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A meteorological database for bioclimatic analysis in the north-west of Italy

by

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SYNOPSIS

To give a synthetic representation of the climatic factors which influence the distribution of the vegetation in LIGURIA Region, a meteorological database was created using data from registration stations and a GIS with topographic informations. Prior to the creation of such a database, controls were effected on the registrations available, on periods of missing data and on consecutive periods of registration, as well as the consistency, compatibility and congruency of the historical data to be used (for example between max and min temperatures). As a result of this spatialization of the original data, in each cell of a reference grid were obtained average mounthly values of rainfall and max. min and mean temperatures from which the following analyses and thematic maps were carried out:

- climatic maps for rainfal' and temperature data

- calculation of monthly 9° isotherm over the region
- Gaussen diagrams of rainfall and temperature with indications of arid periods
- phytoclimatic bands
- AWC and deficits
- thermal and water stress according to Mitrakos

Key words: database, spatialization, cluster analysis, phytoclimatic analysis

INTRODUCTION

For a study of the distribution of the vegetation in the Liguria Region it was necessary to determine the climatic factors of influence based on meteorological data.

Two databases were created based on the registration of the S.I.I. (LL.PP.)[1] and the S.M.A.M.[2] stations for a period of over 20 years (1964 - 1984).

The former network is of sufficient density to guarantee an adequate regionalization of the data, while the latter network, of much lower density, offers the advantage of operating in real time. In addition the SMAM data covers an extensive set of meteorological variables (such as relative humidity, global radiation, cloud coverage, etc) from which it is possible to calcualte the luminosity of the sky, an important factor for the study of phytoclimatic bands of the Mediterranean vegetation, which is at present under way.

METHODS AND MATERIALS

The basic data used in the study consisted of orographic data on the study area under and meteorological data, as follows:

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[1] SII (LL.PP.) Italian Hydrographic Service (Ministry of Public Works)

[2] SMAM Meteorogical Service of the Italian Air Force

1 Elevation data

The elevation data was extracted from a DTM created from topographic maps at scale 1:250.000. Each map has been subdivided into a network of a total of 1800 cells (45 x 40) and the mean elevation calculated in each cell from the map information.

The area under study on the other hand has been subdivided into square cells 4 x 4 km and the mean elevation of each of those cells calculated from the number of points (256) of the DTM falling within them.

2 Meteorological data

The number of stations selected for each network is 247 for the SII and the 18 for the SMAM, while the daily data extracted from the records of each regarded rainfall and maximum and minimum temperatures. This selection was based on the quality of the data available and on the completeness of the registrations in each (always above 80%).

2.1 LL.PP. database

Following the selection indicated above, for the creation of a data base only the period 1951-1971 was considered and the number of stations was reduced to 184 for the rainfall data and 30 for the minimum and maximum temperature (from which the mean temperature was calculated).

Controls were affected on these registrations, on periods of missing data and on consecutive periods of registrations, as well as consistency, comptatibility and congruency of the historical data to be used (for example between maximum and minimum temperatures).

The actual database consists of two files, one for the rainfall data, the other for the temperatures, one record for each mean monthly value of the variables, with indication of the station code and data.

2.2 SMAM database

One further advantages of the SMAM data is the availability of daily registrations up to 1991, for a much greater number of meteorological variables of interest in climatic studies.

For the creation of a database the period 1963-1991 was considered and the number of stations was reduced to only 7 with both rainfall and temperature data sufficienlty complete for the present study.

Controls were affected on these registrations, on periods of missing data and on consecutive periods of registrations, as well as consistency, comptatibility and congruency of the historical data to be used (for example between maximum and minimum temperatures).

The actual database consists of two files, one for the rainfall data, the other for the temperatures, one record for each mean monthly value of the variables, with indication of the station code and date.

For the regionalization of climatic data, the procedure has been as follows(MAF, 1991-1993): from the LL.PP. database the mean monthly values over the period of registration of all stations considered, were extracted for the variables

- rainfall
- temperatures (maximum, minimum and mean)

The area of study consisting of a rectangular grid of square cells 4 x 4 km, containing the Liguria region and all the station considered, resulted in a grid of 36 x 60 cells on which was also available the information on mean elevation.

The regionalization of each of these variables is carried out by using the Cressman (PINNA, 1978) method, the technique being known as "spatialization" (GANDIN, 1983). This method considers not only the distance between stations and the generic cell, but takes into account also the elevations of these as wells as the elevations of cells in-between (that is, whether the stations are visible from the cell and viceversa). The actual number of stations considered in the process is a function of the density of the stations and of their distribution in the area under study.

A radius of influence is considered and the iterative process stops when the number of stations considered for the single cell is greater than a preselected minimum value (6 in this case).

For the temperature variables, a further elaboration is carried out consisting in the correction of the value registered at the station, at elevation H1, due to the temperature gradient between this elevation and the mean elevation of the cell in which the station falls, H2, which is generally different from H1.

RESULTS

As a result of the spatialisation of the original data, in each cell of the reference guid for the region were obtained average monthly value of rainfall and maximum, minimum and mean temperatures from which the following analyses and thematic maps were carried out:

climatic maps for rainfall and temperature data
calculation of monthly 9° C isotherm over the region
Gaussen diagrams of rainfall and temperature with indication of arid periods
phytoclimatic bands
AWC and deficits
thermal and water stress according to Mitrakos

1 Thematic maps

For each climatic variable, at the monthly and the yearly level, maps were generated for various classes between the maximum and the minimum values for each of them, as shown below:

- monthly values
- temperatures max 33°C class interval 3° C for 16 classes min 15°C
- rainfall max 450 mm class interval 30 mm for 15 classes min 0
- yearly values
- temperatures as above
- rainfall max 3300 mm class interval 300 mm for 12 classes (Palmieri e Finizio, 1993)

2 9°C isotherm

The isotherms corresponding to a mean monthly temperature of 9°C were extracted for each cell of the grid and plotted on a map of the study area to see their spatial distribution during the year.

In particular the monthly values from march to october were plotted since these are the ones of interest for the delimitation of bioclimatic units.

3 Gaussen diagrams with indication of arid periods

The Gaussen diagrams for monthly rainfall and temperatures consist of a graph showing the variation of temperature and rainfall during the year for the cells corresponding to the stations used in the study. By selecting the scale of rainfall in mm and the temperature in °C, the diagrams indicate arid periods when the monthly rainfall is less than twice the monthly temperature.

On the diagrams both the minimum and maximum temperatures are indicated, and the results obtained indicate that for about one-half of the stations, arid periods over 1 month are present, while the rest indicate virtually no arid periods, dividing the area under study in three well distinct areas along the coast as well as inland. These results, together with spring rainfall (march to april) and autumn rainfall (from september to november) were plotted on a map of the study area, with a classification of the variables considered.

4 Phytoclimatic bands

A complete classification of each cell of the grid was carried out using the meteorological variables, according to the following scheme (Marchetti, 1987):

- coldest month
- minimum temperature of coldest month
- mean temperature of coldest month
- mean annual temperature
- mean annual rainfall

- coefficient of Angot (ratio of mean monthly rainfall to rainfall in that month according to a uniform distribution of mean annual rainfall)

In table 1 the limits and ranges of the variables considered are given with the resulting classification of the study area in twelve phytoclimatic bands. The results were plotted on a map of the study area, showing the resulting classification.

5 AWC and deficits

The water requirements of plants at the monthly scale may be simulated by considering an initial AWC (available water content, mm, in the soil), the evapotranspiration rate of the plant and the effective rainfall falling on the area, from which eventual deficits may be calculated (Doorenbos e Pruitt, 1977).

On each cell of the grid, the monthly values of rainfall and temperature were used to calculate:

- potential and real evapotranspiration
- final water content at the end of the month
- eventual deficits and related water stress

From these results, the following were calculated:

- month of start of deficit
- month of end of deficit
- cumulative sum of deficit in summer (july and august)
- maximum value of deficit

In addition for the eventual deficit and water stress cumulated from may to october, a cluster analysis was carried out to delimit homogeneous areas within the study region and plot these on a cartographic map of the region.

6 Thermal and water stress according to Mitrakos (1980, 1982)

The thermal and water stresses proposed by Mitrakos were calculated at the monthly level for each cell of the reference grid and a graphical representation of the results obtained plotted on a map of the region under study.

TABLE 1

Limits of variables used for classification of phytoclimatic bands

mean annual temp. (°C)	mean temp. coldest month(°C)	mean annual rainfall (mm)	coefficient di Angot (--)	phytoclimatic band (--)
Up to 2.5				Alpinetum
between 2.5 and 6	less than - 5			Picetum cold
	greater than -5			Picetum hot
between 6 and 7				Fagetum cold
between 7 and 10	less than 0			Fagetum cold
	greater than 0			Fagetum hot
between 10 and 12	less than 0			Fagetum cold
	between 0 e 3			Fagetum hot
	between 3 and 4.5	less than 700 mm		Castanetum cold
		greater than 700 mm		Castanetum cold
	greater than 4.5		with drough	Castanetum cold
			without drought	Castanetum cold a
between 12 and 15	less than 3.5	less than 700 mm		Castanetum cold b
		greater than 700 mm		Castanetum cold a
	between 3.5 and 6.5		with drought	Castanetum hot b
			without drought	Castanetum hot a
	between 6.5 and 8			Lauretum cold
	greater than 8			Lauretum medium
between 15 and 16	less than 7.5			Lauretum cold
	between 7.5 and 9			Lauretum medium
	greater than 9.5			Lauretum hot
between 16 and 17	less than 9.5			Lauretum medium
	greater than 9.5			Lauretum hot
above 17				Lauretum hot

The water stress is calculated with the following formula:
$D = 2\ (50 - P)$
where D = water stress (%)
P = monthly rainfall (mm)
according to the following conditions:
if $P = 0$ then $D = 100$
if $P > 50$ then $D = 0$
The thermal stress is calculated with the following formula:
$C = 8\ (10 - t)$
where C = thermal stress (%)
t = mean minimum monthly temperature (°C)
according to the following conditions:
if $T > 10°C$ then $C = 0$
if $T < -2.5°C$ then $C = 100$

In addition, the water stress for the summer period (june to august) and the thermal stress for the winter period (december to february) as well as their yearly values were calculated by cumulating the monthly values.

At this point it was decided to elaborate SMAM data to extend the study by considering the network of SMAM stations operating in real time, with daily and monthly data up to 1991. Since this network has a much lower density of stations (about 15 for the whole study region) it was necessary to determine the area of influence of each SMAM station by reference to the spatialisation already performed. This was carried out by application of the Cluster analysis technique. Following this, the SMAM registrations at each station were "regionalised" to each area of influence by application of the results of the cluster analysis (a process analogous to the spatialisation already described above).

a) The cluster analysis was carried out with the following options: fixed centroids

unconnected clusters

The results consist of homogeneous areas of influence around each of the SMAM stations (the centroids) and the relevant transposition matrices for each parameter studied (mean monthly values of rainfall, mean maximum and minimum monthly temperature).

b) Spatialisation: with the results obtained above, the monthly values of each parameter for each cell of the study region were obtained by application of the spatialization technique already mentioned, but at this stage with the registrations at the SMAM stations.

c) The analyses and thematic mapping mentioned above was repeated on this SMAM data regionalized to all the grid of the area under study. The results obtained are similar to those using the LLPP and are discussed in what follows.

DISCUSSION AND CONCLUSIONS

The work is at present underway for the use of the databases for specific phytoclimatic analyses focused on mediterranean ecosystems.

The Liguria region is particularly difficult and suitable for checking the methodology, given the complex orography and altimetric variations.

The presence of a narrow coastal zone with high mountains reaching down to the sea but extending as well to the north to the river Po basin, of continental nature, further complicates the study.

The procedure adpoted to optimize the use of the available data from different networks, with quite a different density of distribution and quality of data, has nevertheless given good results as shown by the controls effected on maps at scales up to 1:250000 (see fig. 4).

The main problems encountered are related to the representation of the territory through a grid of cells 4 x 4 km. To obviate these problems, the work being developed will be related to a smaller cells, 2 x 2 km.

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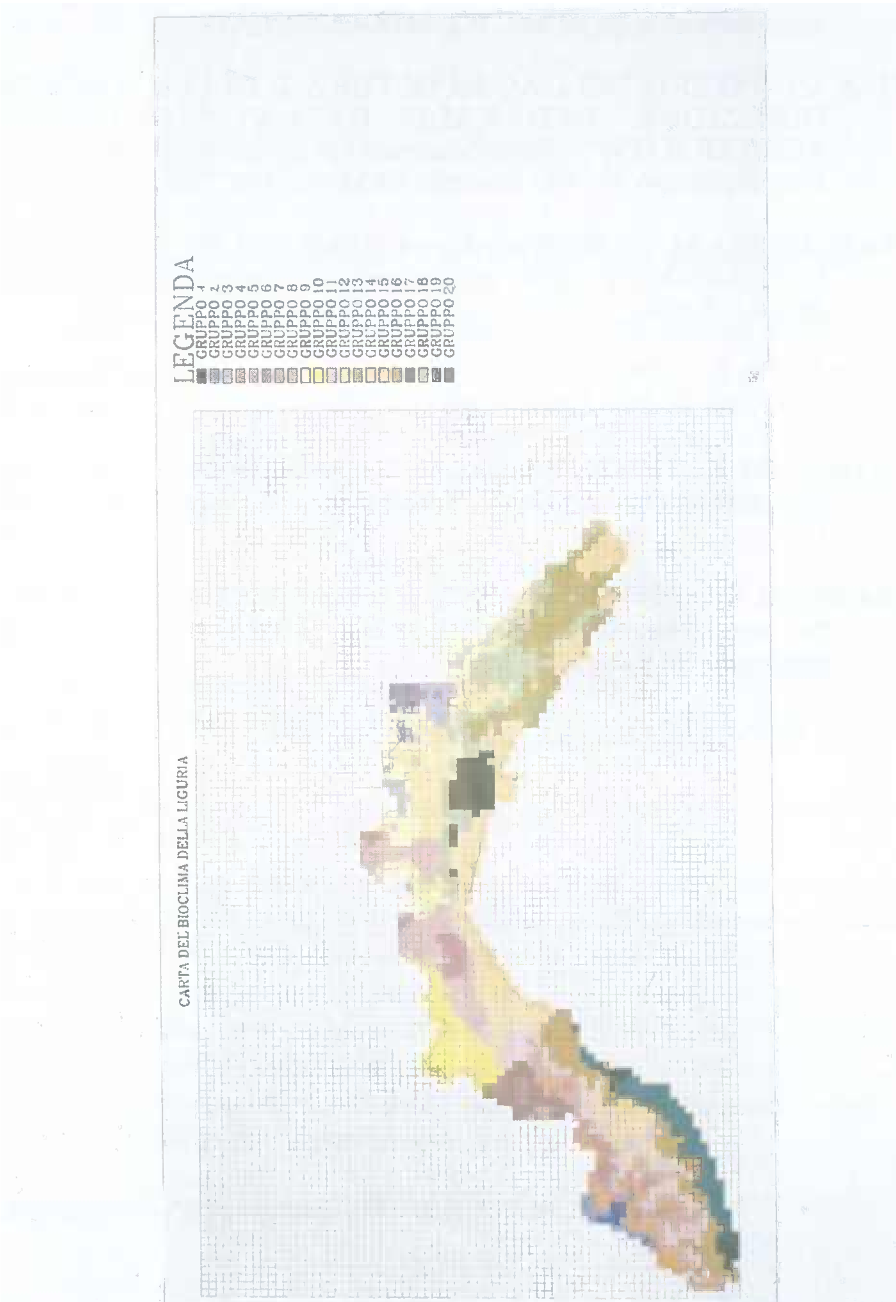
FIGURE 1 – Map of Bioclimatic units (scale 1:250.000) resulting from cluster analysis.



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