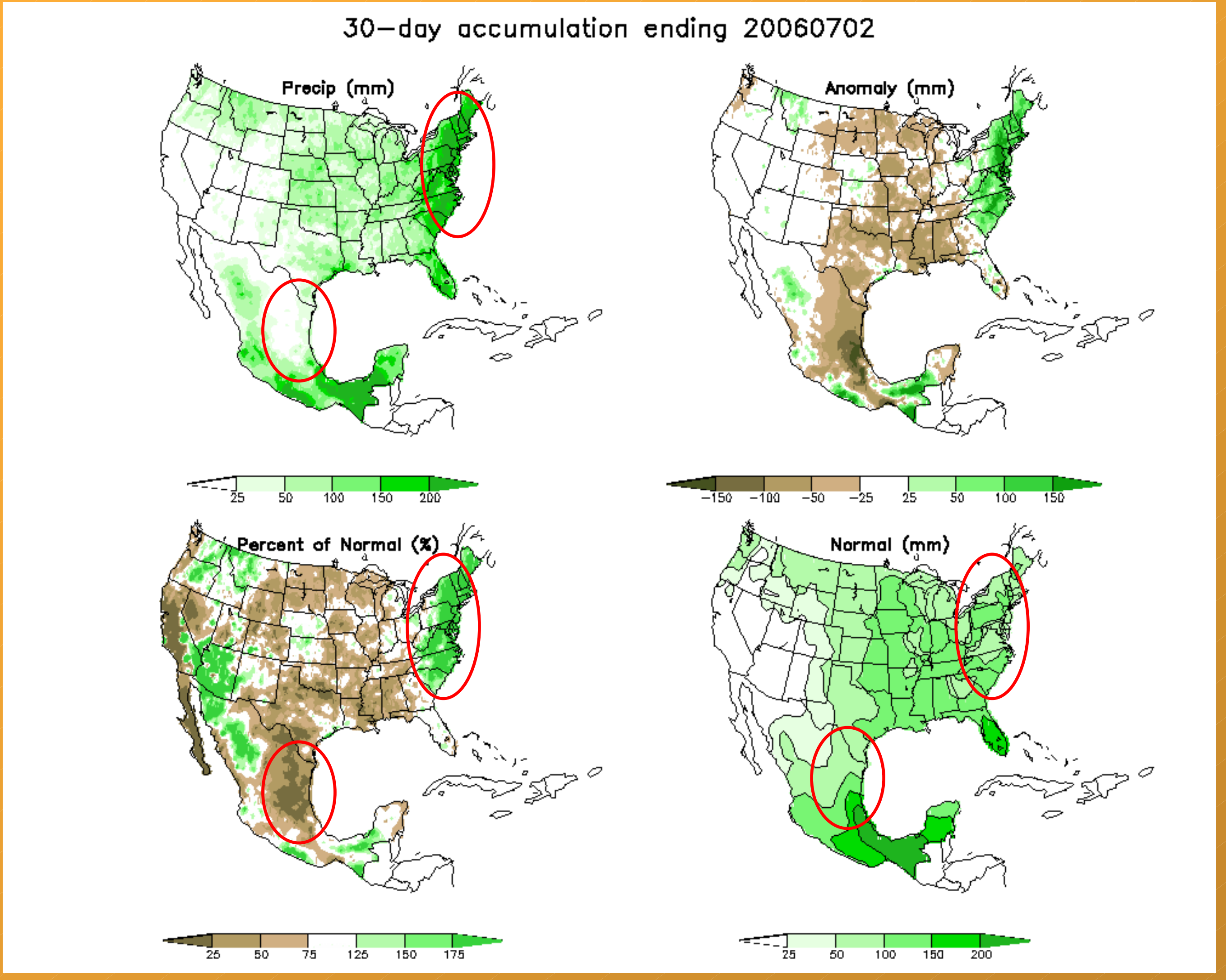
Variety of time scales:

from a single month to a group of months representing a particular season, to an annual or water year.

Normal precipitation for a specific location is considered to be 100%.

The same percent of normal may have different specific impacts at different locations and it is a bit of a simplicistic measure of precipitation deficit.

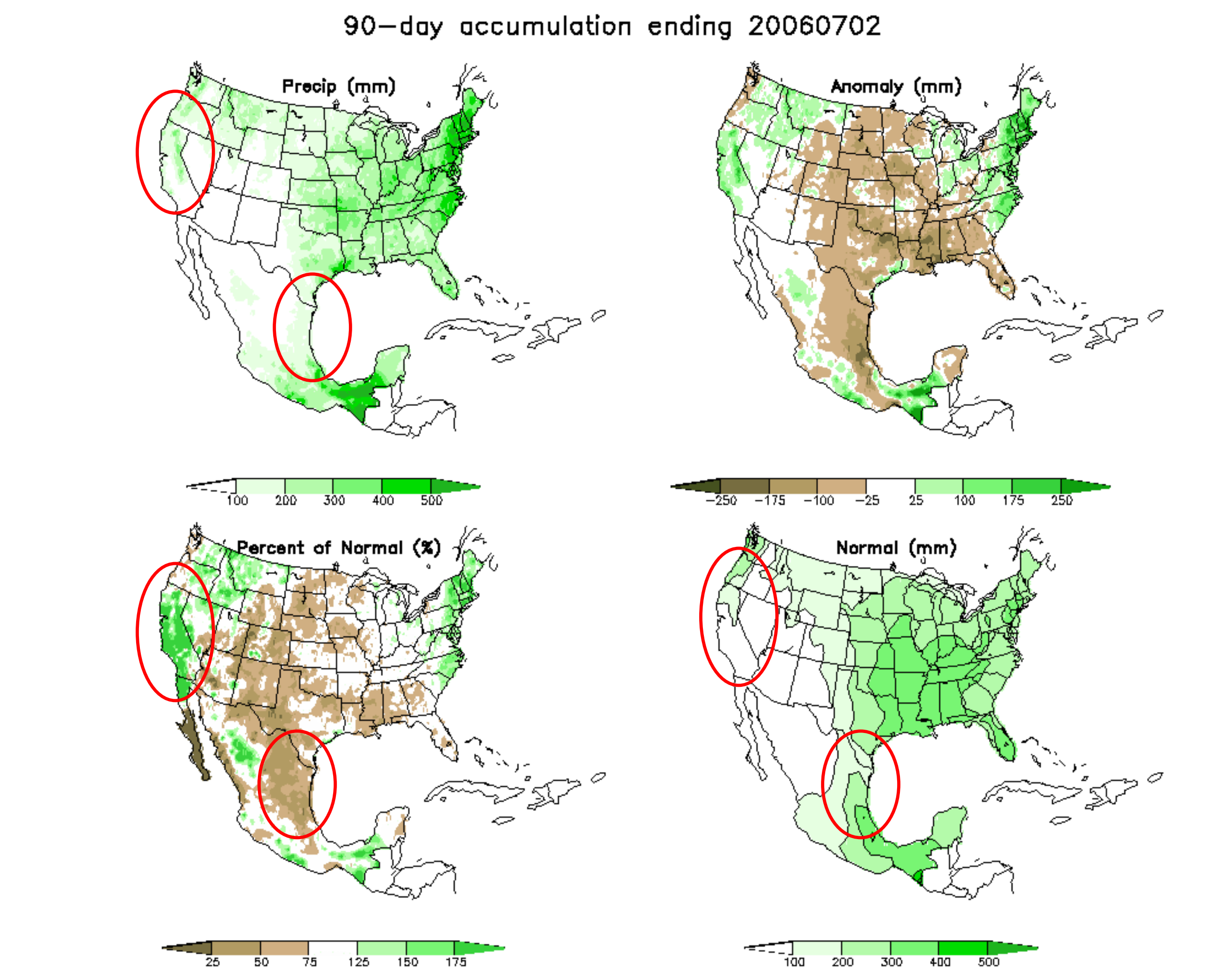
Examples of PERCENT OF NORMAL: 1 month



The base period is 1971-2000.

% of normal is masked out where the climatology is less than 0.1 mm/day.

Examples of PERCENT OF NORMAL: 3 months



The base period is 1971-2000.
% of normal is masked out where the climatology is less than 0.1 mm/day.

METEOROLOGICAL INDICATORS MONITORING

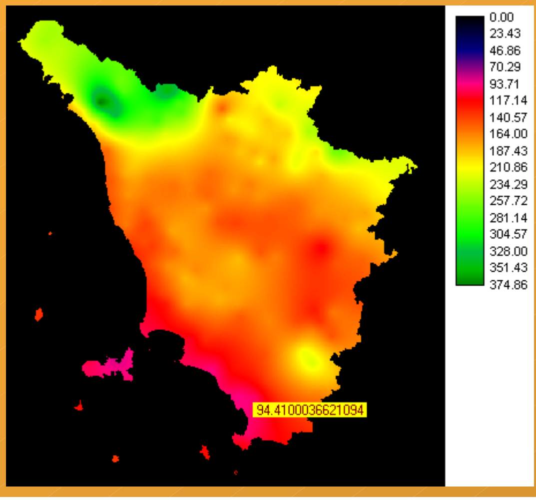
We need to have widespread, accurate and continuous monitoring of rainfall and all phenomena related to it.

MONITORING

REMOTE SENSING OBSERVATIONS
(homogeneous distribution)

METEOROLOGICAL GAUGES DATA
(scattered and not continuous)

but



- GEOSTATISTICS methods of rainfall estimation
- Long period of available data

DROUGHT MONITORING THROUGH REMOTE SENSING

Traditional methods of drought assessment and monitoring rely on rainfall data, which are limited in the region, often inaccurate and, most importantly, difficult to obtain in near-real time.
In contrast, the satellite-sensor data are consistently available and can be used to detect the onset of drought, its duration and magnitude.

Drought-monitoring indices derived from satellite sensors are normally radiometric measures of vegetation condition and dynamics, exploiting the unique spectral signatures of canopy elements, particularly in the red and near-infrared (NIR) portions of the spectrum (e.g., Huete et al. 1997, 2002) and are sensitive to vegetation type, growth stage, canopy cover and structure (Clevers and Verhoef 1993; Thenkabail 2003).

Normalized Difference Vegetation Index - NDVI

$$\mathrm{NDVI} = \frac{\rho_{\mathrm{NIR}} - \rho_{\mathrm{RED}}}{\rho_{\mathrm{NIR}} + \rho_{\mathrm{RED}}}$$

where:

ρ_{NIR} = reflectance in near-infrared band;

ρ_{RED} = reflectance in red band;

- NDVI uses only two bands and is not very sensitive to influences of soil background reflectance at low vegetation cover;
- has a lagged response to drought because of a lagged vegetation response to developing rainfall deficits due to residual moisture stored in the soil (lags behind antecedent precipitation by up to months)

NDVI Deviation Index

The severity of a drought may be defined as NDVI deviation from its long-term mean (DEV_{NDVI}).
This deviation is calculated as the difference between the NDVI for the current time step and a long-term mean NDVI for that month for each pixel:

$$DEV_{NDVI} = NDVI_i - NDVI_{mean,m}$$

where:

$NDVI_i$ = NDVI value for month i;
$NDVI_{mean,\ m}$ = long-term mean NDVI for the same month m

DEV NDVI negative = below-normal vegetation conditions/health

Vegetation Condition Index - VCI

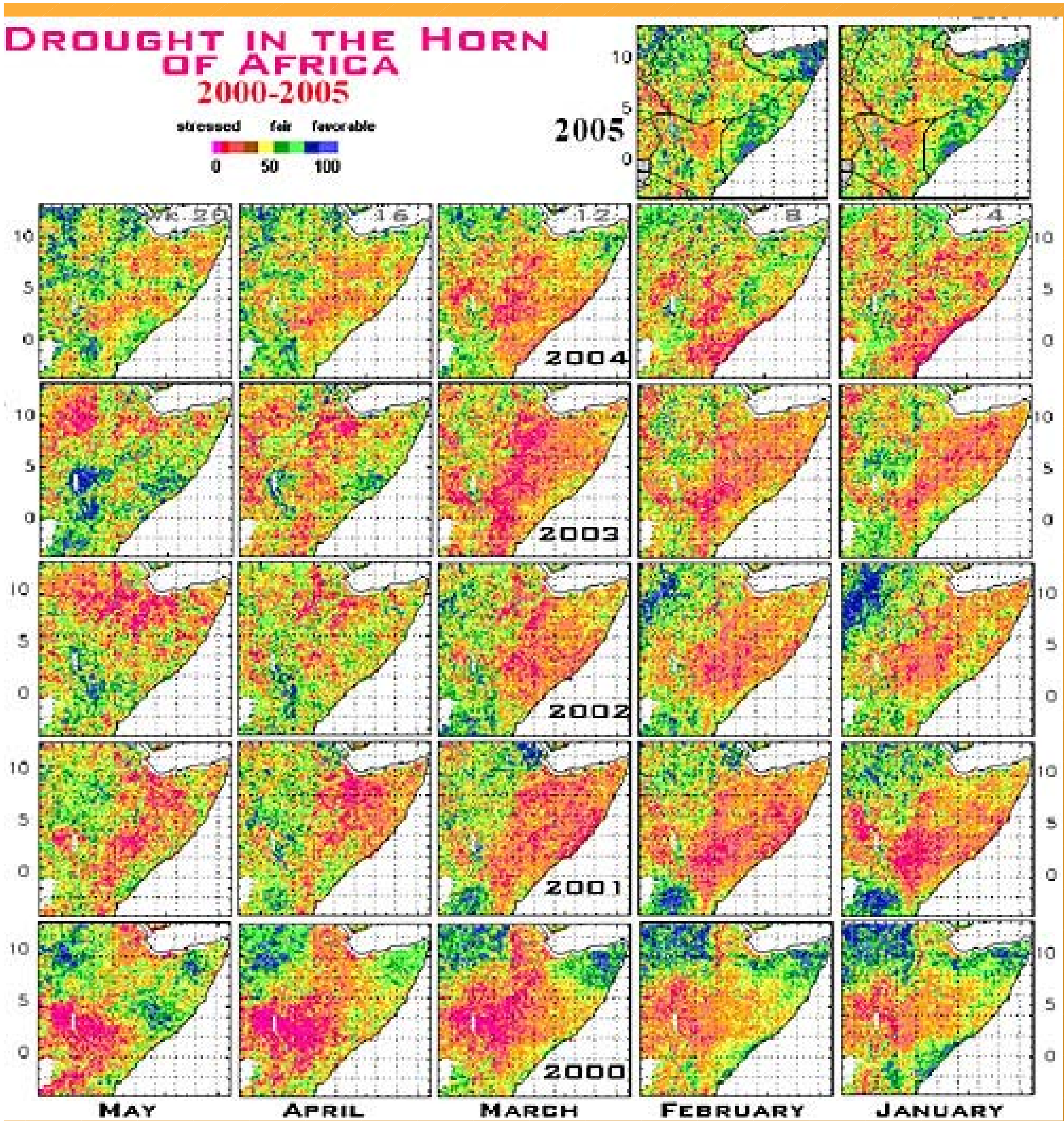
$$VCI = \frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}}$$

The VCI is an indicator of the vigor of the vegetation cover as a function of the NDVI minima and maxima encountered for a given land cover type and a given 10-day period during many years.

Its normalized the NDVI according to its variability over many years and thus results in a consistent index for different land cover types.

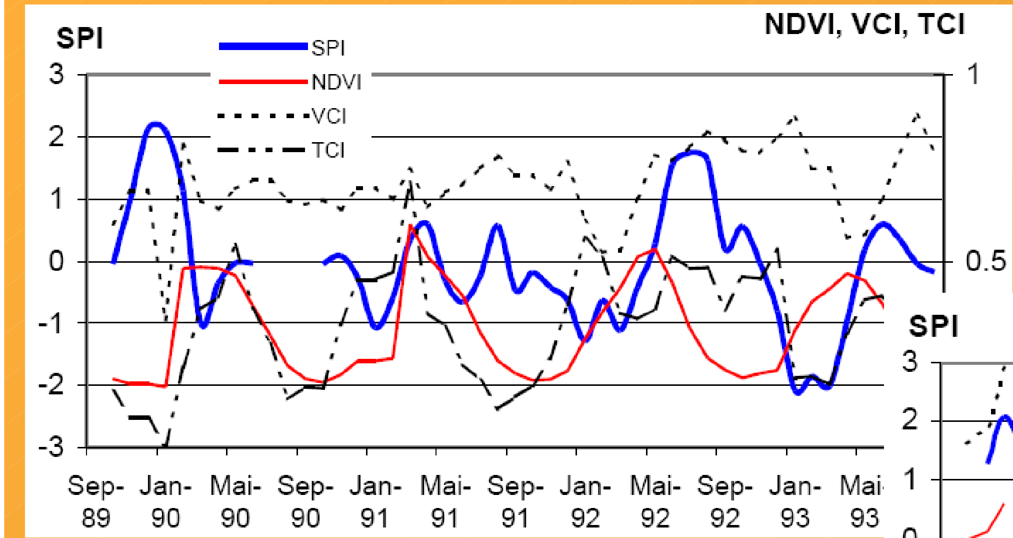
It is an attempt to separate the short-term weather-related signal from the long-term climAtological signal as reflected by the vegetation.

In this sense it is a better indicator of water stress condition than the NDVI.



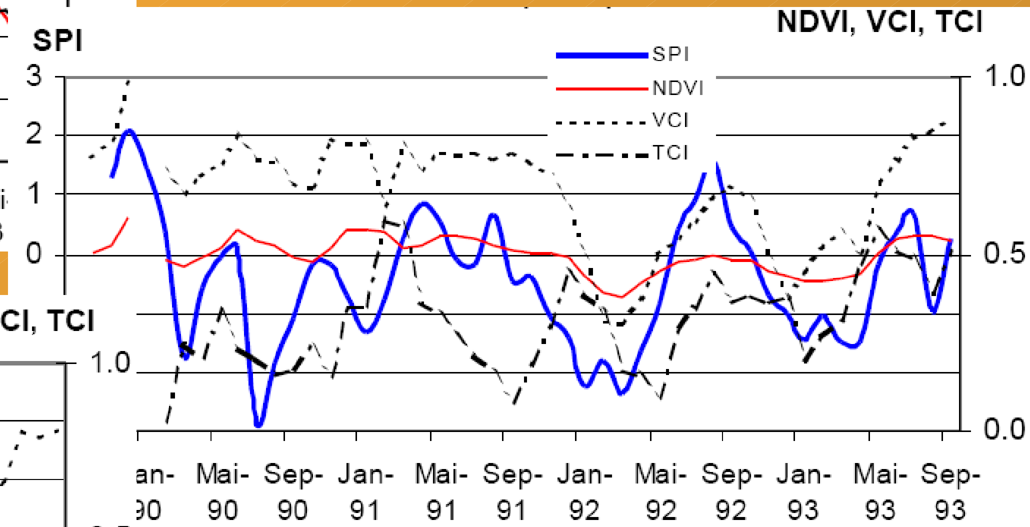
Example of AVHRR **Vegetation Condition Index** to detect areas of extreme drought conditions in parts of Kenya, Ethiopia and Somalia for the sixth year in a row.

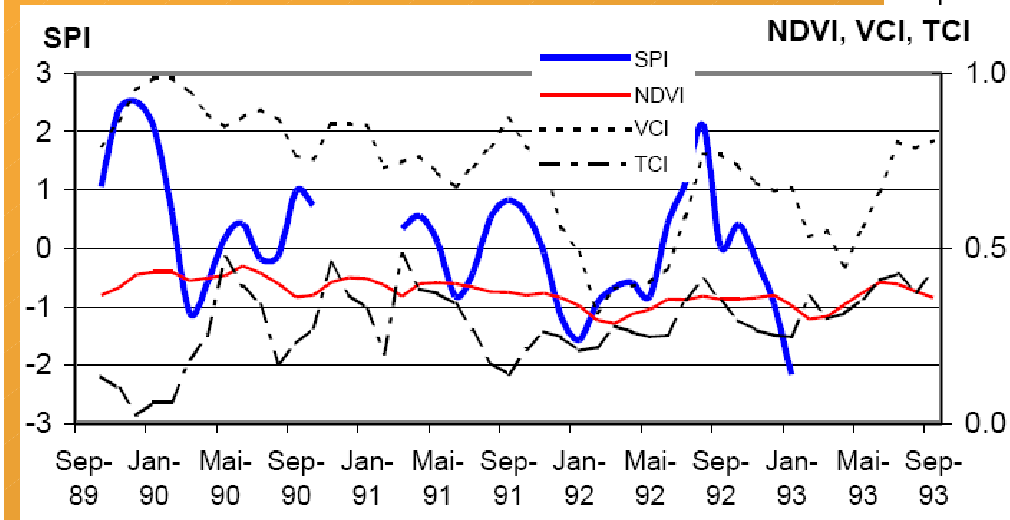
VCI vs NDVI and relation with SPI



Dry farming (71%)
Mean rainfall: 564 mm

Mean rainfall: 1020 mm
Forest (65%)





Mean rainfall: 503 mm
Irrigated agriculture (25%), grassland (25%), tree crops (20%) and forest (10%)

MAPPING DROUGHT

OBJECTIVES OF CARTOGRAPHY

- Inter-regional cooperation policies identification of shared problematic;
- Regional funded cooperation program identification and management;
- Phenomena scientific monitoring to preserve data and information on selected sites;
- Regional phenomena monitoring to support implementation of UN international conferences;
- Economic policies through incentives definition;
- National fund for public interventions management and monitoring;
- Funds allocation for mitigation of extreme events;
- Funds management for mitigation of extreme events;
- Disaster prevention trough the monitoring of vulnerable areas;
- Natural resources management and monitoring of reclamation interventions;
- Planning policies for sustainable development definition, management and monitoring;
- System modelling for phenomena impact assessment and forecast;
- Database management for thematic data;
- Characterization of scientific relevant sites to identify and collect data;
- Management of natural resources existing in protected areas;

ELEMENTS TO START THE REALIZATION OF CARTOGRAPHY

- end users
- objectives
- mapping typology
- spatial scales of representation
- classes for the characterization of the territory
- format of reporting
- methodology for the mapping production
- data required

GENERAL CONSIDERATIONS

- Spatial resolution and time span of the cartography should be able to describe a level of detail significant coherently with the proposed objectives and expected results (state-of-the-art and trend assessment)
- Input data must have a resolution coherent with resolution of final product
- It must be possible to replicate the cartography in time and space and consequently data must be easy to update in terms of data cost and time required for elaboration

PROBLEMS TO FACE FOR AN INTERREGIONAL MAPPING

- Portability of methodologies
- Data availability
- Degree of subjectivity of classification
- Standardization of information layers in different countries

TIME FACTOR

- the length of data series;
- the recentness of information to evaluate the state-of-the-art;
- the comparison of information in different times in order to assess trends;

DIFFERENT MAPPING TYPOLOGY AND SCALE

FOR DIFFERENT OBJECTIVES

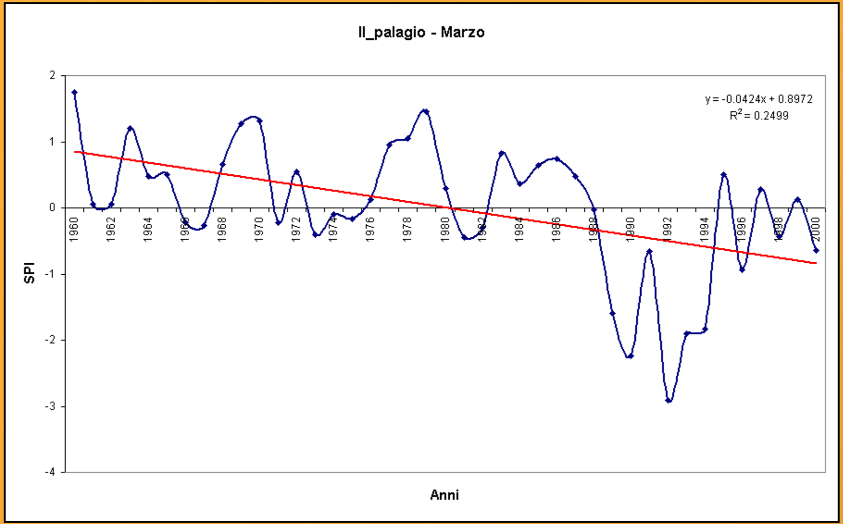
User	Level	Objective	Mapping typology	Scale
political decision maker	Inter-regional	Inter-regional cooperation policies	Inter regional characterization to support regional policies – synthesis thematic map	1 : 5.000.000 1 : 1.000.000
administrative decision maker	Inter-regional	Regional cooperation program management	Selection and monitoring of actions funded for inter-regional policies implementation	1 : 5.000.000 1 : 1.000.000
scientist	Inter-regional	Phenomena scientific monitoring	Characterization of limited areas that are significant and representative for the regional context - agro-ecological thematic map	1 : 200.000 1 : 50.000
technical user	Inter-regional	Regional phenomena monitoring	Monitoring of interregional dynamics of phenomena related to international conventions (UNCCD -UNCBD-UNFCCC...)	1 : 5.000.000 1 : 1.000.000
political decision maker	national	Economic policies through incentives	Identification of third level administrative units affected or sensitive to desertification – administrative thematic map	1 : 1.000.000
political decision maker	national	National fund for public interventions	Identification of administrative units affected or sensitive to desertification through a classification and characterization with fixed parameters or indicators (population density, level of land degradation) in order to obtain a hierarchy in funds allocation – administrative thematic map	1 : 1.000.000 1 : 500.000
political decision maker	national	Funds allocation for mitigation of extreme events	Identification of hardly affected zones (hot spots) with high socio-economical or environmental impact – agroecological thematic map	1 : 1.000.000 1 : 500.000

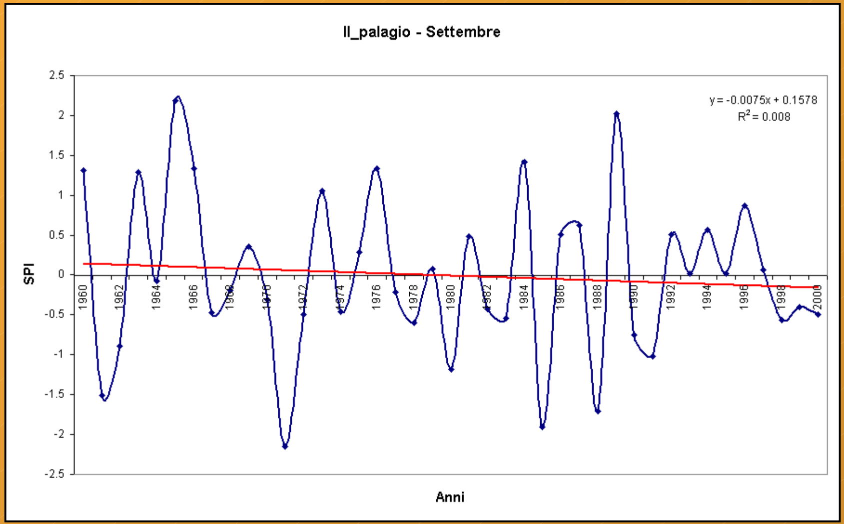
administrative decision maker	national	Funds management for mitigation of extreme events	Monitoring interventions in hardly affected zones (hot spots) – agro-ecological thematic map	1 : 1.000.000 1 : 500.000
administrative decision maker	national / sub-national	Operational disaster prevention	Identification and monitoring of areas vulnerable to degradation and disaster – agro-ecological thematic map	1 : 500.000 1 : 100.000
administrative decision maker	national / sub-national	Natural resources management	Classification and monitoring of the state of resources for planning of interventions – agro-ecological thematic map	1 : 500.000 1 : 100.000
political decision maker	national / sub-national / local	Planning policies for sustainable development	Classification of the territory as related to carrying capacities to establish limits in use – synthesis thematic map	1 : 500.000 1 : 100.000
administrative decision maker	national / sub-national / local	Planning policies management for sustainable development	Management of the territory as related to established limits on carrying capacities – synthesis thematic map	1 : 500.000 1 : 100.000
scientist	national / sub-national / local	System modelling for phenomena impact	Classification based on analysis of the dynamics and modelling from macro to micro-scale – synthesis thematic map	1 : 500.000 1 : 50.000
scientist	national / sub-national / local	Database management	Management of primary and secondary data – agro-ecological thematic map	1 : 500.000 1 : 50.000
scientist	local	Characterization of scientific observatories	Reference classification for analysis of the dynamics and process monitoring – agro-ecological thematic map	1 : 200.000 1 : 50.000
administrative decision maker /	local	Management of protected areas	Resources inventory – agro-ecological thematic map	1 : 200.000 1 : 50.000

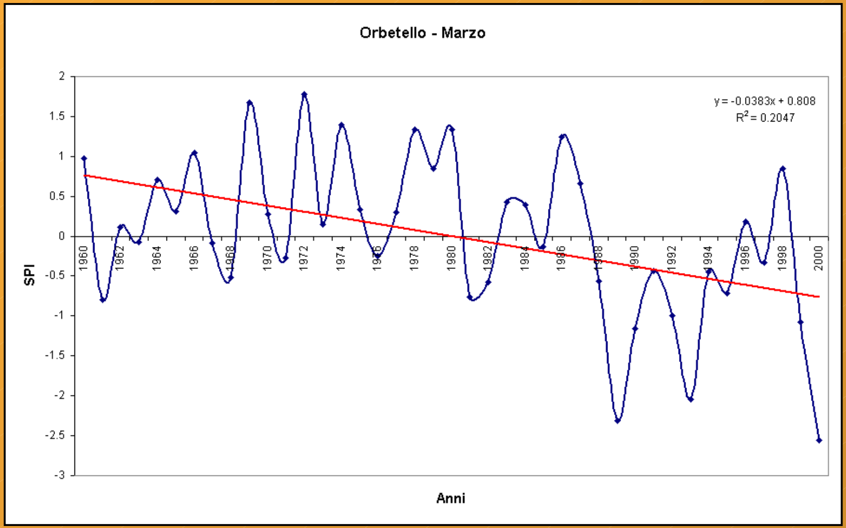
MAPPING DROUGHT INDICES:
THE EXAMPLE OF SPI

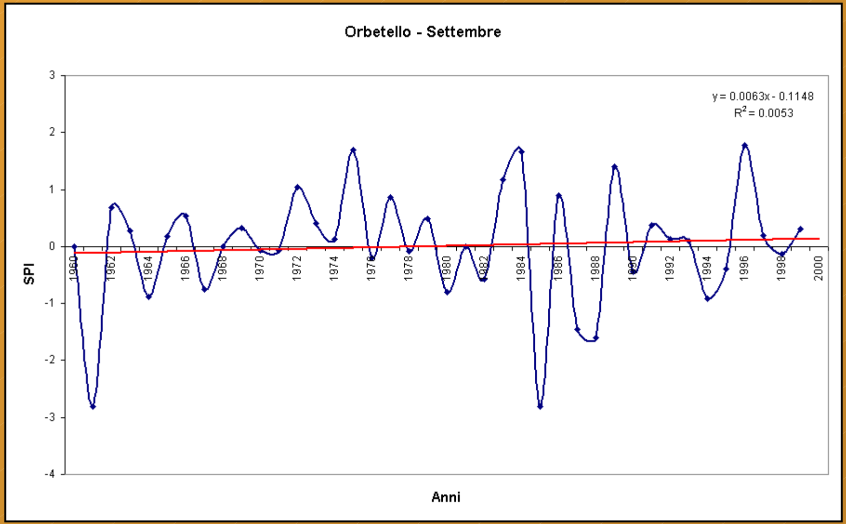
SPI MARCH

SPI SEPTEMBER









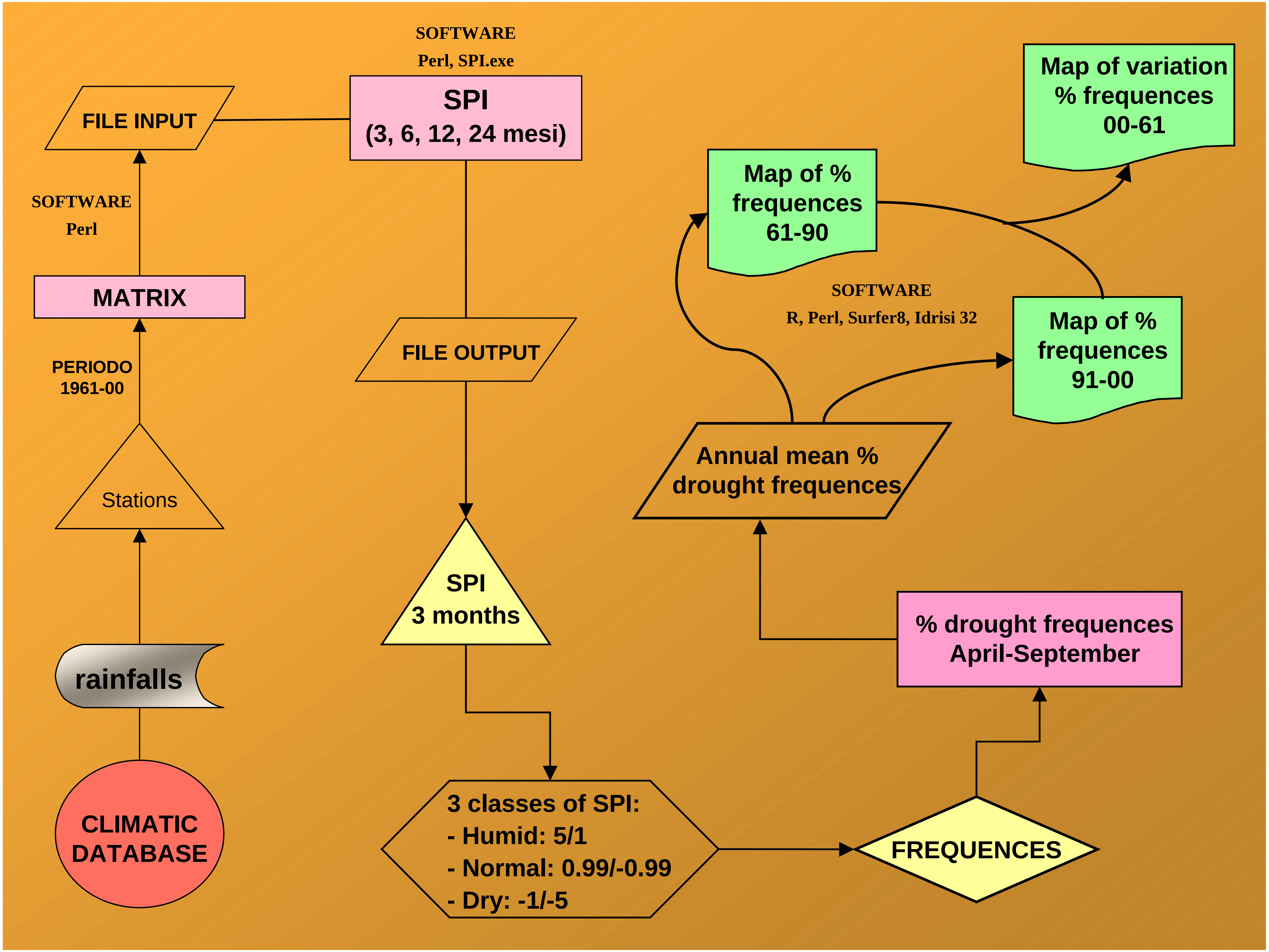
SPI frequences for Tuscany region

CONCATENA | = | =FREQUENZA(D2:D7;$B$9:$B$12)

	A	B	C	D	E	F
1	Anno	Mese	Abbadia_	ACQUAPE	Acquisti	Alberese_
2	1960	4		0.81	1.58	1.39
3		5		0.57	1.18	1.19
4		6		-0.29	0.4	-0.39
5		7		0.27	-0.1	-1
6		8		0.03	0.42	-1.72
7		9		1.64	0.61	-0.0
8						
9	Frequ	5	0	1	2	2
10		1	0	=FREQUE	4	2
11		-1	0	0	0	2
12	mesi_	-5	0	0	0	0
13	tot freq		0	6	6	6
14	% freq sicc		#DIV/0!	0	0	0.33333
15						

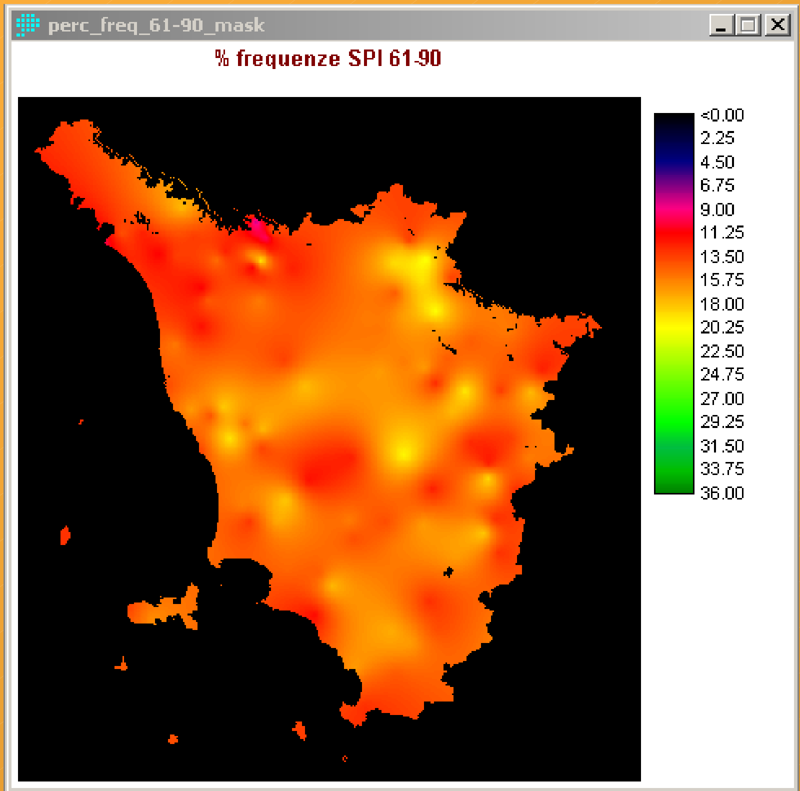
B35 | = | =MEDIA(B2:B32)

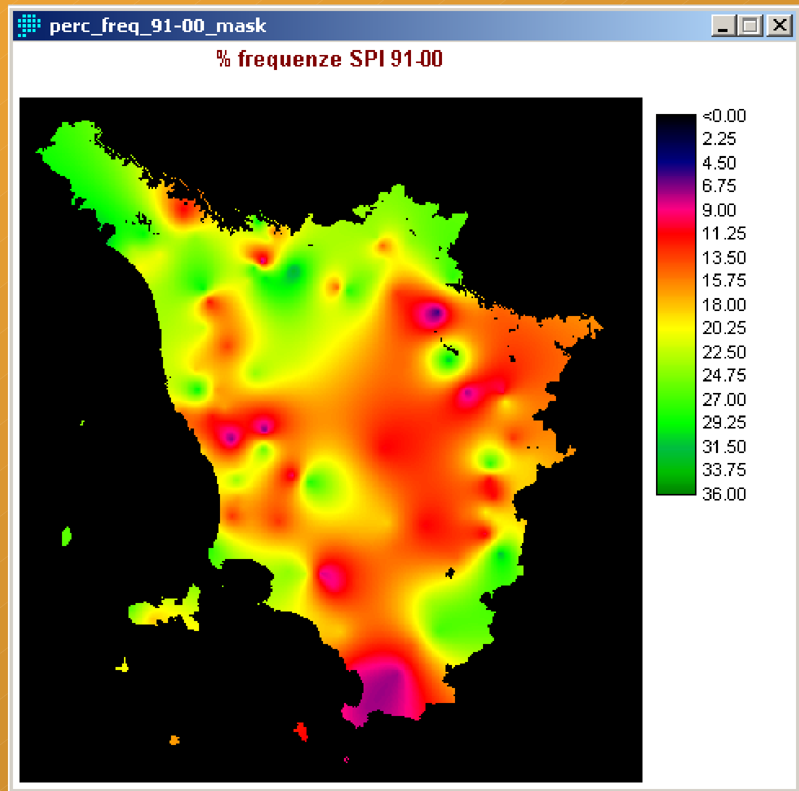
	A	B	C
25	1983	0.5	0
26	1984	0	0
27	1985	1	0.666666667
28	1986	0	0
29	1987	0.333333333	0.166666667
30	1988	0.166666667	0.166666667
31	1989	0	0
32	1990	0.5	0.666666667
33			
34	Conta_valori	30	28
35	Media % freq	0.1611111	0.1547619
36			
37			
38	Stazioni	media % freq	Conta_valori
39	Abbadia_montepulciano	0.161	30
40	ACQUAPENDENTE	0.155	28
41	Acquisti	0.177	31
42	Alberese_cas_idr	0.151	31


SOFTWARE
Perl, SPI.exe
SPI
(3, 6, 12, 24 mesi)
FILE INPUT
SOFTWARE
Perl
MATRIX
PERIODO
1961-00
Stations
rainfalls
CLIMATIC
DATABASE
FILE OUTPUT
SPI
3 months
3 classes of SPI:
- Humid: 5/1
- Normal: 0.99/-0.99
- Dry: -1/-5
FREQUENCES
% drought frequences
April-September
Annual mean %
drought frequences
SOFTWARE
R, Perl, Surfer8, Idrisi 32
Map of %
frequences
61-90
Map of %
frequences
91-00
Map of variation
% frequences
00-61

SPI FREQUENCES (SPRING-SUMMER)

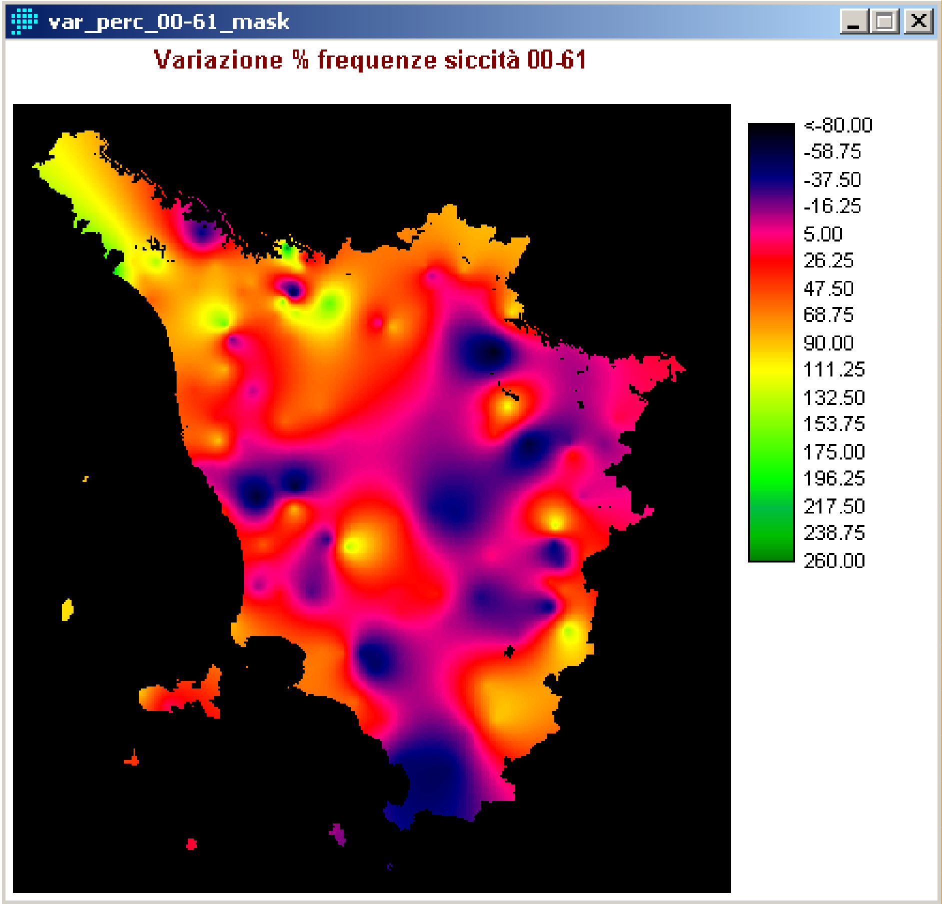
To map drought events or their frequency can be used the same geostatistical method applied for mapping rainfall (kriging), because of the nature of phenomenon:





VARIATION %
DROUGHT FRECUENCES SPRING-SUMMER

$$Var\_\% = \frac{(Freq\_91-00)-(Freq\_61-90)}{(Freq\_61-90)} * 100$$



<u>Negative</u> variation %

<u>Decreasing drought</u>

Positive variation %

<u>Increasing drought</u>