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Aspects of Drought Historical Analysis Accounting for Mitigation Planning: the Case of Apulia (Italy)

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Abstract

The paper presents the preliminary results of a research initiated to elucidate a historical perspective of drought events to be taken as a basis for outlining future drought planning horizons. The research falls in the framework of the strategies to combat land degradation in Mediterranean areas.

The work includes the application of the standardized precipitation index SPI (McKee *et al.*, 1993, 1995), to a southern Italian region (Apulia).

In particular, the magnitude, duration, frequency, location, and timing of the drought events are shown referring to an observation period of 80 years.

The Apulia region shares with the arid and semi-arid Mediterranean countries, similar problems and peculiar characteristics of importance to the analysis of drought disasters.

Therefore, the remarks inferred from the obtained results could be meaningful to the common solution aimed at planning the use of available water resources, which is particularly crucial in the agricultural sector.

Introduction

The course of drought events confirms the high vulnerability of many developed and developing countries of the Mediterranean basin.

Drought mitigation is thus a crucial objective in the region, where generalized though differentiated conditions of water crisis do exist because of water shortages (low water supply with respect to the minimum basic requirements) and water scarcity (unbalance between available supply and demand), exacerbated by population growth, food requirements, competing resource demand, accelerated over-exploitation, mismanagement of the available natural resources, and man-induced land change activities.

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Also in Italy, the meteorological conditions occurred in the last years, characterized by reduced precipitation especially in autumn and winter, have caused critical water supplies - not only in southern regions - with resulting strong conflicts for use and notable impacts on drinking water, agriculture, other production sectors, and on the environment.

The overall situation is further worsened by forecasts on future climatic changes.

The elaborated scenarios (De Wrachien *et al.*, 2002, de Wrachien and Ragab, 2003) showed how consequences might be aggravated in terms of variations of the different components of the hydrological cycle (evapotranspiration, intensity, frequency, distribution, concentration of precipitation, surface and underground flows, recharges of groundwater …).

The responses will have to be sought through new management approaches to the rapidly emerging degraded and increasingly vulnerable systems.

The issue of minimizing drought risks could be analyzed in the framework of the strategies to combat the global land degradation, effectively relying on the water resource management, because water is the key interconnecting link in the causative processes.

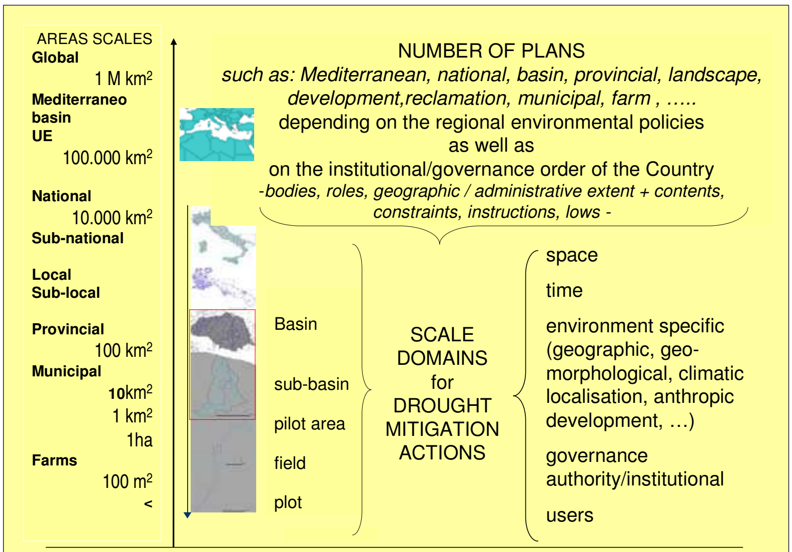
Taking into account the experiences acquired in the last 3 decades in this field, as well as the ongoing activities - undertaken at several levels within various multinational projects, with applications to different (large to small) scales - the following interlinked issues, among others, should be carefully considered when analyzing drought mitigation, which is the dominant component of the degradation management in the Mediterranean region:

- setting up a planning framework integrating drought assessments into all the pertinent levels (BOX 1), within which the conservation strategies are organized,
- the modality of using indicators and indices in the logical schemes, such as the DPSIR[3] (Driving, Force, Pressure, State,

[3] The plentiful activity undertaken to combat soil, land, water degradation largely founded on the use of indicators and indexes, operatively implemented in logical schemes, among which the DPSIR. The environment condition, in terms of quality/quantity of biotic and abiotic resources and related ability to sustain the societal demands (*State*), is resulting from human activities (*Pressures*), following primary causes (*Driving forces*). The *Pressures* trigger changes in the state thus originating impact on the conditions of environmental, social and economic security. The *Responses* from society to impacts, in turn influence

Impact, Response) framework, used by the European Environment Agency (EEA,1995),

- a "targeted" ecosystem assessment, as a precondition upon which the comprehensive natural resource management must be based.



BOX 1 - PLANNING FRAMEWORK

In such a context, and with emphasis to be given to national/sub national policies in mind, a base knowledge of past drought events, in terms of:

- areas affected,
- event characteristics
- interrelated processes (physical, economical, environmental, social, etc.),
- sectors damaged, and
- mitigation measures already applied,

is considered to be useful for:

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either the driving forces and/or the pressures, bringing a feedback mechanism that eventually modifies the impacts.
The DPSIR is proved to be particularly suitable for representing the environmental situation of a territory and understanding linkages between societal behaviour and the degradation or conservation of natural resources (Jesinghaus, 1999). However subjectively the classes of Driving forces, Pressures, State, Impact, Response indicators, are established depending on the aim of the analysis, their interactions still fall within a given, logical scheme for setting up management strategies (Trisorio Liuzzi, 2003).

- identifying the most appropriate "spatial/time/users" scales,

  - within which the drought-impacting and drought-impacted processes can be assessed,

  - within which mitigation planning methodologies should be selected, designed and implemented for different management applications,

- organizing the integrated use of the numerous and different indexes, among which to choose the ones most meaningful to the different needs of policy makers, water planners, agriculturalists, environmentalists, ecologists, socio-economists, etc.

Of course, a drought event causes hardly generalizable direct and indirect impacts in that they are strongly dependent on the physical characteristics of the event (severity, duration, spatial extent, location), as well as on the specificity of the locations of occurrence.

The impacts being referred to specific territorial contexts and anthropic activities, drought has multiple dimensions, from natural to social and economic, and that's why it falls within different categories of characterization, quantification and mitigation.

Such complexity gave rise to studies largely concentrating on both specific areas and specific impacts, which might not be generally applicable. Nevertheless, they may contribute to enrich the global perspective on the implications of drought disasters.

Therefore, some considerations are proposed relative to the preliminary results of an ongoing analysis performed in a region of southern Italy, Apulia, since they are not thought to be solely site-specific, but significant for other areas of the Mediterranean.

In fact, with arid and semi-arid countries, Apulia region shares similar problems of importance to drought (fragility of water resource, climate uncertainty, similar relationships between land use and amounts of water used in the various sectors and similar conflicts of use, similar hydraulic infrastructures, similar poorly effective management forms, and in the agricultural sector in particular).

Process framework

Drought is not univocally defined, since it is not a purely physical phenomenon, but needs to be assessed in the context of application. In general terms, it is considered to be a temporary event (differently from aridity, which is a permanent climatic configuration, limited to geographic areas of low average annual precipitation), leading to water demand conditions, for given uses, exceeding the available water.

Since rainfall is the main hydrological source that affects the supply/demand budget of most utilization systems, drought is accounted for as a deficit in precipitation with respect to normal values and to periods of variable length, which might impede meeting the water demand relative to human and environmental needs.

Since the event severity is dependent on the duration, intensity, frequency, spatial extent, as well as on the demands of available water resources, it was a common practice to identify drought from different points of view (meteorological, climatological, agricultural, hydrological, water management, etc), depending on the impacts it produces. Significant durations and extensions of water stress are correspondingly established and defined.

From the meteorological point of view, drought generally occurs over a certain period of time, namely when its amount is zero or below normal. It’s region-specific. The corresponding reference time interval is relatively short.

The socio-economic points of view relate the event to activity-specific factors.

For instance, if the precipitation deficit affects the amount of available water required for the growth of given crops in a given time, it is referred to as agronomic drought, the definition of which refers to the set of elements that characterize it: type of crop, growth stage, characteristics of the zone, etc. The time reference is defined on the basis of the crop water demand as a function of the production purpose, and thus extends over intermediate time spans.

When precipitation affects the surface or subsurface water supply (stream flows, water levels in lakes, aquifers, reservoirs, wells, etc.), drought is termed as hydrological. It is influenced by long periods of scarce or zero precipitation especially out of season. It doesn’t follow the same pattern as “meteorological” or “agricultural” drought, but anomalies in rainfall will have to be related to the global physical characteristics, land use, interactions between surface and groundwater resources, of the reference watershed.

Since drought is quantified on the basis of the complex interrelationships between the various components of the hydrological cycle and the impact on land, a large number of variables contribute to describe the process (precipitation, temperature, evapotranspiration, soil moisture, runoff, water levels in natural and artificial, surface or underground, water bodies, water abstractions, land cover, vegetation, land use patterns, socio-economic demands for water, etc.). Such variables differ in data characteristics, space and time dimensions as well as dynamics.

Therefore, indicators and indices to be used for its quantitative or qualitative assessment are many (Palmer Drought Severity Index; Deciles; Crop Moisture Index, Surface Water Supply Index, Standardized Precipitation Index, Percent of Normal, etc.) and differ by objectives, inputs and application modes.

Extensive overviews and detailed applications are available in the literature (Gibbs and Maher, 1967; McKee *et al.*, 1993-1995; Palmer, 1965, 1968; Shafer e Dezman, 1982; Vogt and Somma, 2000; Wilhite *et al.*,1987; Willeke *et al.*, 1994).

Appreciable experiences of national and sub-national (regional) integrated drought information systems do exist worldwide and in Italy too (Rossi and Cancelliere, 2002, Mendicino and Versace, 2002, calabretta *et al.*, 2002). They are organized for real time continuous monitoring of meteorological parameters, through the use of a number of different indices.

Focus Aspects

Despite the high number of indices, the space and time variability of the drought events causes difficulties in the generalization and coordination of their use in planning activities.

The related assessments, being the basis for drought monitoring and usually relative to very different land reference units (points, polygons, or administrative entities), reflect the variable nature of different temporal and spatial distribution and dynamics of the source data.

Drought, a complex subject by its own definition, includes several components (from monitoring to early warning systems, from risk assessment to mitigation planning and to the typologies of structural and non-structural measures, etc.).

Specifically, keeping in mind the goal of a comprehensive monitoring system, for it to be really effective for drought mitigation planning, the following issues among others (Wilhite 2003), might be worthy being discussed:

- the integration of climate and water supply data for comprehensive management aimed at verifying the existing supply infrastructures as well as identifying the most convenient new area-based supply interventions,

- the issue of "spatial/time/users" scales, within which planning methodologies should be improved, especially in view of the emphasis to be given to risk management and to national/sub national policies to be set up to face drought.

As for agriculture, production from rainfed areas - the first to be affected in that they depend on stored water - is directly influenced by precipitation, whereas in the irrigated areas, even in the absence of precipitation, it can rely upon storage in natural or artificial surface and underground water bodies (the same as other sectors like municipal supply, industry).

Independently of the future possible expansion of irrigated areas being still debated (Cosgrove and Rijsberman, 2000), the multi-faceted supply matter deserves further and in-depth studies,

Water supply, undoubtedly joined to demand-improving measures (even non-structural and based on the criteria of increasing water use productivity), still needs some improvements of the existing irrigation systems (rehabilitation, modernization, etc.) and hydraulic infrastructures (Hamdy and Trisorio Liuzzi, 2003), and also further investments for increasing water storage capacity.

Dams, water schemes, canals, aqueducts, wells, etc. will be certainly built, especially in those countries where basic needs are not met yet, also together with the implementation of small-scale decentralized, locally based projects, including water-catching and harvesting solutions at a much lower economic, environmental, and social cost. For them to be implemented (designed and maintained) with less investments, lesser costs, lesser environmental impact, and for them to last over time, their efficiency to meet the needs should be increased.

For this purpose, it is important to rely on indicators capable of highlighting information about the flow amounts and the water resource availabilities, as they change over time, over the territory depending on the user's needs.

Hopefully, a proper "set" of indicators and indices (representative of precipitation, surface and underground flows, densities and typologies of structures and infrastructures, water use patterns, land use, etc.) should be established.

Often, at the local and watershed scale, the amount of this resource can only be estimated, since adequate monitoring systems of surface and deep-water bodies are lacking. This doesn't apply solely to the Mediterranean developing countries.

This deficiency jeopardizes the results expected from the application of the tools (Water Protection Plans / Basin Plans) programmed for risk hazard areas, thus further aggravating the recurring effects of critical periods.

A further remark refers to spatial scales, within which planning methodologies, including all the aspects of natural resources management, should be set up.

The mitigation responses are organized upon relationships between competent stakeholders (from the Central to Local, including users), as well as through tools, explicated within an integrated procedure of preparation, processing, monitoring of programmes and plans.

Such programmes and plans – developed according to the governance/political scale, from the EU/Mediterranean, to the national, to the local levels - are the effective domains within which the drought mitigation interventions have to be implemented - geographically based and detailed for each level of planning tool (BOX 1).

In this scale-dependent organization, the interrelationships between drought and aspects of ecology, landscape changing, land degradation, socio-economic factors, etc., can be analyzed and implemented also in terms of indicators /indices for them to be effectively integrated in the overall strategy to combat land degradation.

It is in such a context that the measures and estimates of drought hazard and vulnerability have to be viewed to account for the articulate framework (BOX 2) of drought risk assessment (Wilhite, 1990, 1991, Wilhite, *et al*. 2000; Wilhite, and Svoboda, 2000).

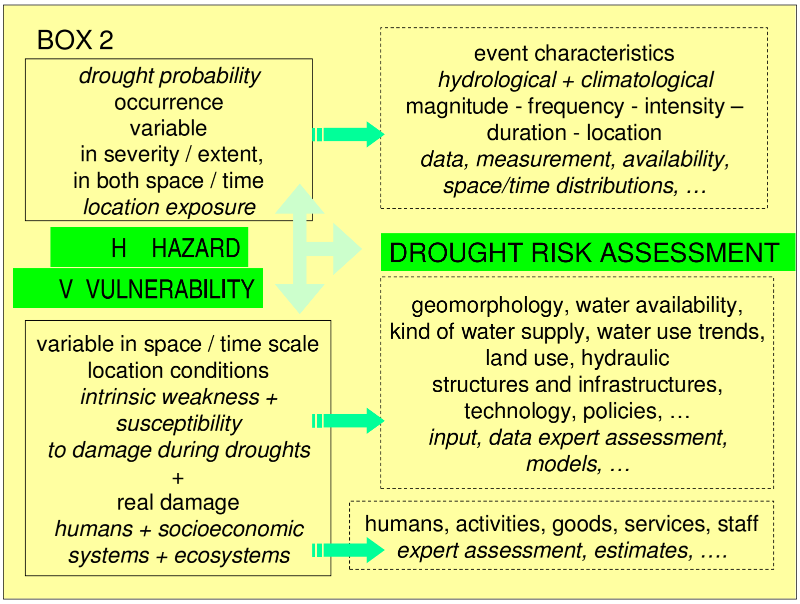
The Case Study

Since the appropriate assessment of the risk means not only improving the event forecast, but also a better understanding of the modes by which it is possible respond to drought, a base knowledge of past drought events, is considered to be indispensable for:

- checking, through back-analysis, the interrelationships between drought periods and areas affected, timing, impacted sectors and mitigation measures applied,

- identifying the most appropriate scale (time, space, users) for different management applications, and related planning tools,

- organizing the use of the different indices that can be chosen as meaningful to the different perspectives of policy makers, scientists, water planners, socio-economists and agriculturalists, etc.



To explicit a historical perspective capable of highlighting future drought planning scenarios, with particular attention to the above-mentioned aspects, a research was started in the Apulia region (South Italy), sharing with the arid and semi-arid Mediterranean countries, similar problems and peculiar characteristics of importance to the analysis of drought disasters as well as suitable for the dimension of its surface.
In particular, some preliminary results related to the first research phase are reported.
They concern the application of the standardized precipitation index SPI (McKee *et al.*, 1993, 1995), to the whole region, based on precipitation data recorded for a long observation period (1923-2001).
The SPI, well usable at different space/time scales, was chosen by its numerous advantages (rapid to apply, non limited to areas of homogeneous characteristics, representative of short and long-term situations, simply implementable in non-equipped areas, etc.) as well as for making considerations based on the knowledge of the realistic changes in water stress in time and space.

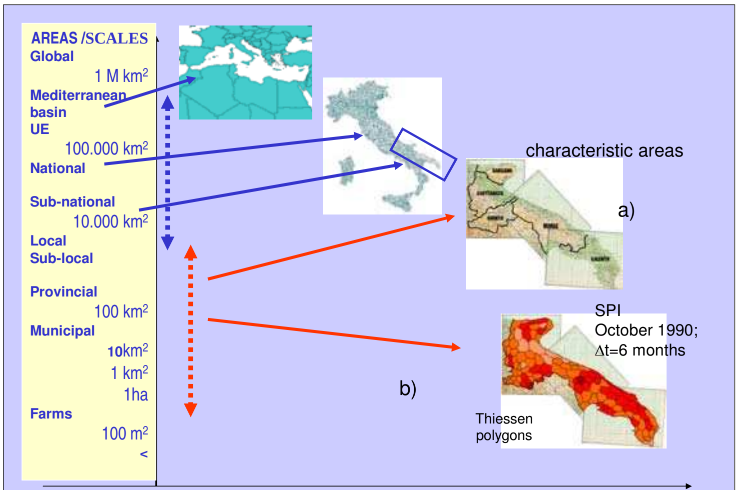
In the Mediterranean basin, Apulia region is a significant case by its peculiarities that distinguish it from other Italian regions[2].

In BOX 3, Apulia region is presented as being subdivided into characteristics zones, in terms of surface hydrology and hydrography. The land (19,400 km^2 approximate surface area) is for more than 70% used for agriculture.

The available water resource (20% of which stored in neighbouring regions) is well below total requirements, met by 4.5% by springs, 16% by consortium and regional wells that use underground waters, by 79.5% by storage surface waters (regional and extra regional storages). It is a region with very few watercourses, mainly ephemeral streams, and relevant groundwater stored in fractured carbonate rocks that were abundant in the past but are currently overexploited and intruded by seawater.

The region is subject to periods of rainfall scarcity that causes severe problems in water supply, with notable impacts especially on water for drinking and agriculture purposes.

The latest crisis occurred in winter and spring 2000 (and it affected also Basilicata, a region that supplies water to Apulia).



BOX 3 – Apulia region (South Italy). a) characteristic areas: 1) Gargano, 2) Capitanata, 3) Ofanto, 4) Murge, 5) Salento.

The effects produced on surface and underground water bodies, are significant for a region where irrigated agriculture is widely present. Together with the problems related to the integration of water supply with the demand, also the problems relative to planning (design,

[2] 2% of the regional surface is classified as Mountain (>700 m a.s.l.), 45% as Hill (300-700 m a.s.l.), 53% Plain (0-300 m a.s.l.).

management and regulation, maintenance) of existing or planned reservoirs, irrigation networks and systems are important.

The standardized precipitation index SPI

It is a probability index based solely on precipitation. It is simply defined as (McKee *et al.*, 1993) “the difference of precipitation from the mean for a specified time period divided by the standard deviation where the mean and standard deviation are determined from past records”. Its peculiarity is that it is designed to quantify the precipitation deficit for multiple time scales, therefore, it is used to represent the drought impact on water resource availability under various conditions, namely for short-term and long-term applications.

Multiple time scales are selected; Δt = 3, 6, 12, 24, 48 months are the typical ones, representing the precipitation deficits affecting the types of usable water sources. For example, the soil moisture content is influenced by precipitation anomalies over very short time intervals, whereas stream flows, groundwater and, even more so, dam storages are more affected by precipitation anomalies over longer time scales.

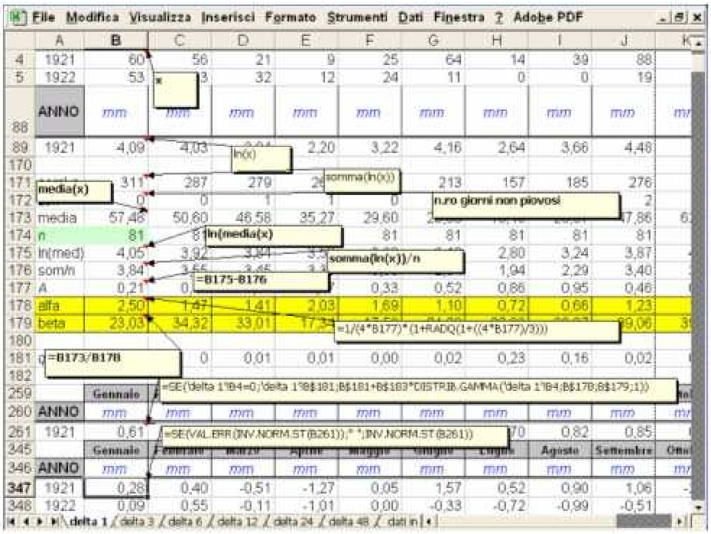
The sequence of calculation by Excel is summarized in BOX 4. The adopted classification is in BOX 5, where the values are shown in a chromatic scale to make the comparison of the data shown in the following figures more direct.

The index thus measures, respectively with positive and negative values, plenty and deficit precipitation with respect to normal mean calculated with respect to the selected time scale (Δt), and its variation indicates the intensity of drought.

The index is normally distributed and allows to compare the monitored wet and dry periods. For each time scale, each drought event (period in which SPI is continuously negative and SPI $\leq$ -1), can be defined through its duration (time from the beginning to the end), severity (SPI value for each month following the classification), magnitude (SPI sum for each month and for the duration of the event), intensity (magnitude/duration ratio of the event).

BOX 5 - SPI classification

SPI *VALUES*	*CLASSES*
≥ 2.00	Extremely wet
1.50 ÷ 1.99	Very wet
1.00 ÷ 1.49	Moderately wet
0.00 ÷ 0.99	Slightly wet / near normal
-0.99 ÷ 0.00	Slightly dry / near normal
-1.49 ÷ -1.00	Moderately dry
-1.99 ÷ -1.50	Severely dry
≤ -2.00	Extremely dry



box 4

Since drought has no unique definition, SPI is versatile, it is easy to interpret, has no limits of area applicability, and allows to define the event characteristics depending on the specification of the time scale. It can be used in analysis aimed to take into account monitoring results related to various observation periods from the seasonal to pluriannual ones, allowing assessments based on time/space differences.

Therefore, a significant potential is its possibility of being used in natural resources planning at various territorial scales and for various management goals.

Preliminary results

From 1921 to 2001, the SPI index was calculated for time scales of Δt = 3,6,12 and 24 months, for all the rainfall gauge stations of the Hydrographic Service, falling within the district of the Office of Bari (105 stations).

The elaboration seems to be rather significant because the available observation period is long and the missing data only, in some rare stations, slightly exceed 5%.

Figures 1a (an enlarged detail is given in BOX 6) and 1b illustrate some examples of the index pattern (relative to the time scale of Δt=12 months), whereas BOX 3 shows an example of zonal representation though *polygons* that can be used because rainfall data of the 105 observation stations and then the derived SPI index are homogeneous. This type of representation being referred to a particular index measured in a given period, can be useful for application purposes.

Since the SPI index showed a uniform pattern in the five characteristics zones into which Apulia was subdivided, it was possible to consider, for subsequent elaborations, a reduced number of representative stations for each zone (totally 19 stations instead of 105).

A subsequent elaboration made for each characteristic zone, aimed at highlighting the dry periods of some relevance since being characterized by a succession of "several" drought months and a given intensity, corresponding to the values of the index below –1 (that indicates the months ranging from moderately dry to extremely dry).

Then we identified the periods of several consecutive dry months with SPI index value ≤ -1, calculated for time scales Δt= 3,6,12,24 months. In particular, the minimum value of consecutive months was chosen to be equal to 4 for the index with time scales of Δ t =3 and 6 months, and equal to 6 months for the index with time scales of Δ t = 12 and 24 months.

The example relative to Δt = 6 months in figure 2a and the one relative to Δt = 12 months in figure 2b are illustrated. An enlarged detail of figure 2 a is given in BOX 7

From the analysis of the results it was found that:

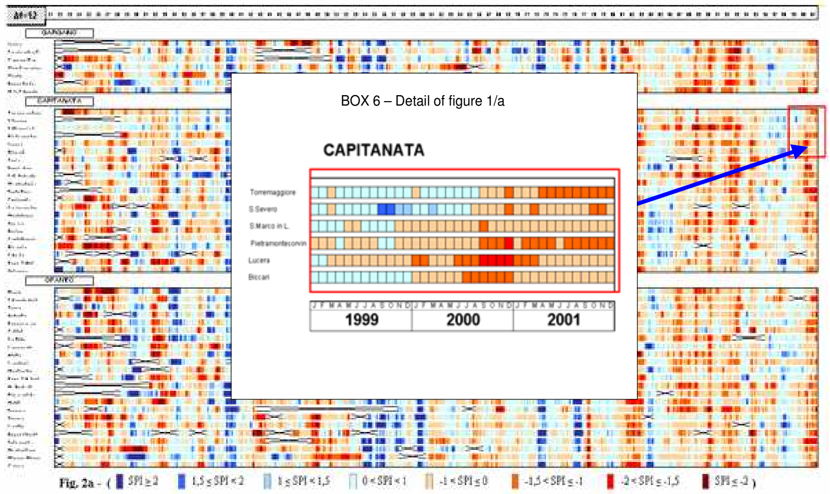


Fig. 1a. SPI indices for the whole Apulia region, calculated per time scale Δt=12 months and observation period 1921-2001.

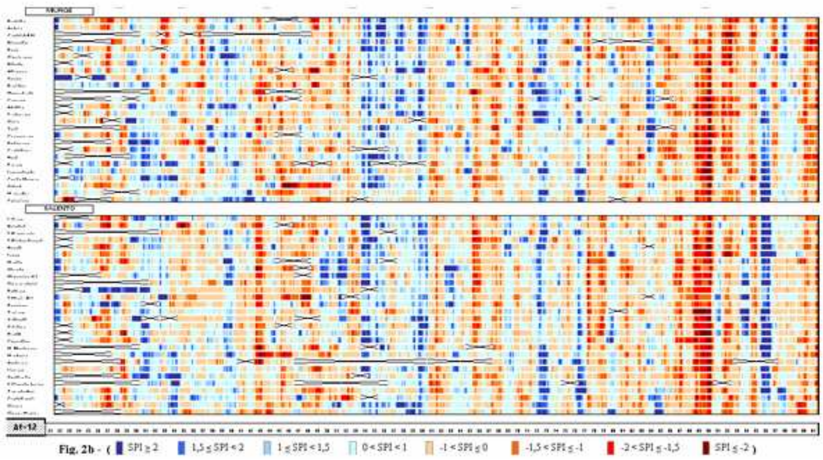


Fig. 1b – SPI indeces for the whole Apulia region, calculated per time scale Δt=12 months and observation period 1921-2001.

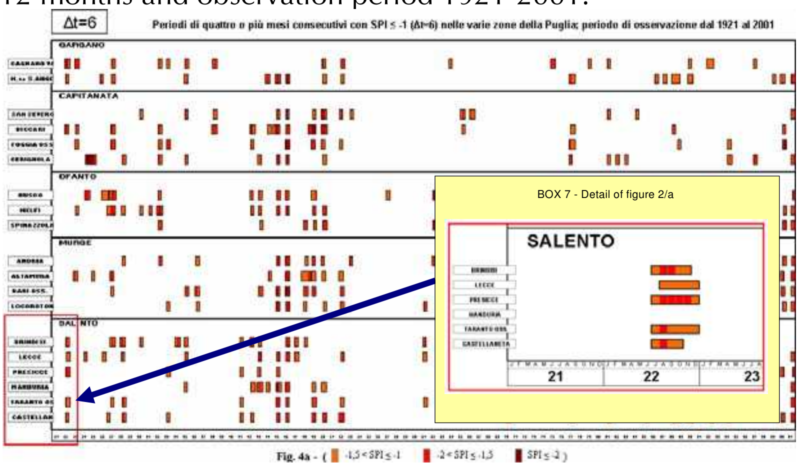


Fig. 2a. Periods of several consecutive months with SPI ≤ -1 in the period 1921-2001, for Δ t = 6 months

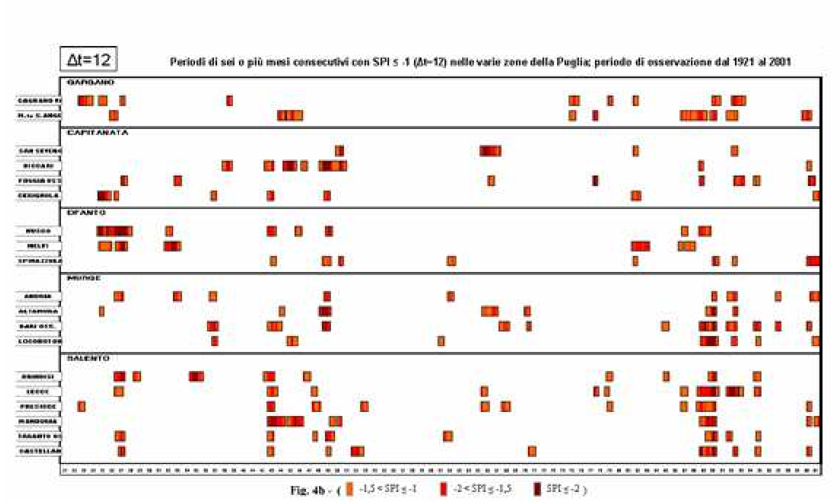


Fig. 2b – Periods of several consecutive months with SPI ≤ -1 in the period 1921-2001, for Δ t = 12 months.

1) Consecutive months with SPI ≤ -1 increase with the increase of the SPI calculation time scale. This depends on the structure of the index. In fact, for instance, for Δ t = 6 months even one month of abundant precipitation may cause an increase in the SPI index, the same rainfall for Δ t = 12 months cannot compensate for the scarce precipitation of the remaining months;

2) Over the whole observation period, there are some time intervals with contemporary dry periods over the whole Apulia region, corresponding to the periods 1923-27, 1942-50, 1988-93, and 2000-2001. In such intervals, the SPI index takes values ≤ -1 for a time sometimes greater than 48 months, especially for time scales of Δ t = 12 (fig. 2b) and 24 months, whereas for Δ t = 6 months (figure 2a), the consecutive periods, only sometimes exceed more than twelve months.

In the period after 1989, this "contemporary drought" caused a reduction in discharges measured at the staff gauge stations of the Hydrographic Service, characterized by the absence of relevant floods. This situation had led to imagine that storage capacity of the existing reservoirs had been over-designed. Only rainfall of late 2002 and early 2003 produced considerable flows in the watercourses with high floods, with peak values generally higher than the previously observed ones.

This is to stress how random drought is since it occurs more frequently and intensely in some periods.

3) The five considered characteristic zones share the same index pattern, with an initial period of thirty years starting from 1921

and another period corresponding to the last twenty years, during which numerous, sometimes intense drought occurred, alternated with a central period of thirty years in between, during which severe rainfall deficit rarely occurred.

To confirm such considerations, again for each characteristic zone, by dividing the long historical series of the rainfall data in the three above-said periods: (1921-50), (1951-80), and (1981-2001), for each period, the *n/m* ratio was calculated, where "*n*" is the number of SPI values ≤ -1, and "*m*" is the total number of months of each period, for time scales of Δ t = 3, 6, 12 and 24 months.

The results - an example of which is illustrated in the bar chart of figure 3/a - confirm the observation that, in the past, a period of high drought frequency (1921-1950) was followed by a more humid one (1951-1980), and subsequently another one referred to the last two decades of more severe drought.

In fact, all the graphs show that in the period 1951-1980, the *n/m* values are lower than those of the two other periods, with rare exceptions. The graphs show that the difference between the low *n/m* values of the central wet period, and the high values of the dry periods, decreases with decreasing Δ t.

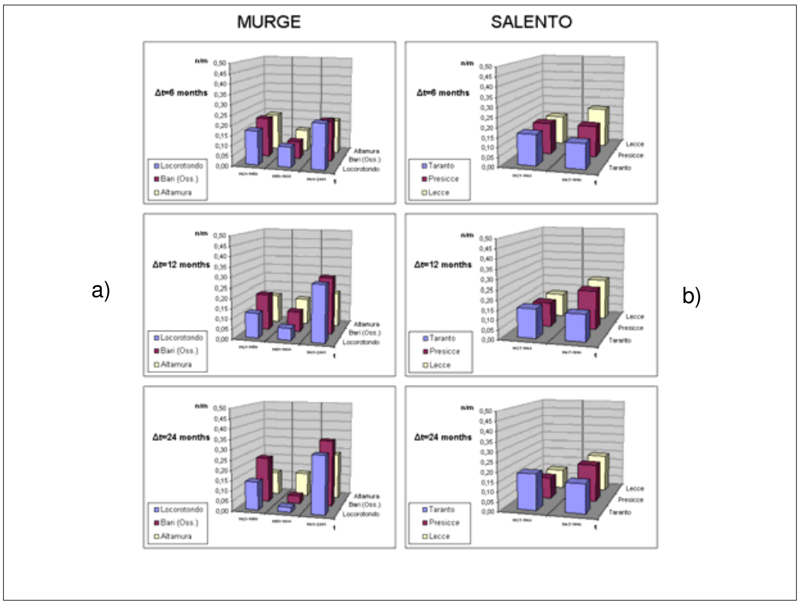


Fig. 3 – a) Frequency of dry periods in the Murge zone for Δ t = 6, 12 and 24 months; b) Frequency of dry periods for two thirty-year periods (Salento zone).

If we plot graphs of the same type, but relative to two different thirty-year periods, the first from 1937 to 1966 and the second from 1967 to

1996 (an example is given in figure 3b), a clear distinction is not generally evident between the two considered periods, nor the same homogeneity in results for the various zones, as observed in the graphs with three periods of about thirty years each (figure 3a). This indicates that the division of the historical series into thirty-year periods, starting from 1921, defines the periods of homogeneous behaviour.

As for the long-term trend, the elaboration of figure 3a, highlighting the presence of two dry periods with a wetter one in-between over the whole Apulia region, have confirmed the absence of a tendency to improving or worsening drought over the years, and this is conflicting with some case studies reported in the literature for other southern Italian regions.

One should underline that in these case studies, the prevailing tendential patterns of drought phenomena were obtained from very short investigated periods.

In fact, even in the case of Apulia (19 representative stations) assuming to consider a short period, for instance 52 years (1950-2001), a negative trend is observed (figure 4).

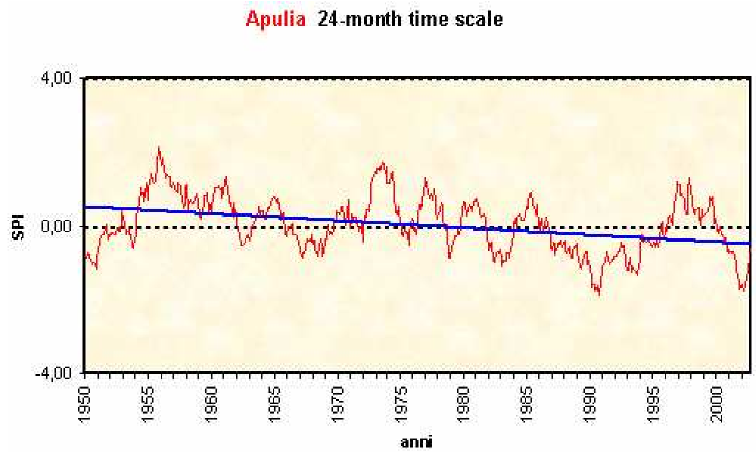


Fig. 4. Apulia: SPI trend for the long-term forecast relative to a "short" observation period (1950-2001)

If the elaboration also includes (figure 5) the years starting from 1923, the relative pattern of the indicator does not exhibit any trend.

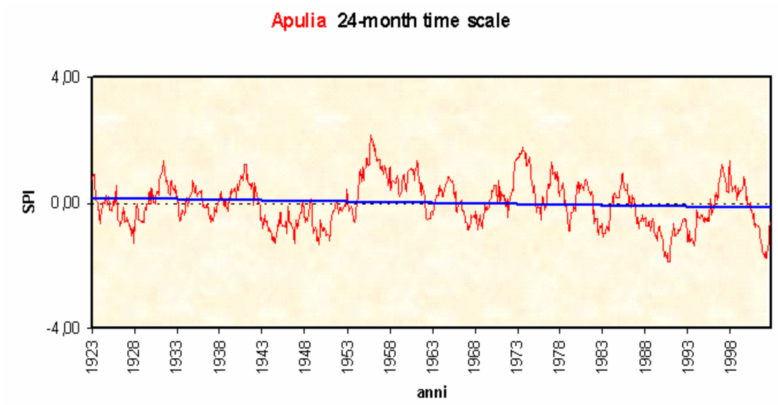


Fig. 5 – Apulia: SPI trend for long-term forecast relative to a "longer" observation period (1923-2001).

Also repeating the elaboration for the representative stations of Apulia, for instance those in figures 6, 6a and 6b, it is observed that the trend lines show the absence of a significant trend.

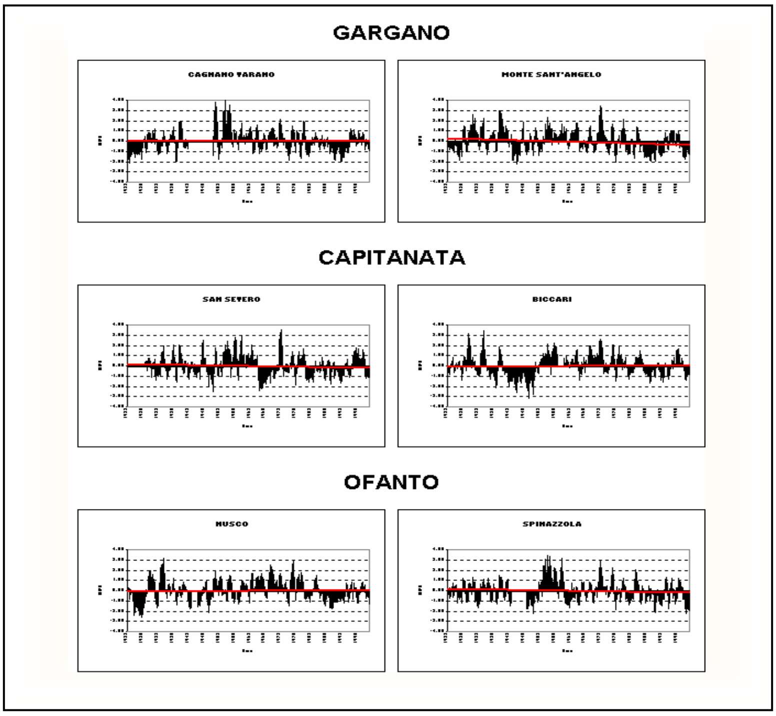


Fig. 6a – SPI trend for the observation period 1923-2001 for some stations in the areas of Gargano, Capitanata, Ofanto.

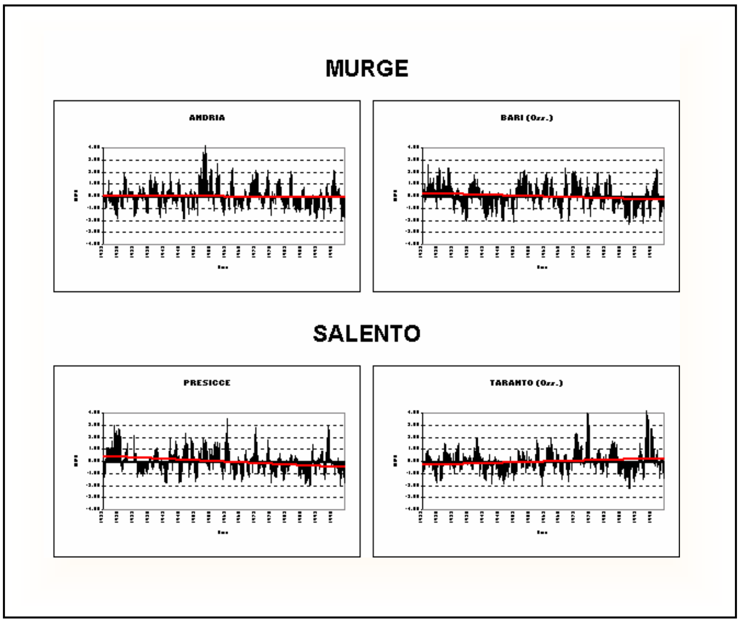


Fig. 6/b – SPI trend for the observation period 1923-2001 for some stations in the areas of Murge and Salento.

Also some research works carried out in Apulia (D'Agostino *et al*.1989,1993; Zanframundo *et al*.,1994) to check if during the frequent winter drought periods a trend due to climate changes was appearing, have pointed out the presence, in some stations, of three-month historical minimum values in the last two winter seasons of the considered historical series, but without stressing a significantly trend or cyclic occurrence of drought in winter.

Concluding Remarks

More intense and concentrated precipitation that by now occur together with non-rainy winter periods, interrupt meteorological drought, but not the hydrological one: the high precipitation intensity does not trigger notable infiltration, nor produces regular flows in the hydrographic networks.

Both the lack of seasonal rainfall, and its distribution over time contribute to determine conditions of water insecurity. The overall situation will be further worsened by climate changes.

If the response to this scenario will have to be sought through new water management approaches, deeper knowledge is required to understand drought risk in its different components and for the pertinent «space, time, users» scales.

A historical analysis of the exposure to drought hazard of the Apulia region, initiated with the purpose of verifying the time trends in occurrence and severity, and examining, in particular, the links between climate and water supply - based on duration, frequency and spatial extension of the past events - has highlighted that :

- Drought is random and occurred more frequently and intensely in some periods.

- Randomness of drought links the trend pattern to time interval of considered historical series.

These are the research findings from the first phase of the program.

The research is ongoing and is elaborating the SPI basic information data through spatial technologies and methodologies. SPI maps are being elaborated for each month and for each considered interval through GIS, in order to obtain the exceedance spatial probability of given SPI thresholds (hazard) to be combined with the thematic information related to vulnerability.

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