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DESERTIFICATION RISK IN SOUTHERN APULIA RAINFALL DECREASING ANALYSIS

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ABSTRACT

Southern Italy has been subject, during the past century, to a general decrease in rainfall more evident in recent years, especially in the southern part of the Apulia region. A territorial analysis based on rainfall and temperature data from 27 rainfall gouge stations for a period of 68 years (1928-96) has shown the intensity of decreasing rainfall trend and increasing aridity all over Southern Apulia. The analysis has shown that decreasing rainfall has a strong influence on groundwater recharge. This situation implies strong desertification risks for the area studied, specially in the Taranto district, also because of the risk of degradation of groundwater resources.

1. INTRODUCTION

Southern Italy has been subject, during the past century, to a general decrease in rainfall more evident during the last years especially in the southern part of Apulia. It is a phenomenon that has strong negative consequences on the availability of water resources and on groundwater recharge, especially in a mediterranean climate.

The Engineering Faculty of Taranto has been studying climatic changes during the last century in the Taranto district (Gelato, 1998; Racioppi, 2000) and their influence on groundwater resources recharge and desertification risk for a long time(Racioppi, 2000; Barbanente *et al.*, 2001; Simeone, 2001). The first results, related to the Taranto district, have been quite interesting and worrying. There has been an evident decreasing of rainfall since the beginning of the last century and a strong reduction of water available for groundwater recharge (Dragoni, 1998). This fact is a consequence of the fact that the groundwater resources recharge is related not only to the rainfall amount but also to their distribution during the year. In a mediterranean climate only winter rainfall can influence groundwater recharge in a significative way. Small decreasing of winter rainfall can extint the groundwater recharge. This sort of phenomena has a strong influence on water resources availability and quality in Southern Apulia where the only significative local water resource is the deep carbonate coastal aquifer (Cotecchia, 1977).

In relation to rainfall decreasing there is a groundwater demand increase, while groundwater resources are not recharged. This situation involves a large risk for groundwater resources degradation. The main Apulian deep carbonate coastal aquifer is really vulnerable to salt water intrusion in consequence of strong drawing and decreasing of recharge (Grassi & Tadolini, 1992). To evaluate these sorts of risks climate analysis has been developed for all Southern Apulia.

2. RAINFALL ANALYSIS

The area studied is the southern part of Apulia region in Italy, and particularly the Taranto, Lecce and Brindisi districts. Monthly rainfall and temperature data from 27 rainfall gouge station (Figure 1; Table 1) of the National Hydrographic Service have been analyzed. These stations are well distributed in the area studied so the result of this study can be considered a territorial analysis. They have been chosen, in a larger group of the rainfall gouge stations over the area studied, because a long series of rainfall and temperature data is available for them. Some of the rain gouge stations used in the study have been working since the last decades of the past century (Min. Lav. Pubbl., 1918; 1925). The longer data series is that of the Locorotondo station for which rainfall data since 1829 are available. The territorial analysis was developed covering the period 1928-96 because for this period rainfall and temperature data for all the stations considered are available. The study stops at 1996 that is the last year for which temperature and rainfall data from the National Hydrographic Service are available. The period of time considered is enough to develop significative and consistent analysis.

Table 2 shows the mean annual rainfall amount in the three districts under consideration. It is evident that they are quite different. The lowest value is that of the Taranto district: 550 mm/y; while Lecce district has the highest value of mean annual rainfall: 715 mm/y. The Lecce value is 30% higher that in Taranto. This is a farily big difference, specially in relation to the fact that the two district are really close and the morphology of both districts are quite moderate. The differences are related to the exposition. The Lecce district is a peninsula with exposition both on the Adriatic and Ionian seas, while the Taranto district has an exposition only towards the Ionian sea.

A rainfall map has been drawn to show rainfall distribution in the area studied . Using Thiessen topoietes method it has been possible to give to each rainfall gouge station an influence area. The area has been divided in 27 small areas each related to one of the 27 rainfall gouge stations considered. The map was drawn using 11 mean annual rainfall classes from 400 to 950 mm/year with steps of 50 mm/y. The map clearly shows the differences in the rainfall amount in the area. The lower values are in the central eastern part of the Taranto districts (Massafra, Taranto, Ginosa), while the higher values are in southern eastern part of the Lecce district. The more severe differences are between the Taranto station 464,8 mm/y and Minervino di Lecce where the mean rainfall amount is 854 mm/y, a little less than the double of the Taranto values. It also shows that there is a sort of continuous trend of increase in the rainfall amount going from the western to the eastern side of the area studied, and that in a small space with quite gentle morphology are possible strong variations of the rainfall amount as a consequence of the different geographical exposition..

To show the variation in the annual rainfall during the period studied two rainfall maps have been drawn. The first for the period: 1928-1957 (Figure 3a) the first thirty years ; the second one for the last thirty years 1967-1996 (Figure 3b) of the period under study. The comparison of the two maps show a clear decrease of rainfall in all the territory. This decreasing is really worrying because it happens in a territory characterized by low value of rainfall. It is also quite severe in relation to the short period of time considered in this study; some-times it is more than 15%-20%, showing that the climate is shifting toward drought conditions.

To evaluate trends in climate changes better, it is necessary to use a parameter that is not strongly affected by the natural annual variability of rainfall. The mean annual rainfall of a thirty year period has been used. Normally thirty years is a period of time which is considered long enough to obtain a stable value of the mean annual rainfall amount (Binnie, in Fasso, 1975). Significative percentage variations in this quantity can be considered an index of climatic changes.

Using, for each station, all the rainfall data available since the last decades of the XIX century, the medium annual rainfall amount of the previous thirty years $h_{30}(i)$ (thirty years mobile mean annual rainfall value) has been evaluated for each year:

$$h_{30}(i) = \frac{\sum_{n=1-29}^{i} h(n)}{30}$$

where $h(n)$ is the rainfall amount during the n-th year.

This quantity has been compared with the mean annual rainfall value of the last thirty years considered (1967-96) $h_{30/96}(i)$, using the percentage rate $R_{30/96}(i)$:

$$R_{30/96}(i) = \frac{h_{30}(i)}{h_{30}(1996)} \cdot 100$$

This quantity expresses the variation of the parameter $h_{30}(i)$ in relation to the value that the same parameter assumed in 1996, the last year for which rainfall data are available for the area. Values of $R_{30/96}(i)$ greater than 100 indicate rainier periods than the present one, while values lower than 100 indicate periods of greater drought. The variation of $R_{30/96}$ over the period studied express long time climate variations. The analysis using $R_{30/96}$ (Figure 4) show that decreasing in rainfall trends are sometimes really severe, specially in the Brindisi and Taranto districts (in Castellaneta more than 25 compared with the end of the last century). The decreasing is less in the Lecce district. Seen as a whole, the analysis has shown that during the last century a general rainfall decreasing trend is evident in the whole of Southern Apulia.

3. ARIDITY INDEX ANALYSIS

To show the drought arid characters of the area studied the aridity index that UNEP (1994) chose as parameter to evaluate the aridity of a zone was used:

$$I_A = \frac{P}{ETP}$$

where P is the mean rainfall amount, while ETP is the mean annual evotranspiration calculated using Thornthwaite procedure. UNEP has introduced 5 climatic zones corresponding to different values of I_A index (Tab 3).

In Table 4 the value of the aridity index in the stations studied for the period 1928-1996 is shown. It is evident that in all the area the aridity index is lower than 0.30. The stations of Massafra, Taranto, Grottaglie e Gallipoli can be classified as arid, while all the others are semi-arid. In good agreement with the rainfall analysis it is clear that the greatest aridity area is Taranto, while the highest value of the aridity index was measured in the eastern zone of the Lecce district (Maglie, Minervino, Ruffano, Presicce, Otranto, Vignacastrisi). In order to show the variation of the aridity index during the period studied, two aridity index maps were drawn. The first for the period 1928-1957 (Figure 6a), the second for the period 1967-1996 (Figure 6b). The comparison of the two maps shows a clear decreasing of the aridity index that implies an increase in the aridity of the area.

4. HYDROLOGICAL SURPLUS ANALYSIS AND IMPLICATIONS

To verify the influence of rainfall decreasing a simplified hydro-geological balance was used:

$$P = ETR + S$$

where P is the rainfall amount, ETR the real evotranspiration and S the hydrological surplus: the amount of water available for infiltration (groundwater recharge) and run-off. The percentage variations of S can be considered a qualitative index of the percentage variation of the amount of water available for groundwater resources recharge, so that low values of S can be considered an index of a little amount of water available for groundwater resources recharge.

Using the Thornthwaite-Mather (1957) method for the hydro-geological balance, assuming a medium field capacity value of 100 mm, for each year the value of S in each station and then the mean annual value has been evaluated. A map of the mean value of surplus has been drawn. Also in this case, in order to show the variation of surplus during the period studied two surplus maps have been drawn. The first for the period: 1928-1957 (Figure 6a), the second one for the last thirty years: 1967-1996 (Figure 6b). The comparison of the two maps show a clear decrease from the first to the second period of the water available for groundwater resources recharge.

This fact is really worrying because groundwater resources are the only local water resources available in this area. The main groundwater resource as the deep carbonate coastal aquifer that is really vulnerable to salt water intrusion. A decreasing in the recharge combined with an increase of groundwater demand can cause a strong salt contamination of this important groundwater resource. The decreasing of rainfall and the increase in water demand for irrigation create a strong withdrawal of water from the aquifer while groundwater is not recharged. This situation favours the alteration of the delicate equilibrium of fresh and salt water in coastal aquifer giving a progressive increasing of salt amount in the “fresh” groundwater. In this way groundwater withdrawal for irrigation has high salt quantity (up to 5 g/l). Many cultivations can tolerate this salty water, but over a long period the soil becomes salty and barren, creating a desertification risk.

5. CONCLUSION

The territorial analysis has show a situation of decreasing rainfall and an increasing of aridity over all the area studied. This situation implies a strong risk of degradation of groundwater resources for the area, specially in the Taranto district and then risk of the beginning of desertification processes. To minimize the negative effects of climatic changes and to reduce desertification process risks it an integrated approach to water resources management and valorization of secondary and not conventional water resources is essential.

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Annex

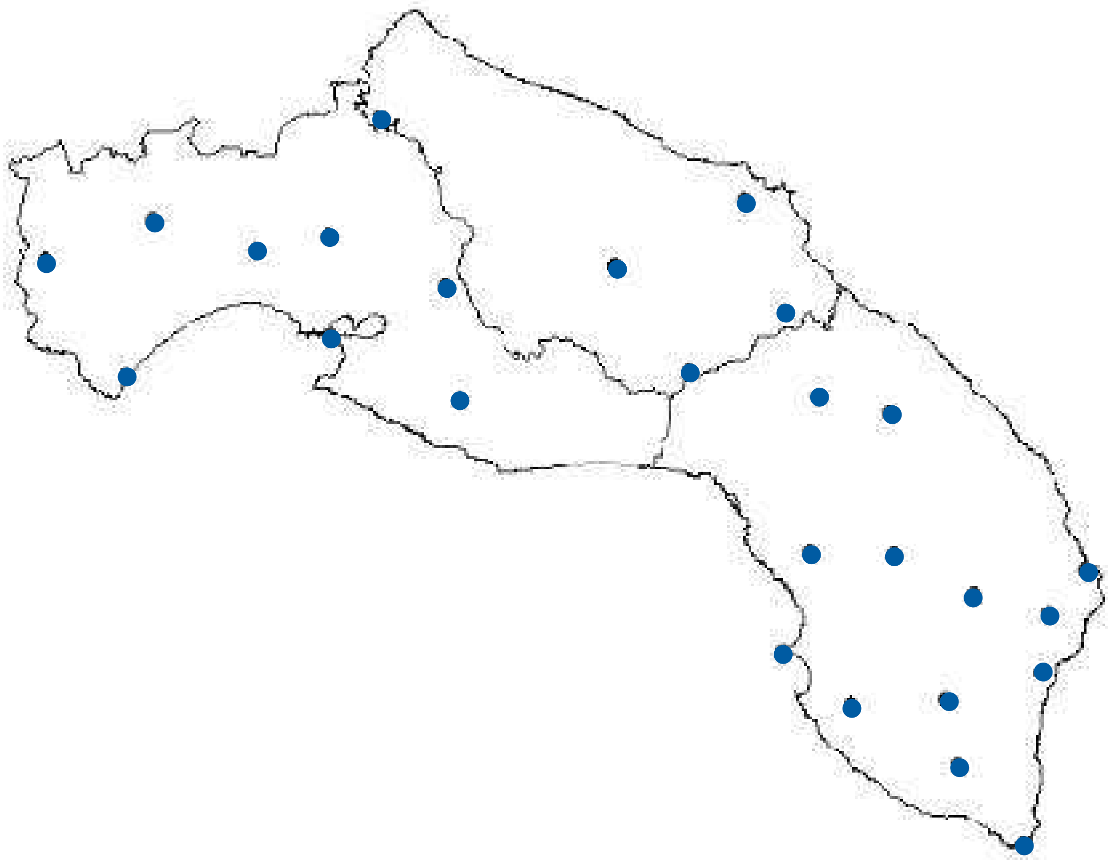

Fig. 1. The area studied and the rainfall gouge stations considered in the study.

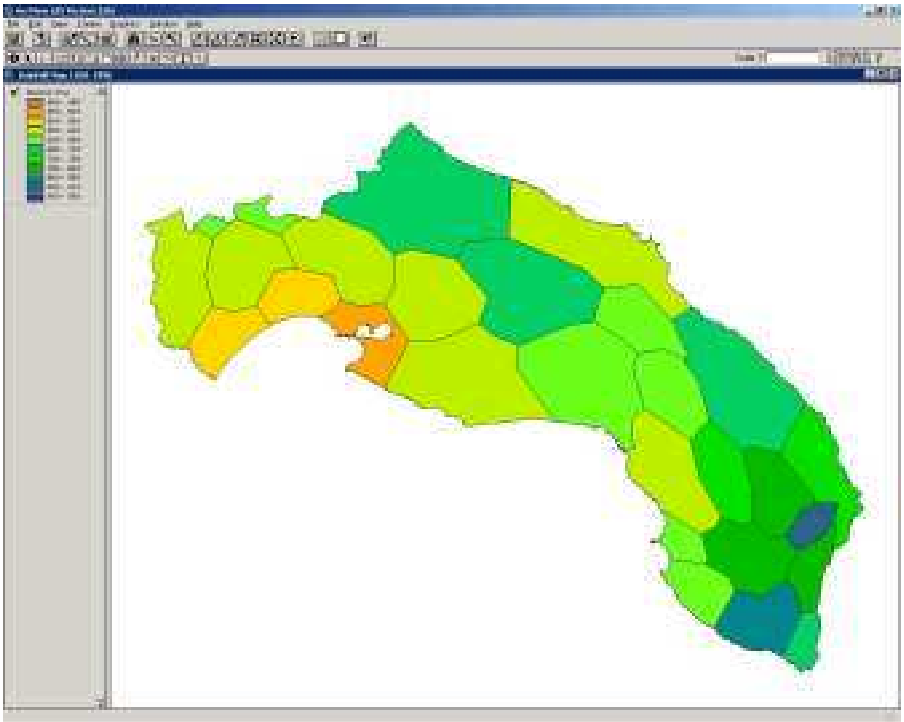

Fig. 2 - Rainfall map for the period 1928-1996.

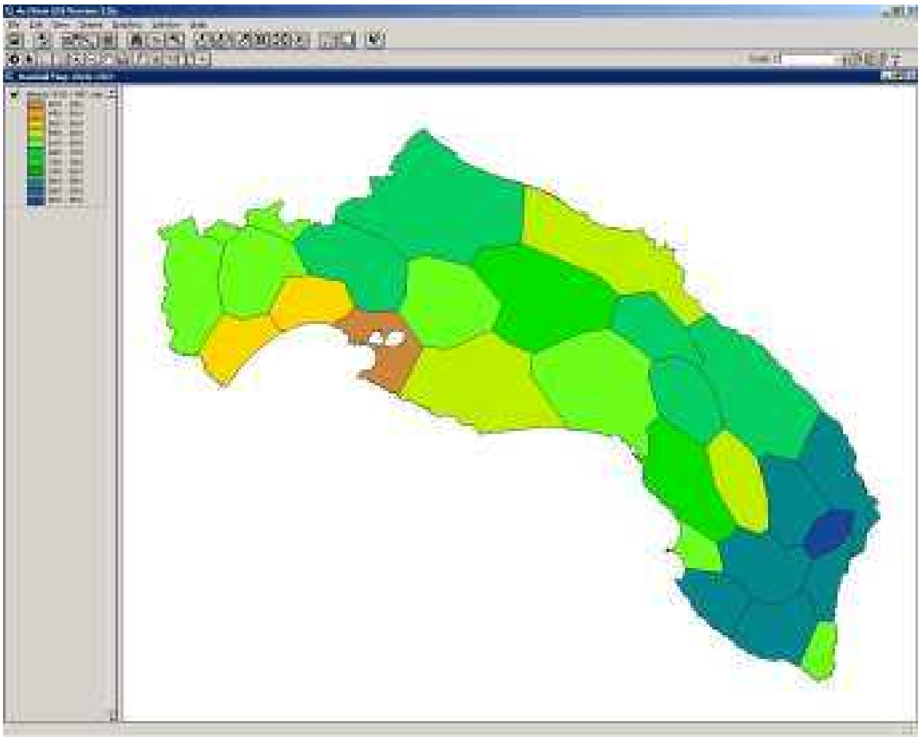

Fig. 3a. Rainfall map for the periods 1928-57.

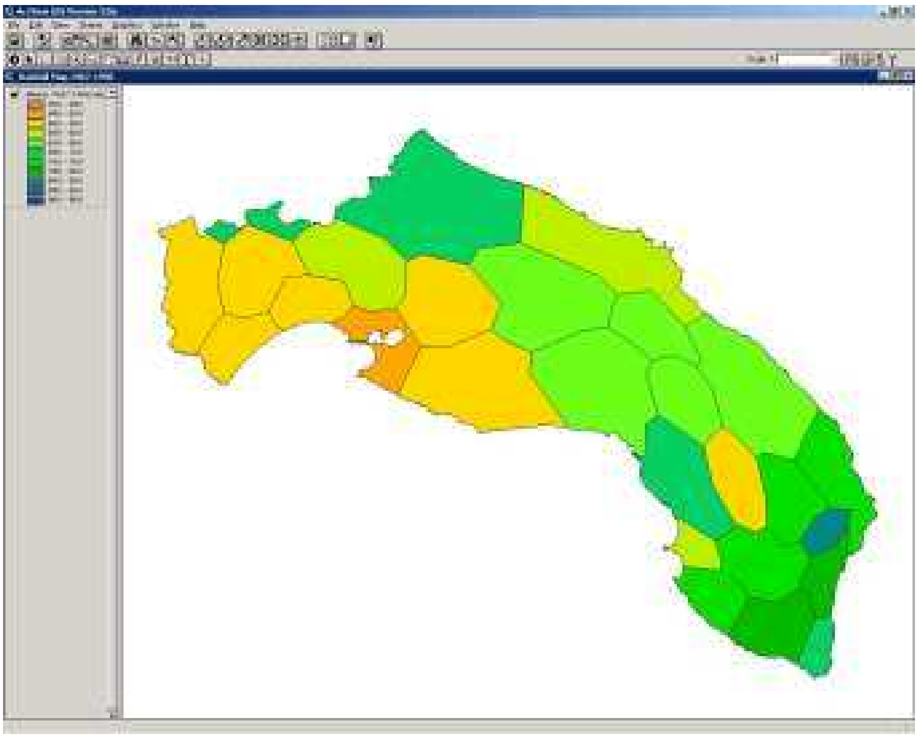

Fig. 3b. Rainfall map for the periods 1967-96.

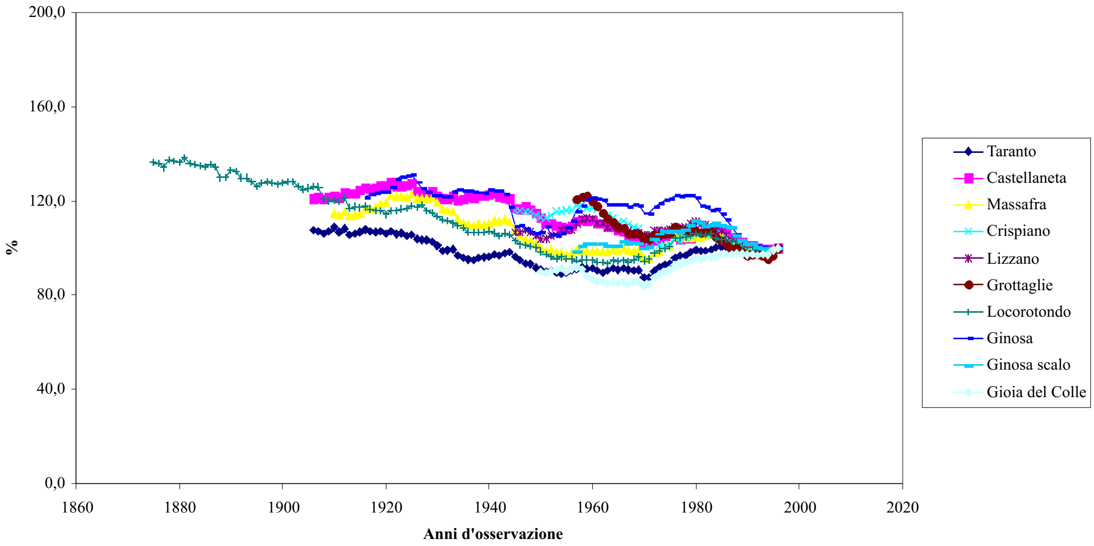

Fig. 4a. Percentage rate of the thirty years mean annual value for the stations of the Taranto district.

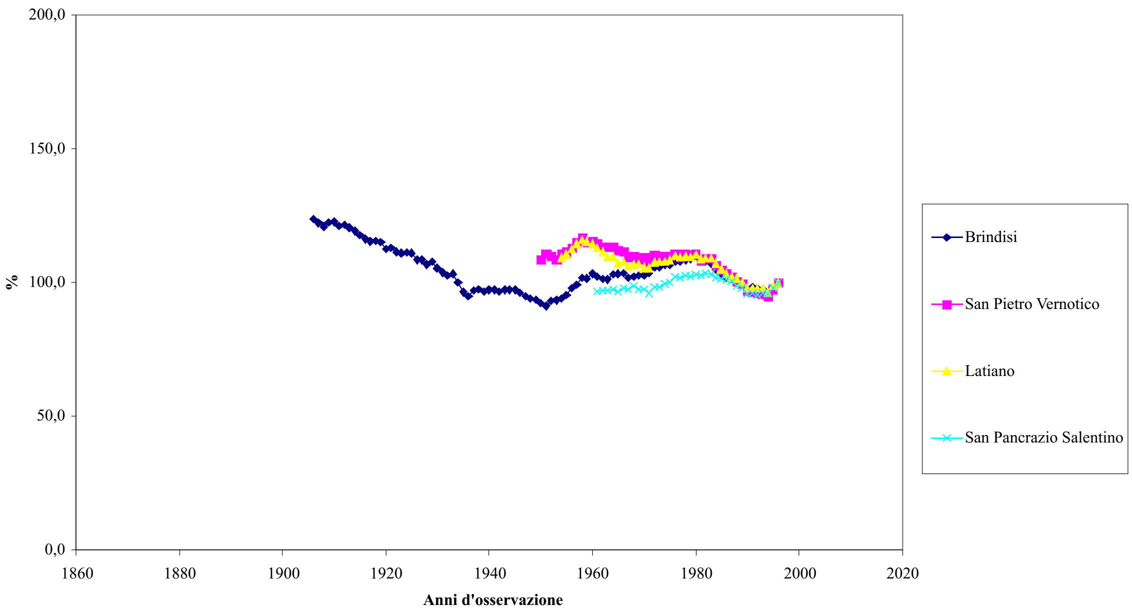

Fig. 4b. Percentage rate of the thirty years mean annual value for the stations of the Brindisi district.

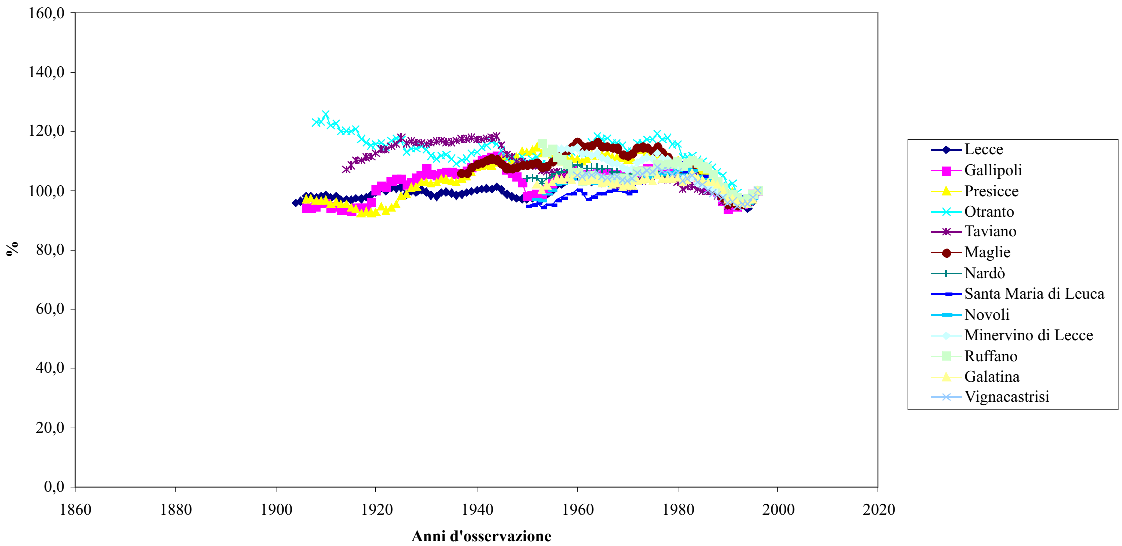

Fig. 4c. Percentage rate of the thirty years mean annual value for the stations of the Lecce district.

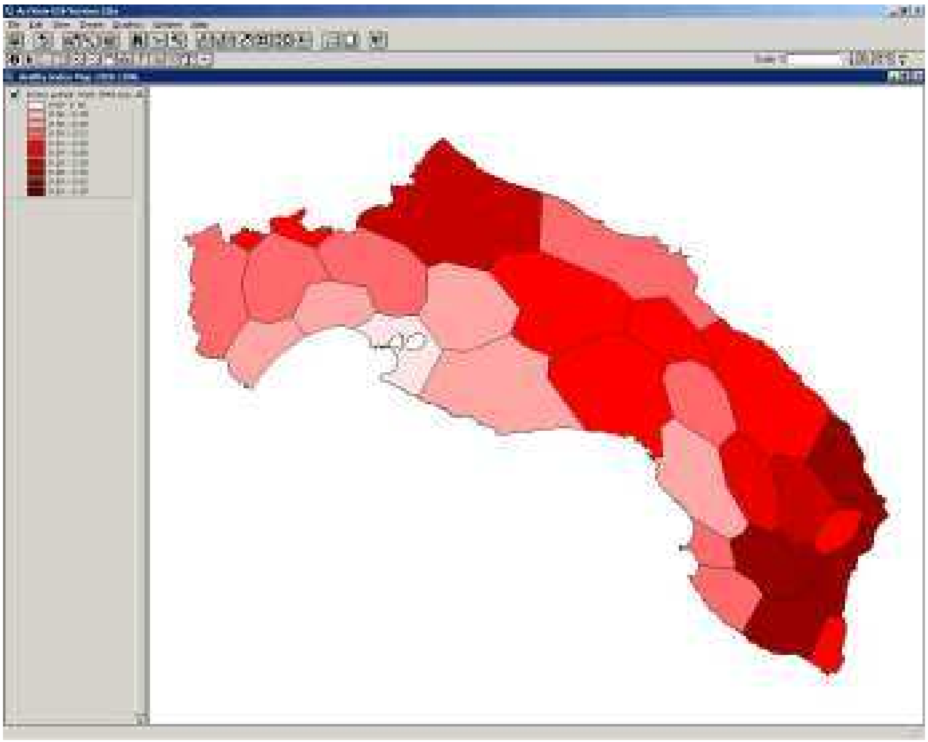

Fig. 5. Aridity index map for the period 1928-96.

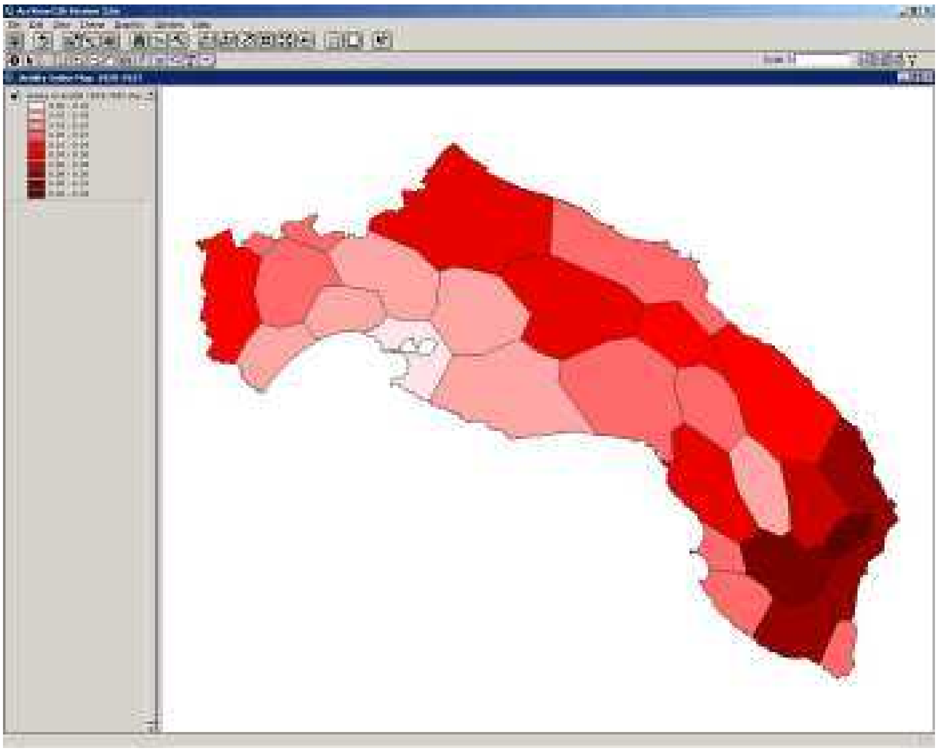

Fig. 6a. Aridity index map for the period 1928-57.

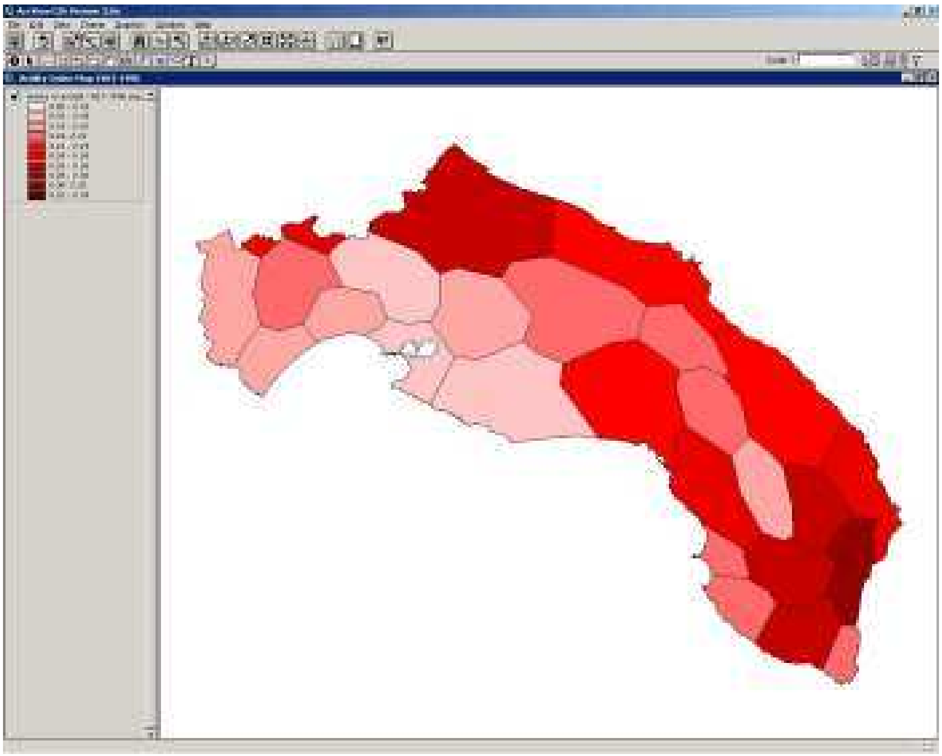

Fig. 6b. Aridity index map for the period 1967-96.

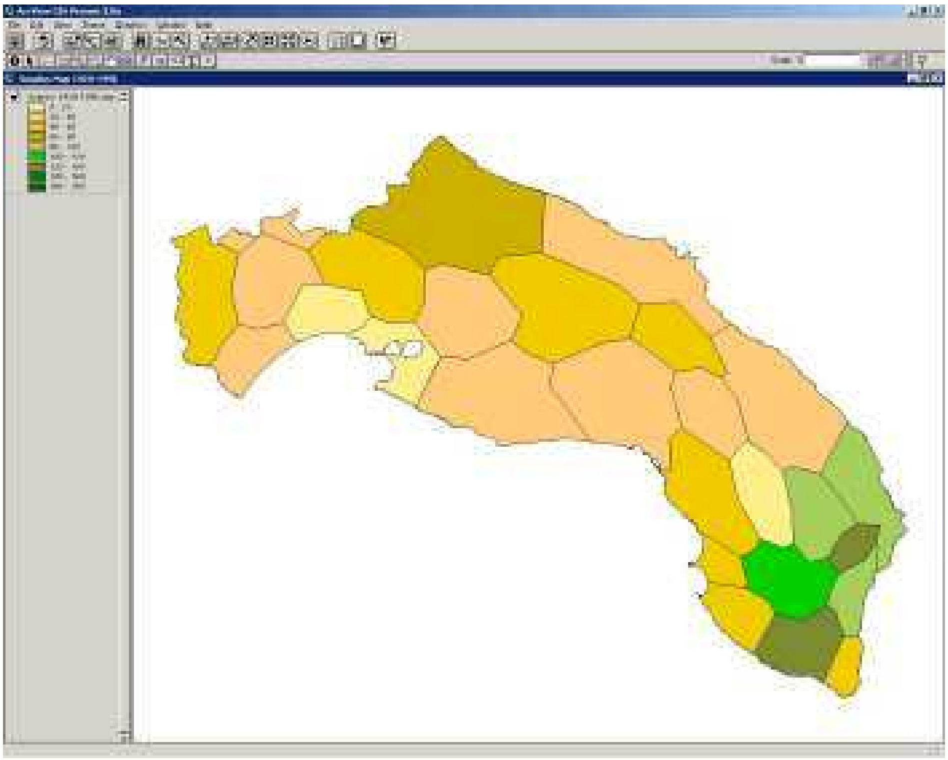

Fig. 7. Surplus map for the period 1928-96.

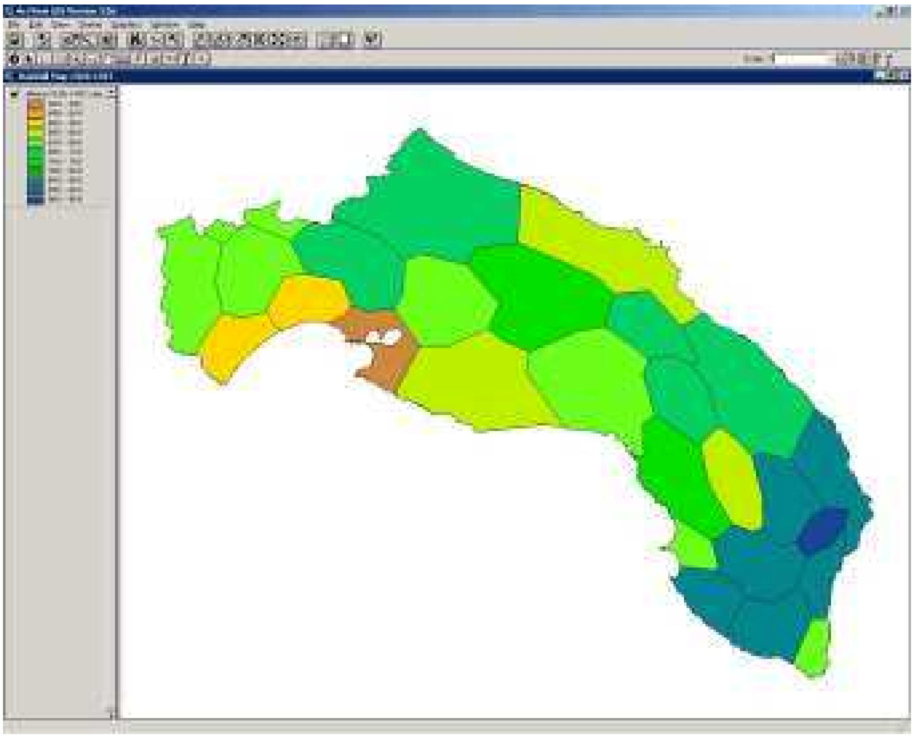

Fig. 8a. Surplus map for the period 1928-57.

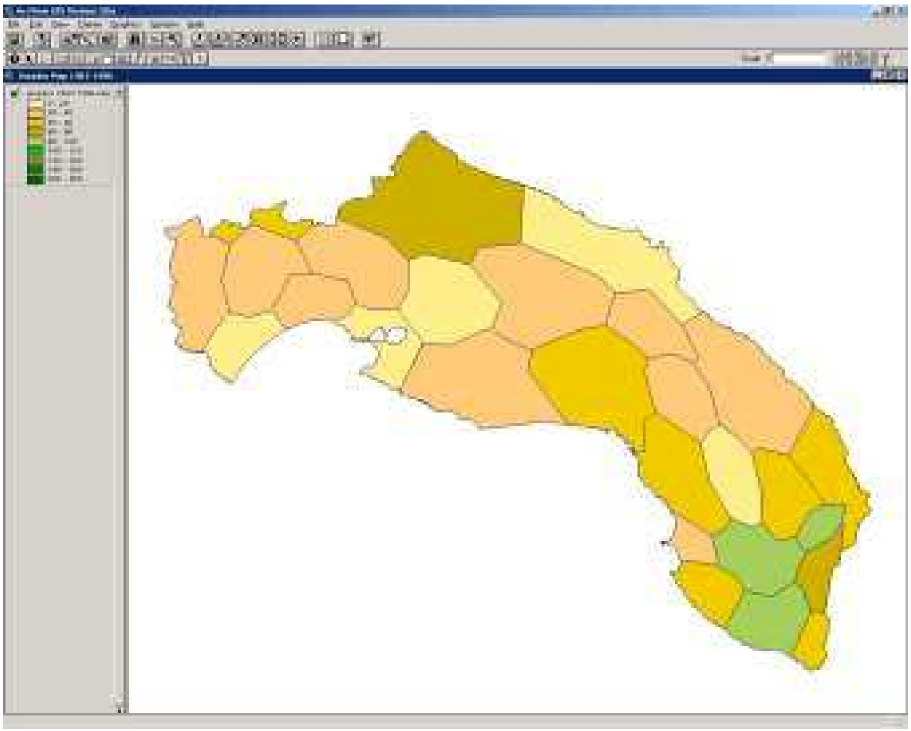

Fig. 8b. Surplus map for the period 1967-96.

Table 1. Rainfall gouge stations used for the present study.

	Station	District
1	Taranto	Taranto
2	Castellaneta	Taranto
3	Crispiano	Taranto
4	Ginosa	Taranto
5	Ginosa Scalo	Taranto
6	Grottaglie	Taranto
7	Lizzano	Taranto
8	Massafra	Taranto
9	Gioia del Colle	Bari
10	Locorotondo	Bari
11	Brindisi	Brindisi
12	Latiano	Brindisi
13	San Pancrazio Salentino	Brindisi
14	San Pietro Vernotico	Brindisi
15	Lecce	Lecce
16	Galatina	Lecce
17	Gallipoli	Lecce
18	Maglie	Lecce
19	Minervino di Lecce	Lecce
20	Nardò	Lecce
21	Novoli	Lecce
22	Otranto	Lecce
23	Presicce	Lecce
24	Ruffano	Lecce
25	Santa Maria di Leuca	Lecce
26	Taviano	Lecce
27	Vignacastrisi	Lecce

Table 2. Mean annual rainfall amount (1928-1996) in the Taranto, Brindisi and Lecce districts.

District	Mean rainfall amount (1928-1996) (mm/year)
Taranto	549.0
Brindisi	629.8
Lecce	711.5

Table 3. Classes of the aridity index.

IA	Climatic zone
< 0.05	Iperarid
0.05 – 0.20	Arid
0.20 – 0.50	Middle arid
0.50 – 0.65	Dry – sub-humid
> 0.65	Humid

Table 4. Mean aridity index values in the studied area (1928-1996).

	Station	IA
1	Taranto	0.16
2	Castellaneta	0.22
3	Crispiano	0.22
4	Ginosa	0.22
5	Ginosa Scalo	0.20
6	Grottaglie	0.19
7	Lizzano	0.19
8	Massafra	0.19
9	Gioia del Colle	0.24
10	Locorotondo	0.27
11	Brindisi	0.21
12	Latiano	0.23
13	San Pancrazio Salentino	0.22
14	San Pietro Vernotico	0.23
15	Lecce	0.23
16	Galatina	0.26
17	Gallipoli	0.19
18	Maglie	0.28
19	Minervino di Lecce	0.32
20	Nardò	0.21
21	Novoli	0.22
22	Otranto	0.29
23	Presicce	0.29
24	Ruffano	0.30
25	Santa Maria di Leuca	0.23
26	Taviano	0.21
27	Vignacastrisi	0.29