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DESERTIFICATION PROCESSES IN THE APULIAN IONIC COASTAL ZONE: CONCEPTUAL MODEL AND EMPIRICAL INVESTIGATION

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ABSTRACT

This paper deals with the assessment of desertification processes in the central-eastern Ionic coastal zone of the Taranto district, Apulia region, Southern Italy. The research followed two parallel directions: the outline of a conceptual model able to take into account the relationships between different factors influencing desertification, and the analysis of a selection of significant parameters referring to the specific study area.

The choice of the case study was based on the different following considerations. Firstly, it presents desertification risks due the climate because it is a dry sub-humid zone, classified in this way also in the World Chart of dry lands. On the other hand, it can be considered as a full scale laboratory for desertification risk processes as a consequence of its varied geologic and geomorphologic structure and the presence of some features common to Mediterranean coastal zones, i.e. maritime climate, conspicuous coastal ground water resources, types of agriculture cultivation and, to some extent, socio-economic structure.

The investigation of long term timeseries of climatic data highlighted a decreasing trend of total annual rainfall and, as a consequence of the Mediterranean climate, a much stronger reduction in the amount of rain that, penetrating into the ground, feeds the ground water resources. The parallel analysis of satellite images and statistical data showed a territory affected in the last forty years by conspicuous changes, above all in the coastal zones: i. patterns and rhythms of development, ii. growth of intensive agriculture practices, iii. consequent increasing water use in agriculture, iv. salinisation and impoverishment of deep ground water resources; v. massive and sometimes uncontrolled urbanisation processes.

The presence of these factors reveals the vulnerability of this territory with respect to desertification phenomena and the need for urgent, effective actions to tackle this problem. In particular, it calls for the implementation of integrated environmental management policies as solicited by international organizations and recent Italian legislation in the field.

1. PROBLEM FORMULATION AND BACKGROUND KNOWLEDGE

Desertification is a complex and broad concept that the recent UN Convention to Combat Desertification (INCD, 1994) has defined as a "process of land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variation and human activities".

The phenomenon, which initially revealed in arid areas, is spreading also in non-arid regions and, in particular, in the Mediterranean basin.

The problem drew international attention in the Seventies, when a long period of drought affected the Sahel countries in Africa (1968-1973). The first attempt to face desertification processes goes back to 1974, when the UN General Assembly passed two related resolutions: the former claimed scientific and technological international collaboration in fields relevant to control desertification and urged developed countries to assist desertification-prone countries to assimilate and apply available knowledge; the second called for a UN Conference on Desertification, which took place in Nairobi in 1977 and produced a Plan of Action to Combat Desertification. After this period of increasing concern about desertification,there followed a period lacking in significant initiatives. This issue emerged again as crucial in the Nineties: the two most remarkable events in this period are the UN 1992 Conference on Environment and Development and the UN 1994 Convention to Combat Desertification.

The great importance of the Rio Conference for desertification consists not only in the general spread of awareness of the urgency and complexity of environmental problems but also in the specific interventions that resulted. In particular, desertification was included in Agenda 21 Chapter 12 on "Managing Fragile Ecosystems: Combating Desertification and Drought". The 1994 Convention highlighted a crucial conceptual issue: desertification processes are influenced not only by physical factors but also by socio-economic ones, and it is just on these factors that it is possible and necessary to act especially in Northern Mediterranean countries included in the IV Annex to the UN 1994 Convention.

A number of recent studies deal with desertification in the Mediterranean countries. Medalus I (Mediterranean Desertification and Land Use) project tried to create quantitative models able to manage information on climatic change, water supplying, vegetation growth in the Mediterranean (Brandt and Thornes, 1996). Medalus II thoroughly analysed the aspects especially related to the integration of different components and to social and economic parameters. It tried to develop research at a large scale and a national level, using to this purpose techniques already applied at a small scale (Mairota et al., 1998). In the EFEDA project a number of pilot studies were carried out on the interaction among vegetation, climate and water resources in the context of soil erosion and desertification processes. Using a dynamic regional model, in the MODMED project, vegetation change and Mediterranean ecosystem degradation were evaluated. ERMES programme dealt with relationships between climatic change and land degradation also in the light of socio-economic and political indicators. ASMODE project, using data derived from METEOSAT, NOA and LANDSAT satellites, carried out two different assessments: one was related to the monitoring of equilibrium between water and energy, the second was connected to vegetation, soil and spectral reflectivity. D142E project considered the problem of assessing perturbations of hydrologic cycle and soil erosion in coastal zones.

2. THE CONCEPTUAL MODEL

The conceptual model on which the empirical analysis was based is derived from the FAO/UNEP provisional methodology (Krugmann, 1996). A fundamental reason determined this choice: as emphasized in the above-mentioned Chapter of Agenda 21 and other important initiatives to combat desertification, an integrated and coordinated information system based on appropriate technology and embracing international, national and local levels is essential for understanding the dynamics of desertification caused both by climate fluctuations and by human impact. In this perspective, to assume a common background model, of course to be adapted and specified according to local peculiarities, seems important to implement the system of bench marks and set of agreed-upon indicators to be monitored, which is required to combat desertification (Dregne, 1999).

Since the model was conceived essentially for developing countries, it was necessary to adapt it to a developed country: in particular, the study area is a densely populated region that, notwithstanding it being deeply embedded in the global market economy and thus presenting features characteristic of a consumer society as well as intensive agriculture practices and industrialisation, it still maintains some features typical of traditional agricultural societies. In the light of these characteristics, it is clear that the economic model is to be considered one of the main causes of land degradation.

The parameters that were eliminated or more profoundly modified are those peculiar to the specific context, in particular the socio-economic and biophysical ones. For example, the parameter concerning the use of biomass cannot be considered since it is a typical feature of some developing countries where other forms of fuel are still not available. Again, within biophysical indicators, those describing animal populations and their distribution must be taken into account with a lower degree of importance. Moreover, there are parameters that do not fit developed countries at all: just think of those related to transhumance and nutritional condition of population.

Desertification is a phenomenon that presents an intrinsic complexity for assessment. In fact, it is a broad concept, affected by multiple interrelated factors, with relevant processes presenting a multi-scale character. Moreover, it is difficult to select significant indicators, to measure them properly, and to single out correlations among them.

We tried to elaborate a model suitable for monitoring the state of a territory and to manage it from different points of view, according to an integrated planning approach.

In the conceptual model the indicators are divided into two macro-categories:

- physical factors (climate, land use, topography);
- socio-economic factors (water use, settlements, human and biological factors, social factors).

The following schematic diagrams show how the parameters interact with each other. Anyway, it is important to make it clear that cause-effect relationships are not so linear as would seem from the diagrams, especially as far as socio-economic parameters are concerned. It is clear that the significance of different factors should be defined in close relation with the territory to which they refer. For example, in a coastal zone the parameters related to seasonal population or salinization of deep ground water table assume crucial importance for degradation processes.

As far as physical factors are concerned, temperature, length of daylight and rainfall determine evapotranspiration that, together with permeability, land use and surface runoff (that is, in its turn, determined by precipitation) influence rain erosion. Wind characteristics (speed, direction and frequency) determine the presence of vortices that, together with sand and dust storms, rain, soil granulometry and land use, affect Aeolian erosion. Surface, textural and structural properties condition soil permeability that, together with alkalisation/salinisation, erosion and fire, bears upon soil fertility. Slope, vegetation cover, geomorphologic asset, typology and soil resistance determine the presence of landslides.

Within socio-economic factors, areas equipped with hydraulic structures, but also road infrastructures, together with the quantity of available water, influence land use, which, in its turn, together with infrastructures, is linked to Gross Domestic Product per capita.

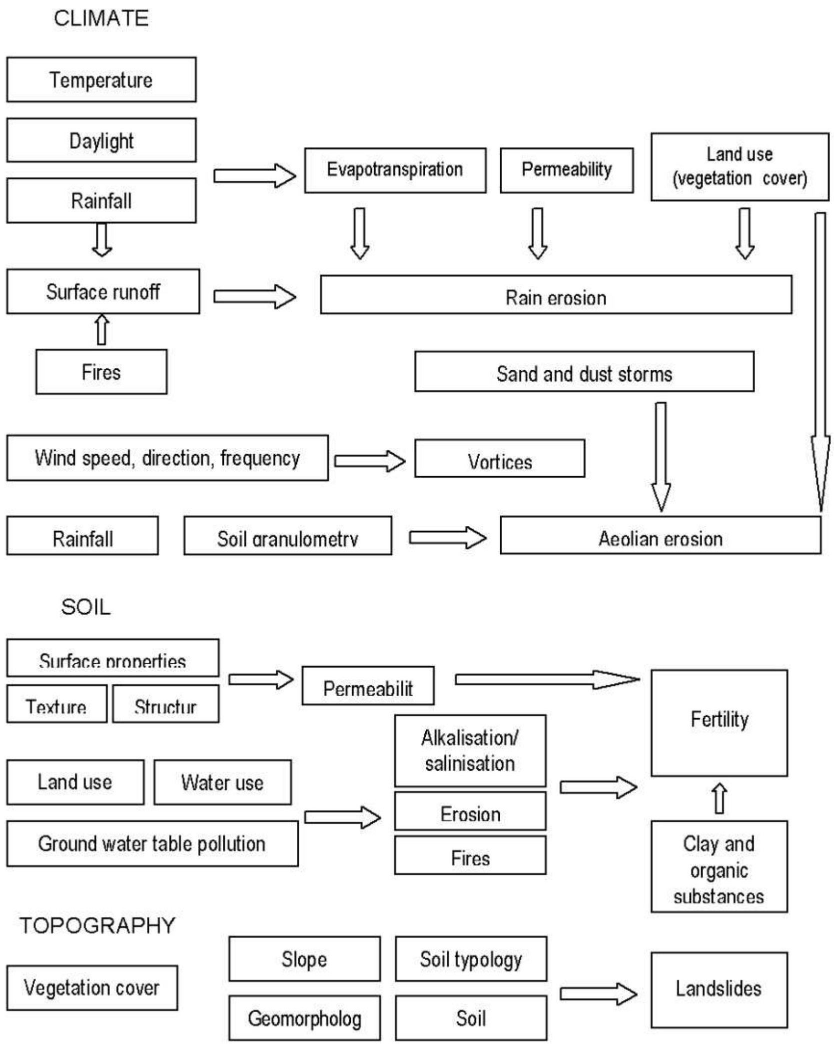


Figure 1. Conceptual model: physical factors

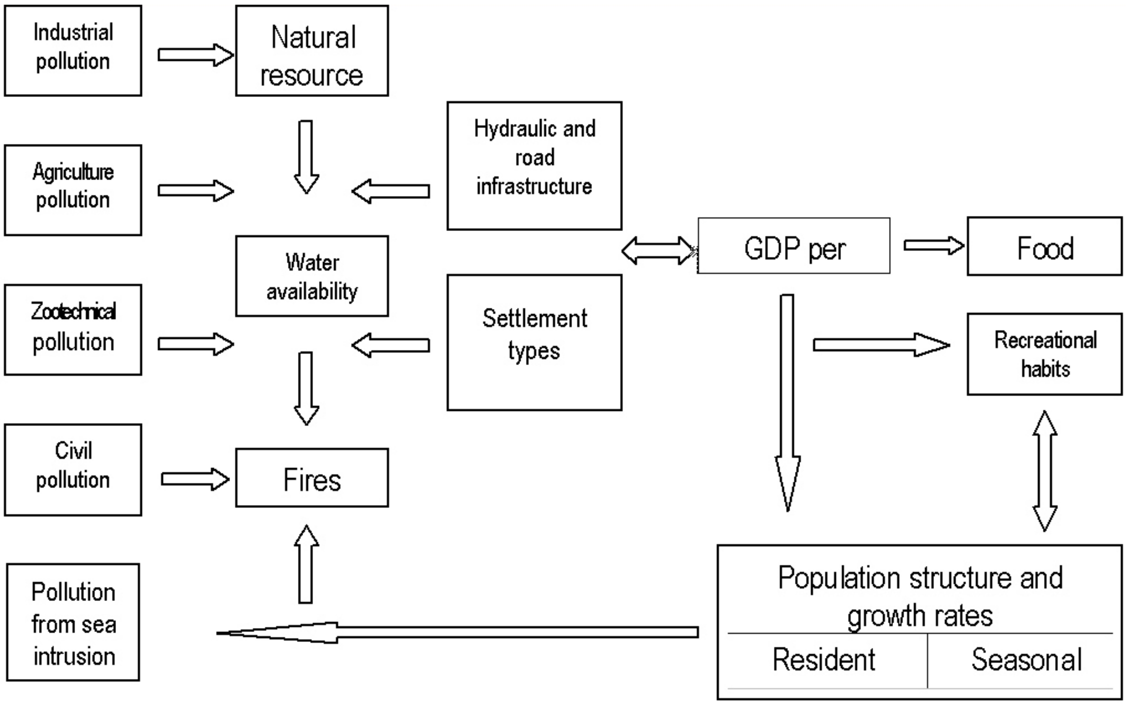


Figure 2. Conceptual model: socio-economic factors

Water resource use and availability are aggregated within a single item in the FAO/UNEP model, whilst in our case they are divided: in fact, technological evolution and dominant development model rarely lead to awareness of actual conditions of water supplying sources, their vulnerability and exhaustibility.

Water availability favors farming but also industrial activity. Gross Domestic Product per capita bears upon food and recreational habits. Furthermore, it is very important to break up the population into residential and seasonal components, since they are associated to different forms of land use and households' behaviours.

Recreational habits may influence seasonal population: the presence of tourist places, for example along the coastal stream, and/or entertainment places give rise to flows of temporary population.

3. THE STUDY AREA

It is becoming accepted that it is very difficult to understand broad-scale processes without adequate knowledge of processes at a finer scale (O'Neil et al., 1986; Imeson et al., 1996). Moreover, Agenda 21 asserts that the global assessments of the status and rate of desertification conducted by the UNEP in 1977, 1984 and 1991 have revealed insufficient basic knowledge of desertification processes, and emphasises local levels as essential for understanding the dynamics of desertification processes at a global level. The decision to experiment the conceptual model in a local context never studied before , was also influenced by these considerations.

The area examined is the portion of the South-Eastern Ionic arch located in the Taranto district. It covers 800 km^2 stretching for about 40 km along the NW-SE line and including 15 towns with a population density ranging from 400 in the coastal stream to 150 in the upper zone. The choice to analyze this area was based on the following considerations. It is a dry sub-humid zone (Fig. 3), defined at risk by the World Chart of dry lands (1977). Moreover, it presents a varied landscape and morphology, connected to its geo-lithological variability, which make it a sort of interesting full-scale laboratory of different situations that can be found in the Mediterranean region. It is also characterised by some features common to Mediterranean coastal zones, i.e. maritime climate, conspicuous coastal ground water resources, remarkable transformations in agriculture and a varied socio-economic structure in which agriculture still plays a crucial role.

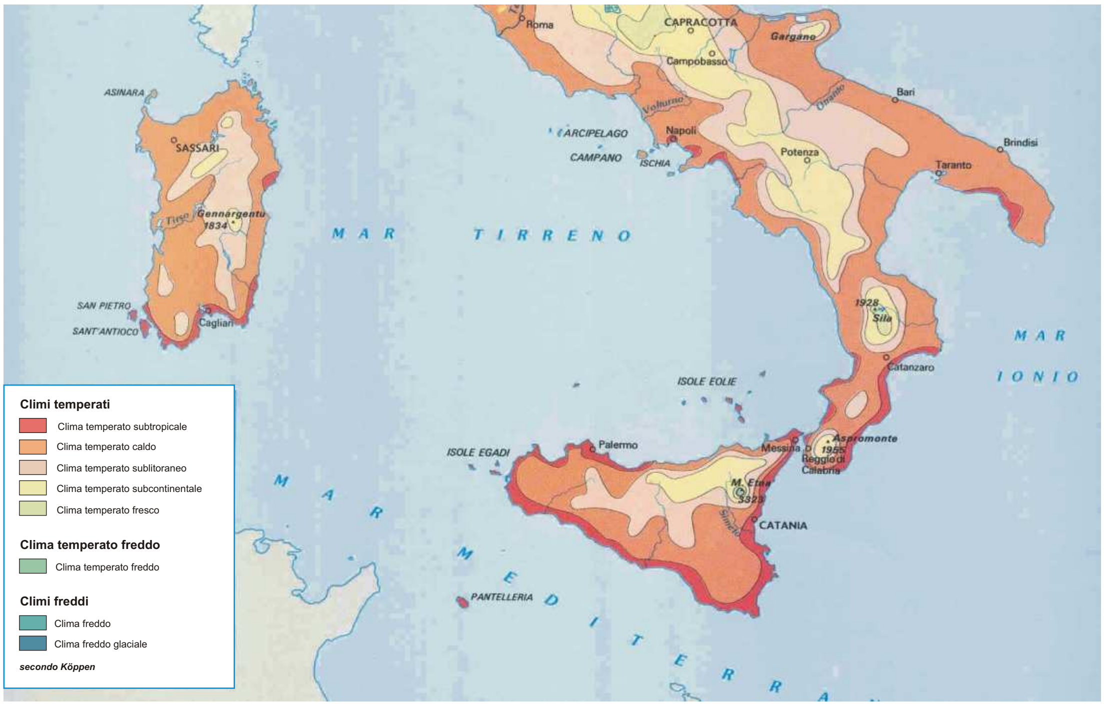


Figure 3: Climatic map of Southern Italy

From the geological point of view (Fig. 4), the area is constituted by a calcareous basement of Mesozoic limestone of the Apulian platform. Severe tectonic actions have faulted the basement in the area, so that it has assumed a horst and graben structure. In the area there aremainly quaternary sea deposits with a strong carbonate composition outcrop. They lie with a stratrigraphic hiatus on Mesozoic limestone of the Apulian platform. Locally, in connection with the top of the main horsts there are limestone outcroppings (Martinis e Robba, 1971; Ciaranfi et. al 1988; Cotecchia et al., 1998).

From the morphological point of view moving from North to South we can distinguish, , three zones directly linked to the geological formations: a) the Murge zone characterised by outcrops of carbonate rocks and moderate slopes; b) the intermediate zone characterised by quaternary outcrops and an undulating morphology with faint slopes; c) the coastal zone. Surface active hydrography is almost completely absent and, with the exception of some deep fractures in the territory called "gravine" and other less profound cuts ("lame"), the area also lacks precise run-off lines.

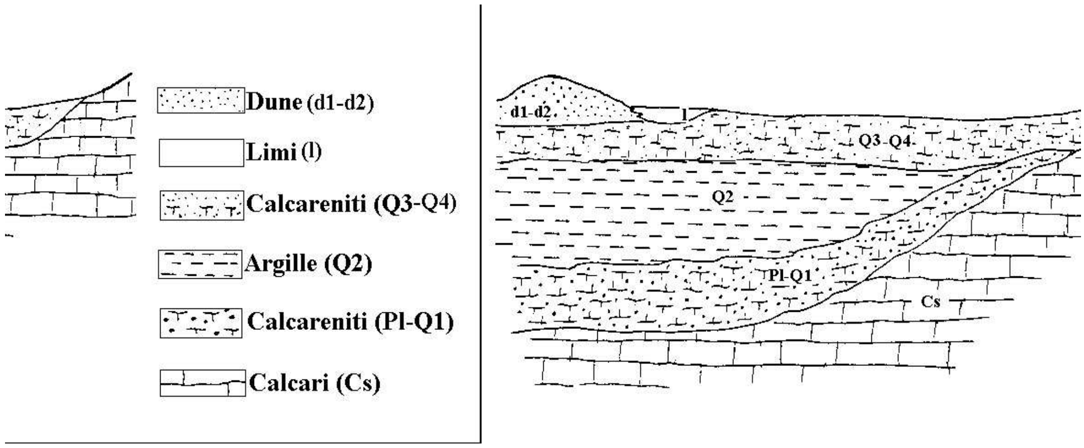
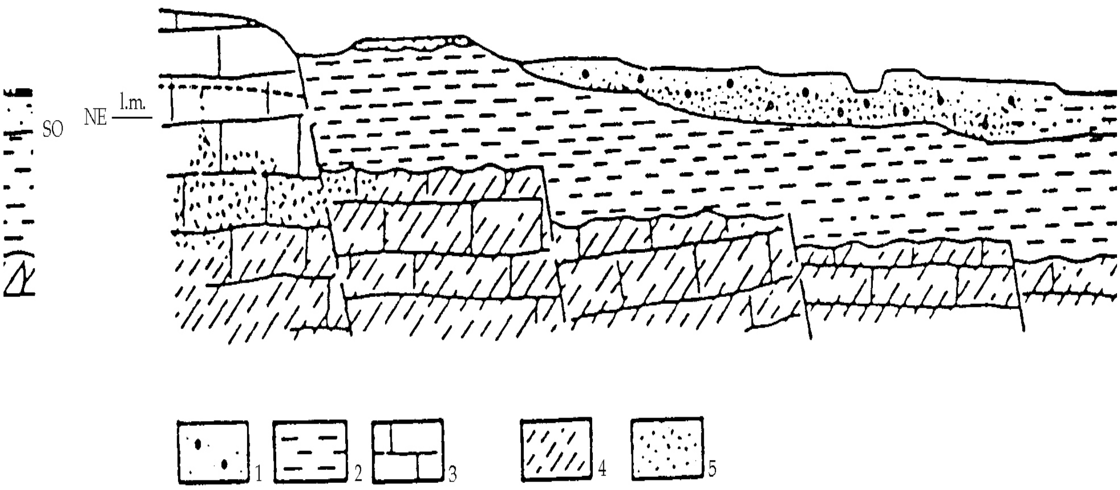


Figure 4. Sketch of relationships between the lithostratigraphic units of the area

Dune = Lunes [Quaternary]; Limi = Silts [Quaternary]; Calcareniti Q3-Q4 = Calcareous sandstone [Monte Castiglione calcareous sandstone Pleistocene]; Argille = Clay [Blue-grey sub-apenine clay - Upper Pliocene Lower Pleistocene]; Calcareniti Pl-Q1 = Calcareous sandstone [Gravina calcareous sandstone Upper Pliocene Lower Pleistocene]; Calcari = Limestone [Altamura Limestone Cretaceous]



Hydrogeological sketch of the area (from Maggiore, 1992)

1) Calcareous sandstone and/or quaternary gravel and sand deposits; 2) Blue-grey sub-apenine clays (Upper Pliocene Lower Pleistocene); 3) Altamura Limestone Cretaceous; 4) Salt water; 5) Fresh water

Depth, extension and potentials of the aquifers present in the area are conditioned by the geologic succession characterised by lithotypes with different degrees of permeability. In particular, the geological asset and permeability character contribute to the formation of two main aquifers (Zorzi e Reina, 1962; Cotecchia et al. 1998). The main one is the deep one constituted by Mesozoic limestone, whose permeability is due to fracture and karsification, and represents the most significant water resource in the region. The second is surface and flows in permeable sediments, more recent from the geological viewpoint, which rest on sub-Apennine clays. The ground water resources included in the deep aquifer are held at its basis by seawater intrusion and freshwater flows on saltwater of sea ingression. The delicate equilibrium at the interface between freshwater and seawater assures the existence of fresh ground water table. Lack of adequate recharge, together with conspicuous pumping, can give rise to perturbations in this delicate equilibrium- freshwater/seawater- up to the deterioration of all the ground water resources (Cotecchia, 1977).

The climate is Mediterranean maritime, with long hot summers and not very rainy winters. Minimum winter temperatures (January-February) rarely fall under 5-6° C; maximum summer temperatures (July-August) can be higher than 30° C. Precipitations are concentrated between October and March. Average precipitations vary between 450 e 600 mm/year.

This area is one of the most arid regions of the Italian peninsula. Referring to Köppen's (1940) climate classification, it can be attributed to the *group of temperate climates, sub-tropical climatic type* and, in particular, to the *Mediterranean sub-type.*

4. CLIMATIC AND LAND-USE CHANGES AFFECTING DESERTIFICATION PROCESSES

4.1 Selecting key-indicators

The most significant indicators for the case study at hand were selected based on the conceptual model above described. In particular, they follow some of the essential suitability criteria outlined by literature (Krugmann, 1996), i.e., they have sufficient sensitivity to provide warning of change, are distributed over a broad geographical area, are easy to measure, collect, assess and/or calculate, and relevant to the phenomenon under consideration.

Among physical parameters, data on temperature and precipitation were considered, since they are available in long time-series and allow to develop easily meaningful indicators on the state of recharge of deep freshwater resources of the coastal aquifer.

Among socio-economic parameters, changes in land use and agriculture were examined in depth, paying particular attention to the richest sources of water consumption.

Moreover, precipitation and temperature allow linking to the global scale, where climatic changes are appraised, to the local scale, where the effects of those changes are perceived. Their magnitude is essential to define the climatic picture of a territory and its evolution over time, and thus to analyse desertification processes. In order to assess these processes the study of the climate was carried out referring to the data of three thermo-pluviometric stations of the National Hydrographical Service located in the area (Tab. 1). In particular, monthly mean values were estimated for precipitation and temperature referred to the same period long time-series 1930-1994 (Tab. 2 e 3).

Table 1. Input data for climatic indicators

Station	Latitude	Longitude (M. Rome)	Mt a.s.l.	Precipitation time series	Temperature time series	Main Basin
Taranto	N. 40° 28' 21''	4° 47' 06'' E	15	Since 1877	Since 1930	Pen. Salentina
Lizzano	N. 40° 23' 24''	4° 59' 54'' E	67	Since 1919	*[1]	Pen. Salentina
Grottaglie	N. 40° 32' 03''	4° 58' 44'' E	133	Since 1928	Since 1919	Pen. Salentina

Table 2. Monthly mean precipitation (mm) 1928-1994

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Tot
Taranto	47.4	48.2	49.9	30.7	26.2	18.2	11.1	17.1	29.9	57.9	58.2	62.4	457.2
Lizzano	57.9	52.4	56.1	38.7	27.1	19.4	18.3	21.9	38.1	67.3	76.6	79.3	553.1
Grottaglie	55.9	56.4	57	42	34.8	25.1	22.1	21.6	39.2	60.8	76.6	77.2	568.7

Table 3. Monthly mean temperatures (°C) 1930 - 1994

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Taranto	9.3	9.7	11.4	14.4	18.6	22.9	25.7	25.9	22.7	18.5	14.1	10.8
Grottaglie	8.5	9.2	11.3	14.7	19.2	23.7	26.5	26.5	23.1	18.4	13.8	10

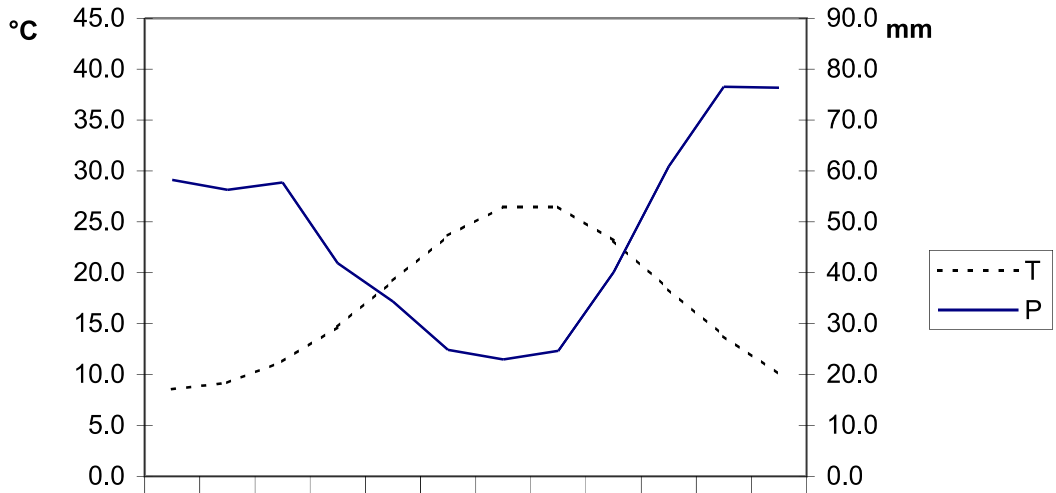
4.2 Assessing risk of desertification

The Grottaglie station presents monthly mean temperature values which are lower in winter and higher in summer than those of Taranto. As far as precipitation values are concerned, there are no substantial differences between the Grottaglie and Lizzano stations, while Taranto always shows lower monthly mean precipitation values.

Climate diagrams relating to these stations (see an example in Graph 1) highlight a wide period of Gaussen conventional aridity[2]. Thus, their climate can be classified as semi-arid with little water surplus.

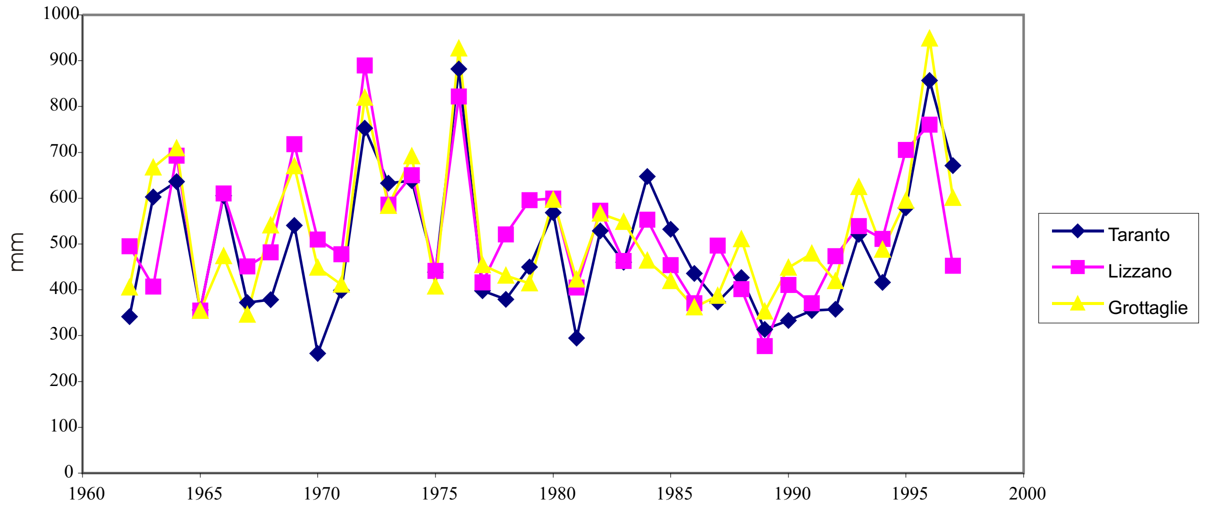
Firstly, annual mean precipitation was analysed in the three stations (Graph 2), then, in order to point out climatic trends in the long-term, thirty-year floating means were calculated (Graph 3)[3]. This graph clearly shows that a decrease in total annual rainfalls is under way. Such a decrease assumes particular importance in the study area as a consequence of its climate, characterised by limited annual rainfalls. In such a situation, slight reductions in precipitation can have a significant impact on recharging of ground water resources, the only ones in the areas.

Therefore, for the latter aspect we tried to understand which kind of change affected the amount of rainfall available for the recharge of ground water resources. To this purpose the well-known method for calculating the hydrogeologic balance was applied (Thornthwaite-Mather, 1957). It estimates the water surplus, for each month, by subtracting evapotranspiration to monthly precipitation.

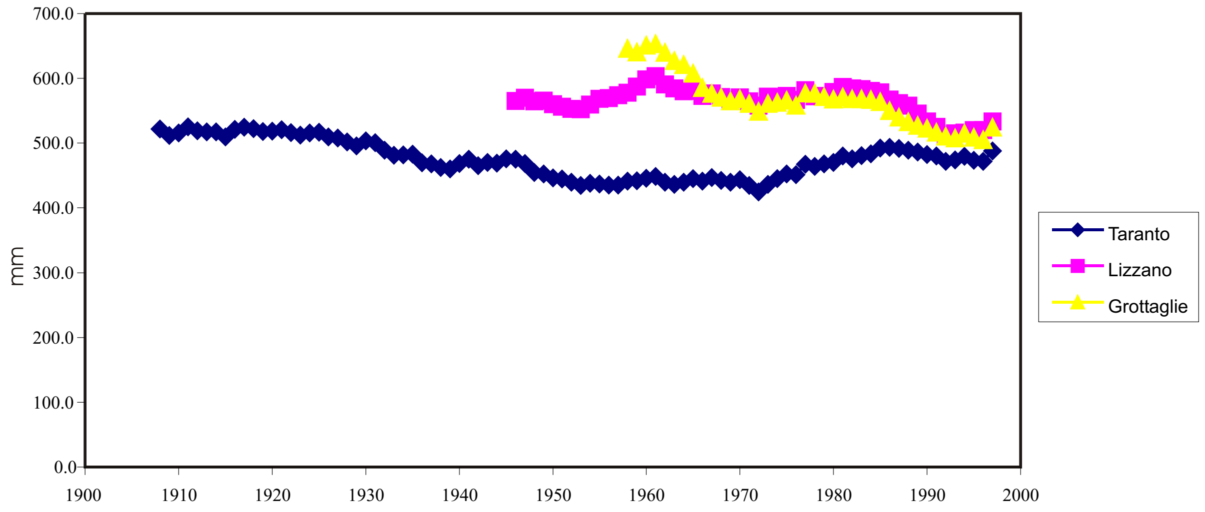


	Jan	Feb	Mar	Apr	Mar	Jun	Jul	Aug	Sep	Oct	Nov	Dec
T	8.5	9.2	11.3	14.7	19.2	23.7	26.5	26.5	23.1	18.4	13.8	10.0
P	58.2	56.3	57.7	41.9	34.3	24.9	22.9	24.7	40.1	60.9	76.6	76.4

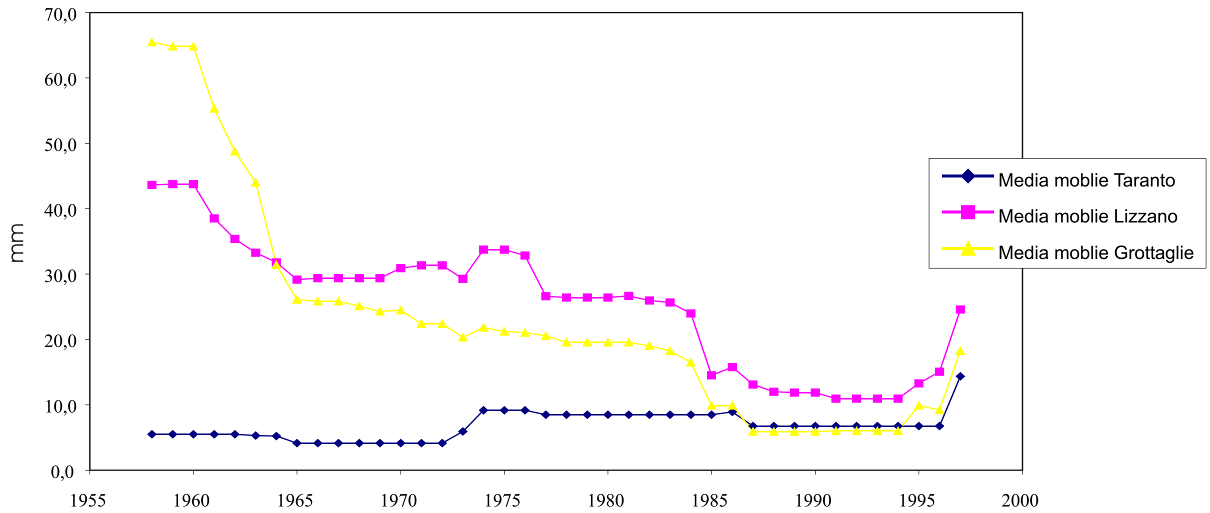
Graph 1. Grottaglie station climate diagram (1928-1994)



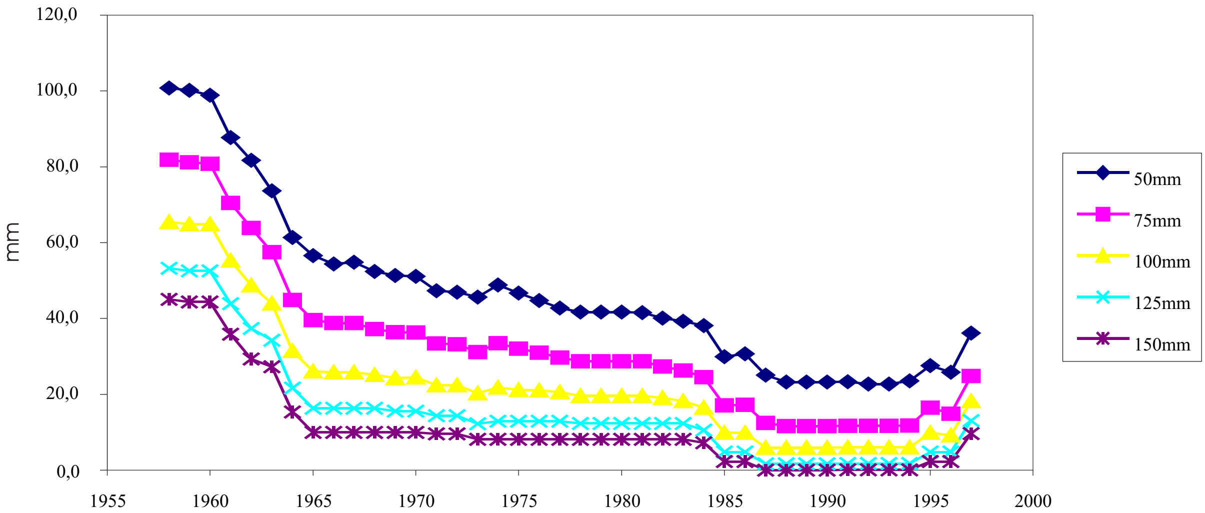
Graph 2. Annual mean precipitation (1928-1994)



Graph 3. Thirty-year floating means of precipitation in the three stations



Graph 4. Thirty-year floating means of surplus in the three stations



Graph 5. Thirty-year floating means of surplus in Grottaglie station

This kind of model requires three parameters: monthly mean temperature, precipitation, and ground water supply. The latter depends on both the intensity of precipitation in the previous months and the maximum value of soil moisture storage that, in its turn, depends on soil type and varies on average from 50 mm to 150 mm and more. Since, its values are usually close to 100 mm, this is assumed as an indicative measure.

As Graph 4 clearly shows, the annual water surplus varies considerably in the three stations and does not always show a strict correlation with precipitation. In particular it is worth noting that:

- the years in which there is a surplus are mostly the same in all the stations, due to the similar trends of precipitation and temperature;
- the surplus level does not depend on annual mean precipitation or temperature, but on their distribution during the year. This implies that the years with more intense precipitation does not always correspond to those with higher surplus;
- during the 1980s, in general, precipitation was scarce and, consequently, we face low and often zero surplus values;
- whilst Lizzano and, above all, Grottaglie often show surplus values higher than zero, Taranto very often presents zero values.

In order to evaluate the incidence of the combined effects of precipitation and temperature on water surplus in the three stations, for each month of the period under consideration (1928-94) we estimated, in percentage, how often precipitation values were higher than the evapotranspiration ones, and thus could regenerate soil moisture (Tab. 4).

Table 4. Percentage of cases in which precipitation is higher than evapotranspiration (1928-1994)

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Lizzano	51.5	50.0	24.2	0	0	0	0	0	0	1.5	24.2	57.6
Grottaglie	51.5	53.0	25.8	0	0	0	0	0	0	3.0	28.8	59.1
Taranto	34.8	45.5	25.8	1.5	0	0	1.5	0	1.5	0	10.6	37.9

In particular, Grottaglie and Lizzano stations show precipitation values higher than ETP ones in about 60% of cases, Taranto only in 38%. It is worth noting that percentages showed by Taranto in July and September are due to the presence of only one case within the entire time interval under observation.

The high surplus values of Grottaglie station are influenced by two factors: lower mean temperatures during winter months, which give rise to limited potential evapotranspiration, and higher mean precipitation in the same months. The combined effect determines P - ETP > 0 and allows first regeneration of soil moisture, and then infiltration of surplus.

In order to test how much taking the 100 mm of field soil moisture affects the results, the analysis was repeated, only for Grottaglie, considering a variability of maximum soil moisture storage between 50 and 150 mm [4].

As for precipitation, in order to understand the surplus trend, thirty-year floating means were calculated. Both Graph 4, showing the thirty year floating means of surplus in the three stations with 100 mm field, and Graph 5, showing the same indicator in the Grottaglie station with field varying from 50mm to 150mm, reveal a decrease in surplus over time. This is common to all the stations and becomes more conspicuous in the 1980s. These outcomes are coherent with the decrease in rainfalls highlighted in Graph 3.

In conclusion, the reduction of water surplus has to be attributed to the reduction in annual precipitation, but above all to the fact that it essentially affects winter precipitation. More worrying is that the decrease in rainfall, and consequently in surplus, concerns not only the coastal and central-western zones of Taranto district, traditionally 'very thirsty', but also the internal central-eastern zone, where the surplus was, as already shown, often higher than zero. It is worth noting that the central-eastern zone is the recharge area of both deep and surface aquifers. This is symptomatic of a phenomenon affecting areas that are crucial for rechargingthe whole water resources in the area.

In order to evaluate the impact of changes in land use on desertification processes, we focused on agriculture and urbanisation using both statistical data[5] and information derived from satellite images (1990) and thematic maps (1950) confronted by using GIS techniques[6]. Land cover/land use data were re-grouped into the following comparable classes: sea, olive-tree/vine, orchard, vine, irrigated cultivation, dry cultivation, settlement, wood (they are listed in the order displayed in Figure 5). The third GIS image, which is obtained by overlaying the two maps, distinguishes the areas characterised by changes in land cover from those that remained unchanged.

The outcomes show that agriculture still dominates land use in the region, but its nature has changed a lot in the post-war period, having been transformed from dry to irrigated, from extensive to intensive. In particular, while in the 50s traditional cultivation of olive-trees and vines, together with dry crops, prevailed in the area, in the 90s olive-trees and vineyards remained almost unchanged, but parallel with a remarkable increase in the agricultural land area devoted to irrigated cultivation.

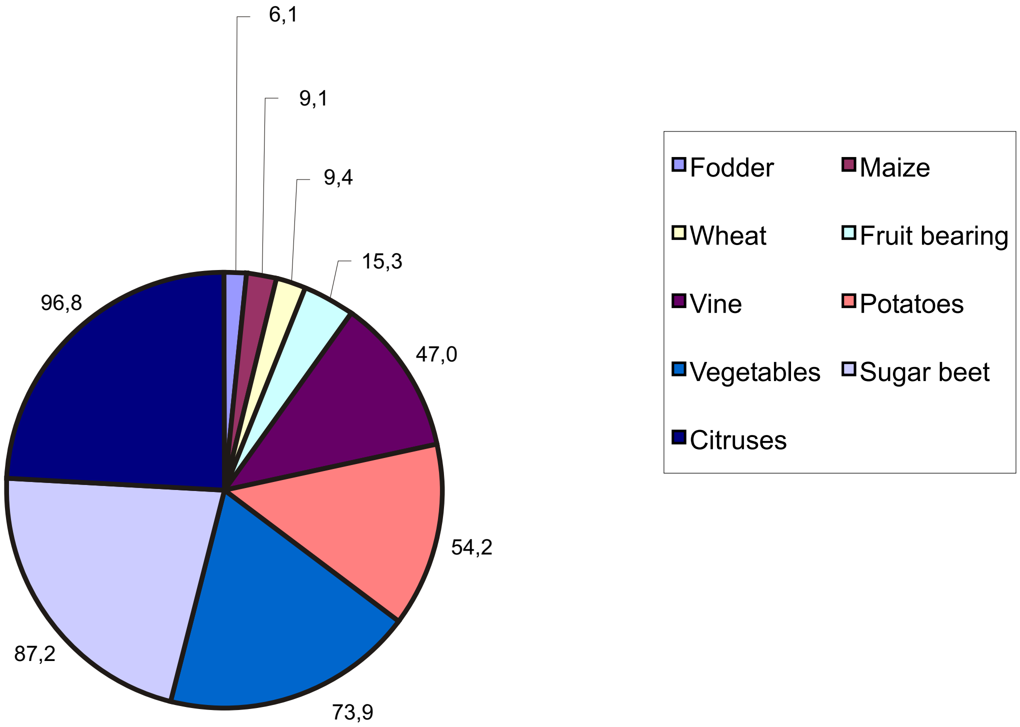
A more detailed analysis integrating map information with census data reveals that tperennial crops[7], and in particular olive-trees and vines, typical of the Apulian agriculture as well as the Mediterranean one, are still predominant in the whole area. In particular, over the last ten years we have faced a decrease in cereals, wheat, maize, vegetables (extraordinarily), fruit-trees, olive-trees, and vines, whilst there is an increase in the cultivation of citruses, sugar beets and potatoes.

It is also important to consider not only the variations in agricultural land area under irrigation as a percentage of total arable land area, as defined in Agenda 21, Chapter 14, “Promoting sustainable agriculture and rural development”, but also, on the one hand, in water consumption for irrigation depending on cultivation (Graph 6), on the other hand, cultivation being equal, in the growth of consumption for irrigation over time (Graph 7) [8].

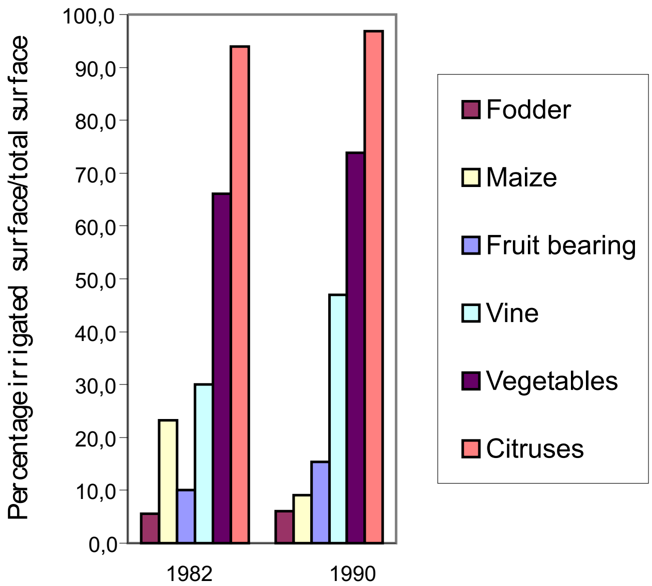
On the whole, irrigation represents 73% on the total consumption of water, with seasonal peak values of 90%. It is also clear that, in only ten years, water consumption for vine has increased dramatically in parallel with the decrease of vine surface in the same period. For fruit bearing, fodder, maize, fall in water use is due to the decrease of such cultivations.

These trends should be put in connection also with the huge increase in agriculture mechanisation, which, bringing about soil compression, positively influences the feed of desertification processes. Also cattle breeding, becoming more and more intensive and concentrated in a few big farms, favors desertification processes.

The interpretation of land use images clearly highlights that in the last forty years, within the context of a general expansion of urbanised areas, the coastal stream, which in the 50s appeared almost clear of settlements, has been nearly completely urbanised. The parallel shift from compact urbanisation forms to suburbanisation is particularly dangerous for the problem under consideration, since the spread of suburban settlements causes difficulties in providing them with adequate water and wastewater infrastructure equipment. Moreover, the integration of this information with indicators obtained by census data on population and building makes it clear that in the coastal zone urbanisation processes are mostly related to secondhouses, whose amount is larger than primary houses in all the coastal municipalities. This is confirmed by the figures of settlement density calculated for total houses and occupied houses: rooms/km^2 are respectively 560 and 340 in the coastal stream, 560 and 460 in the intermediate area, and 350 and 200 in the most internal area. If we consider density, form and building typologies characterising these settlements, together with household behaviors especially in terms of water consumption (and wastewater treatment), we can easily understand that their impact on desertification is more severe than that of primary houses, the number of units being equal.



Graph 6. Water consumption depending on cultivation type (source: our elaboration of census data)



Graph 7. Trend in water consumption depending on cultivation type (source:our elaboration of census data)

5. DISCUSSION AND DIRECTIONS FOR ACTION-ORIENTED PROGRAMS

The analysis presented in the previous paragraphs makes it clear the vulnerability of territory with regard to risk of desertification in the study area. It is indicated by the combination of various specific factors: use of huge amounts of water for irrigation, overexploitation of ground water resources, and difficulty in their recharge due to the decreasing trends in precipitation and surplus. Moreover, the essential carbonate nature of the region and the consequent predominance of calcareous soils, whose drying process favours the formation of calcareous crusts, stress the difficulties in vegetation growth. Spreading and often uncontrolled urbanisation processes worsen the situation. Thus, a crucial issue for this region is to reduce the on-going phenomena and to avoid further impoverishment of ground water resources, which risks becoming irreversible and compromising the use of such water resources by future generations.

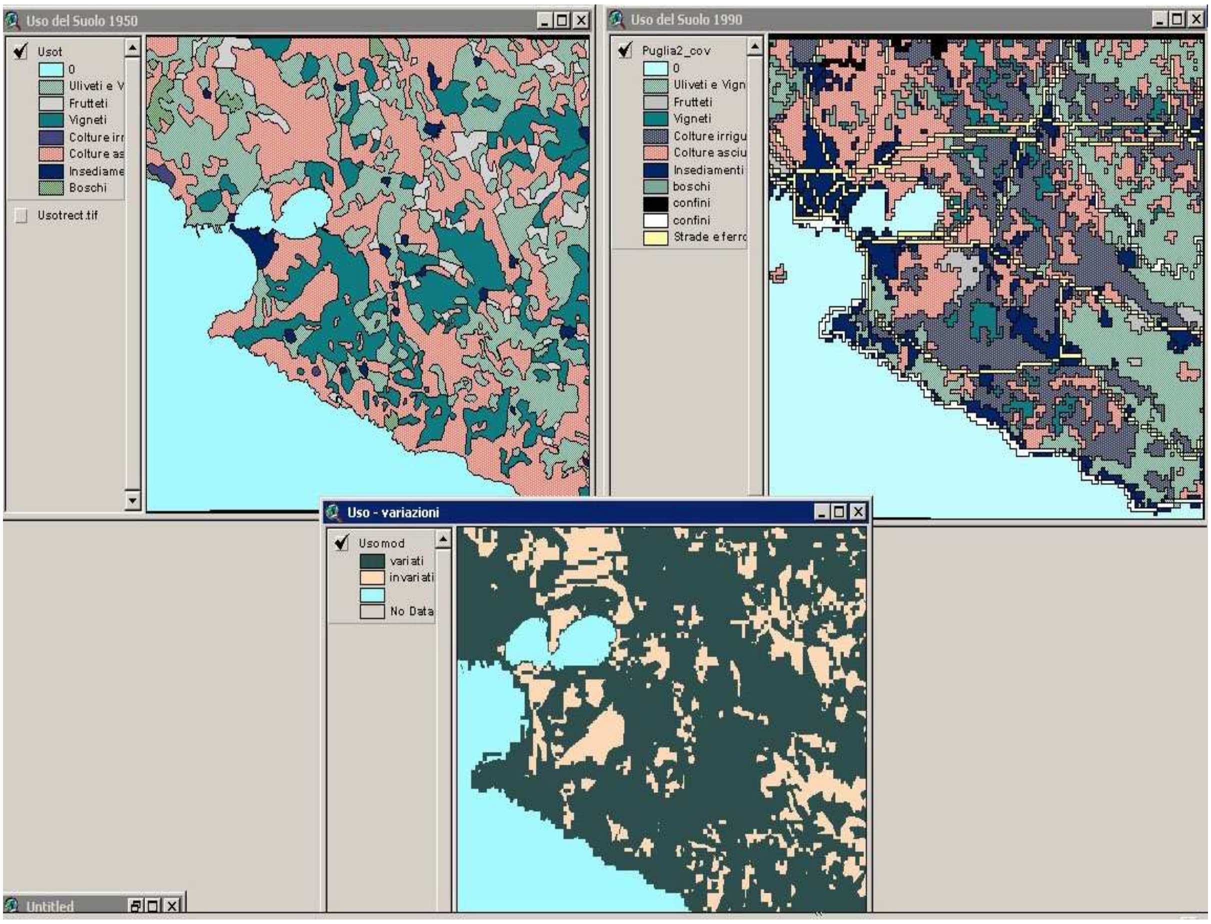


Figure 5. Land use map (1950) confronted with satellite image (1990) and the overlay pointing out changes in land cover

International programs and resolutions suggest a number of measures to transform study outcomes into recommendations to policymakers and action-oriented programs for regions prone to desertification: within them, a central role is assigned to the strengthening of knowledge base and developing information and monitoring systems, including the economic and social aspects of the concerned ecosystems.

The UN 1994 Convention called for national plans of action to combat desertification. The Italian National Plan of action was approved in 1999. In particular, point 1.d provides that support will be given to Regional Governments and Catchments Basin Authorities in order to single out “areas vulnerable to desertification". This research can give a contribution to this aim.

Moreover, the Italian National Plan proposes t implementation of a monitoring network and prescribes the adoption of more suitable standards and methods to improve knowledge, prevention and mitigation of desertification phenomena in vulnerable areas. The search for appropriate indicators is crucial for this purpose. It should follow some essential criteria: i. to single out a limited number of indicators, able to represent the territory in effective and meaningful way; ii. to take into account the possibility to find up-to-date information and to communicate them to decision-makers and the general public, iii. to reconstruct a trend, even incomplete and uncertain, of indicator variation over time. Moreover, the indicators pertinent to desertification are usually subdivided into three categories: pressure, state and response indicators.

Figure 6 below suggests a number of essential pressure and state indicators that seem suitable for the territory under consideration. It is worth mentioning that state indicators are proposed according to the above-mentioned chapter 12 of Agenda 21, i.e monthly rainfall index, vegetation index derived from satellite data, and land affected by degradation. This is important to favor co-ordination and integration embracing international, national and local levels, which is essential for monitoring the dynamics of a phenomenon such as desertification, remarkably affected by scale problems.

While some indicators can be easily and to some extent - objectively derived from, and up- dated through, satellite or statistical data, others are collected only on the occasion of censuses and present reliability limitations: in particular, the reliability of fertiliser and pesticide data is questionable. Moreover, current data sources, on the one hand, ignore toxicity, mobility, and level of persistence, spatial and application variances, on the other hand, they do not consider the use of pesticides outside of agriculture, which is significant in our area.

Further limitations consist in the fact that “area-based” studies on desertification carried out so far in developed countries, emphasise the technological aspects related to the aim developing information and monitoring systems for regions at risk of desertification. Also Agenda 21, as far as desertification is concerned, seems to suggest a linear and sequential model of action plan that emphasises the role of public participation only in controlling and managing the effects of desertification and drought, and does not consider the possible crucial contribution of “non-expert” stakeholders in understanding land degradation dynamics, using local knowledge and capacity to monitor and interpret environmental change (Hambly and Onweng Angura, 1996).

As far as response indicators are concerned, agricultural education and extension are essential, as asserted in Agenda 21, Chapter 14 on “Promoting sustainable agriculture and rural development”, since they can provide evidence of preventive action to counter land degradation. In any case , it is not correct to pre-define these indicators, as they should emerge during the plan implementation phase and through the participation in it of government and non-government actors. The same pressure indicators can change during implementation due to the rise of underestimated aspects or unexpected events affecting, on the one hand, land degradation processes, on the other, increase in local stakeholders' awareness of the problem, expansion of protected areas with consequent intensified soil conservation, afforestation and reforestation activities, and diffusion of preventive measures.

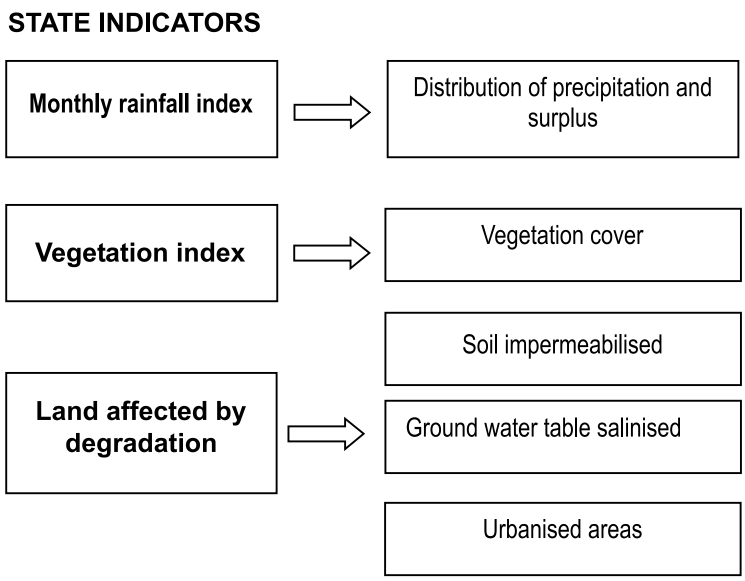


Figure 6. Suggested pressure and state indicators for the study area

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[1] The temperatures of Lizzano were obtained from of those of Grottaglie since they present basic similarities.

[2] I.e. periods with monthly mean precipitation, expressed in cm, twice lower than monthly mean temperatures expressed in °C.

[3] In the calculation for each year the precipitation mean value of the previous thirty years was assigned, considering, according to nternational hydrological assumptions, that it should be sufficiently stable and subjected to modest variability referring to a long time period.

[4] Grottaglie was chosen for its high levels of surplus and morphological asset that make it one of the areas where the recharge of deep ground water resources occurs.

[5] In particular, the ten-yearly census data about population and dwellings, industry and services, and agriculture.

[6] Data sources are, respectively, the CORINE classification of land cover and the Touring map on land use. Both were elaborated and compared using the software Arc-Info.

[7] Perennial crop include woodagricultural cultivation (that, in its turn, comprehends vines, olive trees, citruses, fruit-bearings) and fruit chestnut trees.

[8] Data on irrigated land area for each type of cultivation were estimated. Then, in order to make them comparable, they were related to the surface extension of the same types of cultivation.